

**Crispy, Crunchy and Crackly: An Exploration of Food Textural Acoustics on the Swallow
Mechanism**

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219094365



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As the above candidate's supervisor, I AGREE to the submission of this doctoral dissertation in the form of a thesis by publication. This thesis comprises five chapters; introductory chapter, three chapters in between- consisting of three papers- and a concluding synthesis chapter.

This is to certify that the contents of this thesis are the original research work of Tasneem Fareed Karani.



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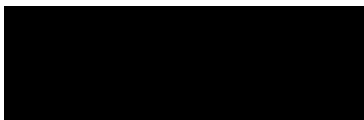
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DECLARATION

I, TASNEEM FAREED KARANI, declare that:

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“Promise me you’ll always remember that
you are braver than you believe,
stronger than you seem and
smarter than you think”

Christopher Robin to Winnie the Pooh (Carter Crocker)

(Milne, 1926)

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DEDICATION

This thesis is dedicated to my precious Dad, Mum, Sister and Husband.

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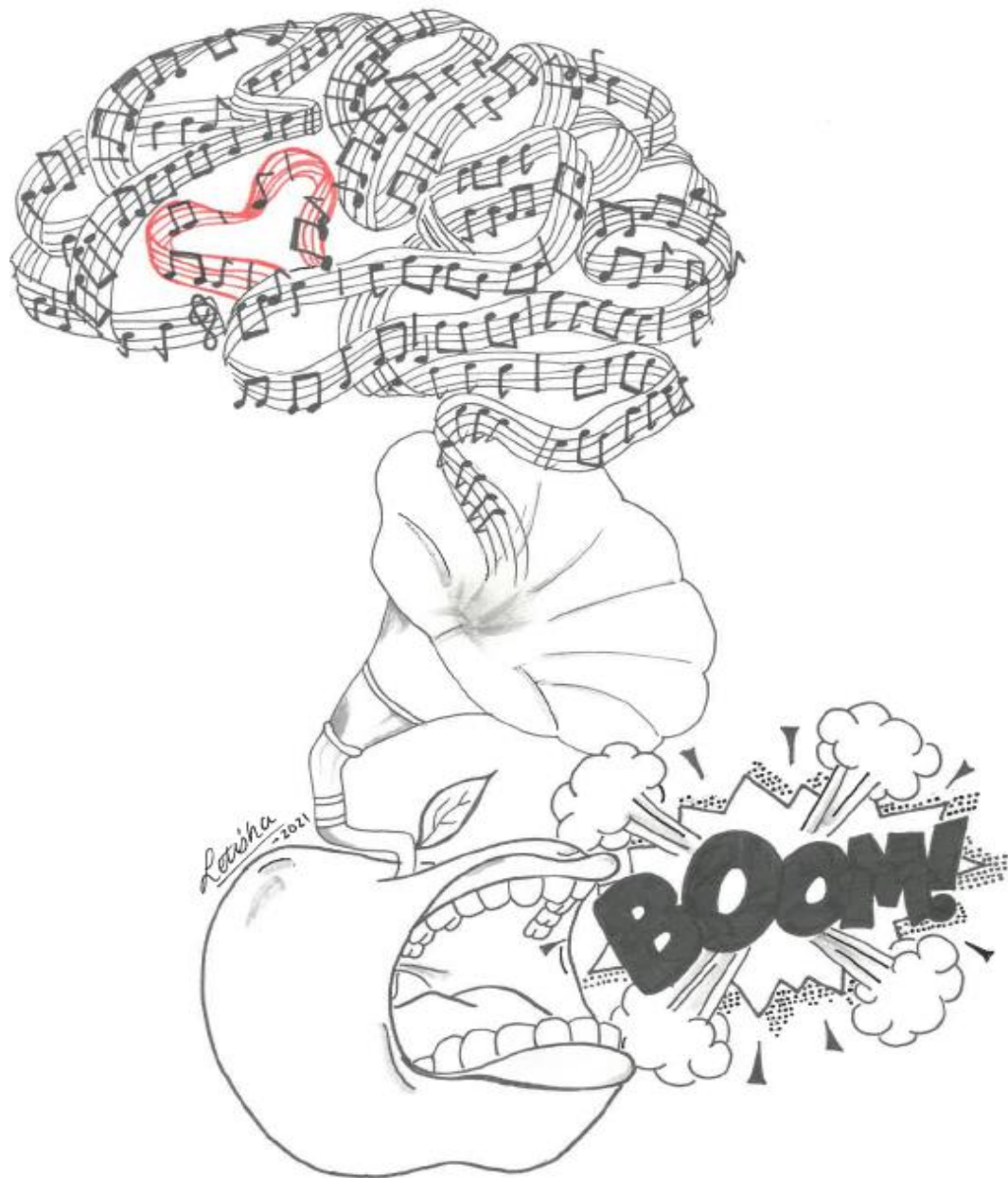
sleepy eyes. Thank you for the unconditional love and being my biggest supporter and strength, especially on my worst days. Thank you for understanding me at times when I barely understood myself. Your hands have carried me, at times physically, to the end (P.S. I love you- most).

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ILLUSTRATION: LISTEN TO THE CRUNCH, IT'S MUSIC TO MY EARS!

(Latchman, 2021)



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Above is a lovely illustration by one of my talented colleagues, Letisha Latchman. It provides an overall depiction of my study in the form of a sketch.

Illustration explained from bottom to top:

- *Apple mouth:* Mouth in the shape of a bitten apple to express food oral processing and the textural and acoustic properties of the food explored in this study (i.e. texturally hard foods that produce crispy, crunchy and/or crackly sounds).
- *“Boom!”* Explosion of sounds produced when biting into texturally hard foods- like “boom on your palate” (a reference to a statement made by expert Chef Centelles in my study).
- *Music horn/trumpet:* Depicts the ear and the salience of acoustic stimuli. This music horn/trumpet presents sound processing from the ear and its transmission to the brain for neural processing.
- *Musical notes shaped like a human brain, with a heart at the centre:* Potential physiological responses to food sounds. The heart represents the notion that food sounds are like music to the ears/brain (i.e. hedonic and enjoyable).

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POEM: BITE-SIZE DELIGHT

(Mohamed, 2021)

I enjoyed a harmonious mastication.

I am afraid you may not quite understand.

Have you ever spoken unintelligibly?

It is an acquired taste I must say,
possessing an uncoordinated melody.

One day,

my supper was served so soft,

I could barely hear my satisfaction.

My theatre of enjoyment became a silent symphony.

I became a spectator in my own production.

Better safe than sorry! was how I said grace.

But what do I hear?

What are you saying?

Can I now,

stop and bite,

crunch and savour

control and delight?

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ABSTRACT

Background: Dysphagia (swallowing disorders) leads to a myriad of consequences such as dehydration, malnutrition, aspiration pneumonia, reduced quality of life and mortality. As a result of the dysphagia, individuals face concerns with safe feeding, and those mainly from low-to-middle income contexts may encounter further challenges such as limited access to suitable foods and dysphagia services. This may contribute to the global crisis of food insecurity and challenges to food sovereignty. Given these challenges faced by individuals with dysphagia, this study aims to address this by re-aligning the lens from the limited access to resources and practitioners toward the food provided to individuals with dysphagia. In the field of dysphagia, textural and its associated acoustic properties (i.e. food textural acoustics) has not been sufficiently considered in diet textural modifications. As a result of this gap, the purpose of this study is to explore the influence of food textural acoustics on human swallow responses and on dysphagia.

Methods: This study employed an exploratory study design that used a mixed-methods approach. The broader study consisted of four components; (a) conceptual and theoretical exploration of the construct of food textural acoustics, (b) pilot study to evaluate the swallow responses to food acoustics of texturally hard foods, (c) exploration of the sensibility of the construct using revised scoping review methods and expert consultations, and (d) exploration of the utility of the construct for dysphagia research and practice.

Results: A synthesis of the overall doctoral study results demonstrated the complexity of eating, emphasising the salience of acoustic properties. The preliminary result of the pilot study revealed the positive influence of acoustic properties of texturally hard foods on physiological and perceptual swallow responses in healthy adults. The results further highlighted the sensibility of considering the construct of food textural acoustics to understand eating for individuals with dysphagia. The study concluded by proposing four subject areas undergirding the construct of food textural acoustics; multisensory eating, auditory processing, swallow physiology responses, and perceptual swallow responses, with the need to acknowledge the methodological dilemmas of studying the construct.

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Conclusion: Food acoustic stimuli are salient. We propose investing in the sensory aspects of diet textural modifications through consideration of food textural acoustics. This will promote the development of foods for individuals with dysphagia that are safe, pleasurable and potentially therapeutic to improve swallowing. We anticipate that this paper will inspire further inquiry into food textural acoustics and its potential use in global dysphagia practice. It is time to start promoting the change of the rhetoric of sound, the “forgotten flavour sense” to the “celebrated flavour sense.”

Keywords: *textural acoustics, swallow physiology, multisensory eating, dysphagia practice, auditory processing*

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RESEARCH OUTPUTS

Peer-reviewed publication (presented in chapter three):

Karani, T. F., & Pillay, M. (2021). It's crunch time: Exploring the sensibility of food textural acoustics for individuals with dysphagia. *The South African Journal of Communication Disorders*, 68(1).

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Karani, T.F. (2020, November 06 - 07). *Exploring food acoustic properties and the swallow properties and the swallow mechanism: Possible implications on dysphagia management: Dysphagia in low-middle income contexts: Opportunities to reimagine practice* [Panel presentation]. South African Speech-Language and Hearing Association-American Speech Hearing Association, Virtual Conference.

Karani, T.F., & Pillay, M. (2019, October 03-05). *It's crrr...time: Swallowing responses to food acoustic stimuli* [Oral presentation]. South African Speech-Language and Hearing Association Conference, Durban, South Africa.

Karani, T.F., & Pillay, M. (2020, October 8-10). *Neurophysiological and perceptual swallow responses to acoustic properties associated with texturally hard foods: A pilot study* [Poster presentation]. European Society for Swallowing Disorders Congress, Online Virtual Conference.

Karani, T.F., & Pillay, M. (2020, November 06-07). *Have you heard about "HEARD" (Human Eating and Acoustic Rheology for Dysphagia)? Exploring food acoustic properties on the swallow mechanism: A pilot study* [Oral presentation]. South African Speech-Language and Hearing Association- American Speech Hearing Association, Virtual Conference.

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CHAPTER ONE: INTRODUCTION

Sound has often been regarded as the “forgotten flavour sense” (Spence, 2015). The focus of this study is to explore the relationship between food textural acoustics and the human swallow physiology. Food textural acoustics refers to sounds produced when eating foods like when biting into crunchy, texturally hard foods. Of course, as a Speech and Language Therapist, I am interested in how the senses influence the individuals I work with living with dysphagia (swallowing disabilities). Interestingly enough, with the advent of Coronavirus Disease 2019 (COVID-19) pandemic over the last two years, people have never been more aware of how senses, like smell, are affecting the way we respond to food. Indeed, COVID-19 has undeniably impacted several vocational, educational and leisure aspects. It has also influenced my perspective of conducting my doctoral study, serving as a catalyst to further illuminate global social, economic and health inequities. Additionally, COVID-19 has reduced clinical choices in the assessment and management of individuals with dysphagia globally, e.g. restricted use of videofluoroscopic swallowing studies due to the contact involved. These kinds of restrictions has driven me to consider and conceptualise novel methods to reimagine practices. In this study, this means exploring theoretical and methodological investments in food as a therapeutic tool (Pillay, 2020). Specifically, in this study I consider how sensory aspects like food acoustic and textural properties may be therapeutically harnessed to manage individuals with swallowing disabilities across all contexts.

1.1. Introduction to the study

This study focused on the interconnected nature between textural and acoustic properties of food. For instance, sounds are produced when slurping, drinking and when biting into texturally hard foods. This interlinked notion has been supported by the fields of engineering, physical sciences and food science by prostrulating the psychoacoustic theory of crispiness (Vickers & Bourne, 1976) and the constructs of acoustic rheology and textural acoustics (Drake, 1965; Peleg, 2017; Swan et al., 2015; Zadeike et al., 2018). This study has borrowed from these constructs and will refer to the term “food textural acoustics.” The innovation of this study is the exploration of the influence of the construct of food textural acoustics within the field of dysphagia.

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Previously, the acoustic sense in food was under-researched and overlooked compared to the other senses and referred to as the “forgotten flavour sense” (Spence, 2015). In recent years particularly over the last 15-20 years, there has been a burgeoning interest in studying the influence of audition given its documented salience (Spence, 2015). Both non-food related sounds such as music, background sounds and packaging, and food-related sounds (i.e. crispy, crunchy, crackly, squeaky and carbonation), have shown to have a positive influence on behaviour, perception and overall enjoyment of food (Carvalho et al., 2016; Demattè et al., 2014; Kantono et al., 2016; Spence, 2015, 2016, 2017; Trautmann et al., 2017; Zampini & Spence, 2004, 2005, 2010). These studies span across the fields of cognitive neuroscience (Callan et al., 2018; Kantono et al., 2018; Lowe et al., 2018), gastronomic sciences (Knöferle et al., 2015), marketing (Spence, 2016; Wang & Spence, 2019), and beyond (Spence et al., 2019). Despite this well-researched area, there is still a gap in exploring the influence of food-related sounds (i.e. food acoustics) on the physiological responses, with two known studies conducted that have studied the influence on the perception of food texture (Endo et al., 2016, 2017).

When considering food acoustics, it is necessary to acknowledge that textural and acoustic properties are closely linked and cannot be viewed in isolation. For example, the force applied to a texturally hard food when biting into the food results in vibrations transmitted to the ear as a wave via air-conduction and bone conduction (Duizer, 2001; Vickers & Bourne, 1976). Despite the fields of engineering, physical sciences and food science supporting this interconnected relationship between textural properties and acoustic properties (Drake, 1965; Swan et al., 2015; Peleg, 2017; Zadeike et al., 2018), deglutition sciences such as studies of diet textural modifications tend to marginalise how texture and acoustic properties are intimately connected. When food is texturally modified, other sensory properties such as visual, acoustic and olfactory properties are also altered. For this study, this construct of food textural acoustics will be explored concerning the dysphagia management of diet textural modifications. Within this study, several methods were used to critically explore the swallow responses to food textural acoustics, the sensibility of this construct for dysphagia, and methods and considerations when studying this construct in a research setting. The emphasis is on discussing the potential utility of food textural acoustics as a way to reimagine global dysphagia practice.

1.2. Background and context to the study

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1.2.1. Dysphagia and dysphagia management

Dysphagia refers to any difficulty or disorder transporting food or drinks from the oral cavity to the stomach or the sensation of foods or liquids being obstructed anywhere between the mouth to the stomach (Malagelada et al., 2015; Singh & Hamdy, 2006). Dysphagia may lead to a plethora of consequences such as dehydration, malnutrition, aspiration pneumonia, reduced quality of life and mortality (Abu-Ghanem et al., 2020; Cichero et al., 2017). According to the World Health Organisation (WHO), over one billion people live with a disability, approximately 15% of the global population and this prevalence is reported to be increasing (WHO, 2021). The prevalence of dysphagia is stated to affect 8% of the world's population, approximately 590 million people worldwide, which is an issue that needs consideration (Cichero et al., 2017). This prevalence of disability and particularly dysphagia may very well increase due to the outbreak of COVID-19. COVID-19 has shown links to dysphagia due to the close association between the respiratory and swallowing systems, which are affected in individuals with COVID-19 (Frajkova et al., 2020). Patients with COVID-19 who require ventilation for more than 72 hours may also be higher at risk of post-extubation dysphagia, increasing the prevalence of dysphagia (Bhatraju et al., 2020; Frajkova et al., 2020).

Dysphagia management may involve rehabilitative and compensatory intervention strategies (Easterling, 2017; Mittal et al., 2015). Rehabilitative approaches function to change the swallow physiology and include swallowing manoeuvres such as effortful and supraglottic swallows and Mendelsohn and Shaker manoeuvres (Mittal et al., 2015). Traditionally in deglutition sciences, it was also believed that one could rehabilitate the swallow mechanism by using various sensory stimuli and through changes in the cortical neuronal reorganisation by neural plastic changes of the intact hemisphere (Lee et al., 1999; Michou & Hamdy, 2013; Steele & Miller, 2010). This may encompass non-electrical peripheral sensory stimuli such as tactile, thermal or chemical stimuli (Steele & Miller, 2010). There also exists a plethora of evidence to support the positive influence of sensory modalities of vision, olfaction and gustation on swallow physiology and dysphagia rehabilitation (Loret, 2015; Michou et al., 2012; Nagy et al., 2014; Pelletier & Steele, 2014; Sdravou et al., 2012; Wahab et al., 2010, 2011; Welge-Lusse et al., 2009). Conversely, compensatory strategies include compensatory postures such as chin tuck and diet textural modifications, which have dominated the field of dysphagia, to ensure safe feeding

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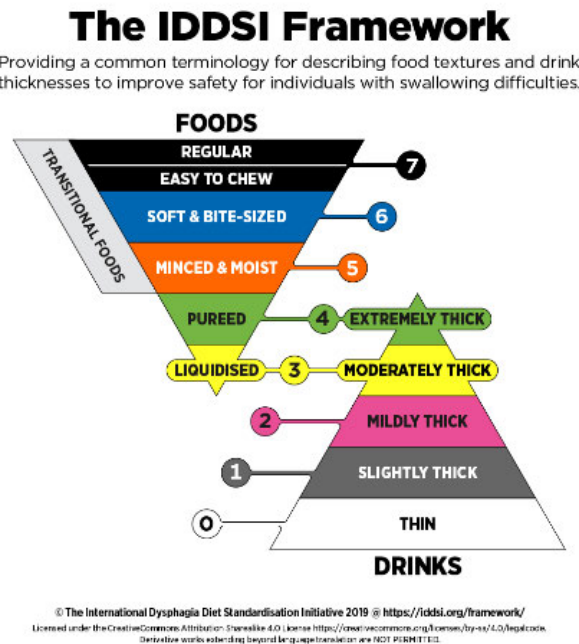
(Cichero, 2020; Cichero et al. 2017; de Villiers et al., 2019; Keller et al., 2012; Mittal et al., 2015; Simons & Hamdy, 2017; Steele et al., 2015; Swan et al., 2015).

This study mainly focuses on the sensory aspects of diet textural modifications. Diet textural modifications is essentially a classification system for dysphagia diets that can be prescribed using the International Dysphagia Diet Standardisation Initiative (IDDSI) framework (Cichero et al., 2017). The IDDSI framework is an objective technique to measure the consistency of foods and drinks. Deglutition sciences recognise the IDDSI framework as a universal and systematic approach to textural modification for individuals with dysphagia (Cichero et al., 2017). The IDDSI framework involves a continuum of eight levels (0-7) for foods and drinks and is suitable for all ages, cultures and care settings (Cichero et al., 2017; Lam et al., 2017) (see Figure 1). A study was conducted by Cichero et al. (2017) using participants from 33 countries. Participants were required to complete a survey on the classification of dysphagia diets. The results showed that participants used 27 different labels to refer to less than five levels of drink thickness and 54 labels to refer to less than five levels of food. The lack of standardised terminology, as depicted in the study by Cichero et al. (2017) and others, drove the development of the IDDSI framework to classify various consistencies (Cichero et al., 2013, O’Keeffe, 2018; Steele et al., 2015). Within this current study, the IDDSI framework has been used as a standardised guideline to understand and apply diet textural modifications, a framework has been used as a standardised guideline to understand and apply diet textural modifications.

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Figure 1.

International Dysphagia Diet Standardisation Initiative (IDDSI) Framework



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Regarding effective dysphagia management, deglutition sciences have suggested combining the rehabilitative and compensatory approaches to ensure swallow safety and rehabilitation of the swallow physiology (Arslan et al., 2017; Vose et al., 2014). To promote this effective dysphagia management, this study focuses on the sensory aspects of diet textural modifications by considering food textural acoustics for swallow safety and enjoyment and as a potential therapeutic tool for swallow physiology to improve dysphagia. This will be explored further throughout this thesis.

1.2.2. Dysphagia practice in low-to-middle income contexts

Low-to-middle income contexts such as South Africa and Brazil face myriad challenges such as a quadruple burden of illness, disease and disability like HIV/AIDS and tuberculosis, compounded by complex socio-economic challenges (IHME, 2018; Pillay-van Wyk et al., 2016).

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These low-to-middle contexts also encounter crises to food security and food sovereignty concerning the paucity of access to affordable and suitable foods and limited resources and workforce. Food security and food sovereignty are global concerns. According to the global report on food crises (2021), approximately 155 million people suffered from acute food security in 2020, nearly 20 million higher than in 2019. Food security includes four dimensions; food availability, access, utilisation and sustainability (Food and Agriculture Organization [FAO et al., 2015]; Webb & Rogers, 2003). Food sovereignty is connected to food politics and a nation's right to develop culturally diverse, socially and economically appropriate foods (Campesina, 1996; Patel, 2009). These economically challenged contexts may also present unequal distribution of therapists between public and private settings (Andrews & Pillay, 2017; Pillay et al., 2020). We can expect that these conditions influence the services provided to patients and overall health outcomes.

Across some of these low-to-middle income contexts, healthcare challenges such as the high patient-to-therapist ratio may pose difficulty to therapists like dysphagia practitioners to provide adequate services daily (Andrews & Pillay, 2017). This may cause an overreliance on using the compensatory strategies of postures and diet textural modifications to manage the dysphagia. However, this compensatory approach allows the dysphagia practitioner to adapt to these challenges yet provide food and drink that is safe for consumption for their patients (Swan et al., 2015). Diet textural modifications such as thickened liquids have shown to be beneficial given that it reduces the risk of penetration and aspiration by slowing down the flow to allow an increased time for airway closure (Cichero et al., 2013; Wirth et al., 2016). Conversely, thickened liquids and solid food may be a risk due to the residue post swallow (Clave et al., 2012). Additionally, studies by O'Keeffe (2018), McCurtin et al. (2018), Swan et al. (2015) and Vucea et al. (2017) have depicted that thickened liquids may cause undernutrition and result in poor compliance and reduced quality of life for individuals with dysphagia. Dysphagia practitioners need to consider these implications when recommending diet textural modifications.

In addition to the reduced access to resources and high patient-to-therapist ratio, the global north has mainly produced the dysphagia assessment and practice literature. The global north promotes specific ontological viewpoints (nature of realities) like "gold standard" assessment measures such as videofluoroscopic swallowing studies and fibre-optic endoscopic

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evaluation of swallowing (Fattori et al., 2016; O’Hor et al., 2015). These may be costly tools to evaluate swallowing. As a result, dysphagia practitioners positioned in the global south may be unable to apply these measures in practice due to the unique challenges faced by their healthcare systems (i.e. reduced access to these measures and practitioner expertise) (Andrews & Pillay, 2017; O’Horo et al., 2015; Ostrofsky & Seedat, 2016; Pillay et al., 2020). This dilemma makes it crucial to conceptualise novel measures that are more contextually responsive to these settings, such as this current study.

These conditions associated with the healthcare system of low-to-middle income contexts, described above, echo my sentiments working as a Speech-Language Therapist and Audiologist in South Africa. For my community service year, I was placed at a regional hospital in rural KwaZulu-Natal, where I was confronted with the high patient-to-therapist ratio and limited access to resources and equipment. Many of the patients that I treated were elderly individuals who had suffered cerebrovascular accidents, which resulted in dysphagia, with or without speech, language and motor difficulties such as aphasia and apraxia. In some instances, due to the paucity of access and poor neurological status of the patients, I had to resort to the use of diet textural modifications and commonly prescribed commercial thickeners such as Thick & Easy Original®, Resource® ThickenUp™ Clear and Nutilis powder products. These modified starch-based and/or xanthan gum-based thickeners can be used to alter the consistency of foods and drinks. Some of the patients often complained of their texture-modified diets and the unpleasant taste of these thickeners. This gave rise to poor compliance in following these diets and using these thickeners and further resulted in frequent hospitalisations due to recurrent aspiration pneumonia. This fuelled my passion and the need to more effectively serve individuals with dysphagia who need to be carefully managed for their condition, particularly those from low-to-middle income contexts. I began to question; what can we do to target the rehabilitation of the swallow mechanism of these patients while ensuring that the foods provided to these individuals with dysphagia consider their quality of life and are enjoyable?

1.3. Problem statement

Globally, individuals with dysphagia may encounter food security and sovereignty challenges such as safety concerns and reduced access to suitable foods. In the low-to-middle income context, these challenges are further compounded by the high patient-to-therapist ratio,

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limiting access to dysphagia services. This often leads to an over-reliance on compensatory strategies such as diet textural modifications for dysphagia management. To address these challenges, this study focuses on investing in the sensory aspects of diet textural modifications through consideration of food textural acoustics.

Eating is a multisensory experience and should be enjoyable, and exceptionally safe and therapeutic for individuals with dysphagia. In psychology, gastronomical sciences and marketing, food acoustics have been shown to influence behaviour, perception and overall enjoyment positively. Sensory inputs such as vision, olfaction, tactile and gustation have also influenced swallow physiology and contributed to dysphagia management. However, the influence of food acoustics on physiological responses has not been explored across the fields. Given the interconnected nature between textural properties and acoustic properties, this study aims to explore food textural acoustics concerning dysphagia as a way to reimagine global dysphagia practice.

1.4. Conceptual elements undergirding the study

The following section will critically discuss the two primary conceptual elements undergirding the study; (a) Tackling Hunger by Research and Innovation in Vulnerable Environments (THRIVE) project, and (b) multisensory eating framework.

1.4.1. Tackling Hunger by Research and Innovation in Vulnerable Environments (THRIVE) project

This study was conceptualised to address the challenges and dilemmas met by dysphagia practitioners in low-to-middle income contexts across low-to-middle income countries. The Tackling Hunger by Research and Innovation in Vulnerable Environments (THRIVE) project underpins this study. It is dedicated to repositioning swallowing and feeding in a way that promotes transformative practitioners who are concerned with the food security and sovereignty of their patients (Pillay & Kathard, 2018). Individuals with disabilities such as dysphagia may encounter severe food security and food sovereignty challenges concerning safety concerns and food access (Pillay & Kathard, 2018). This may involve aspiration risks and limited access to commercial food thickeners and suitable foods for individuals with dysphagia, especially prevalent in low-to-middle income contexts (Andrews & Pillay, 2017).

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A specific THRIVE project is motivated to develop more novel dysphagia interventions as a way of reimagining dysphagia practice (Pillay & Kathard, 2018). Due to the lack of access to practitioners, resources and affordable and suitable foods, particularly in low-to-middle income contexts, I believe there is a need to re-align the lens from the practitioner and resources to the food provided to these individuals with dysphagia. There is a need to consider novel ways that are both cost-effective and feasible to manage swallowing. This involves proposing a transformation of dysphagia diets by developing more sensory responsive foods for individuals with dysphagia. The consideration of food textural acoustics in dysphagia management may be used as a way to reimagine dysphagia practice. Food security and dysphagia are interconnected, especially in times of humanitarian crises (Quarmby & Pillay, 2018). In connecting diet textural modifications to food security, then the appropriate food textures that address the physiological needs such as food safety are essential to consider. Food safety for individuals living with dysphagia goes beyond preventing aspiration risks and consequent hospitalisations, and includes hedonic (pleasure) responses.

This study aims to explore the influence of food textural acoustics on the human swallow physiology. This will assist in determining its potential therapeutic benefit on swallow physiology to improve dysphagia. It is also necessary to carefully consider economic and ergonomic viability when developing these foods for individuals with dysphagia, especially its applicability for low-to-middle income contexts. Economic viability relates to the accessibility and affordability of the methods and ingredients used to develop these sensory responsive foods. Ergonomic viability is the ease, and cost and time-efficiency of developing these foods. In this way, through consideration of these factors, we are able to cater for both low-to-middle and high-income contexts (i.e. globally).

Another essential point to acknowledge is that eating is one of the most multisensory human experiences (Piqueras-Fiszman & Spence, 2016; Spence, 2015, 2017, 2020; Velasco et al., 2016). In 2008, Blumenthal expressed on one of his tasting menus at The Fat Duck restaurant, “Eating is the only thing we do that involves all the senses. I don’t think that we realise just how much influence the senses actually have on the way that we process information from mouth to brain.” This notion of multisensory eating will be explored below.

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1.4.2. Multisensory eating framework

Extensive research across the fields of psychology, gastronomic sciences and marketing have highlighted that one should understand eating and flavour perception as a multisensory event and concerning the multisensory eating framework (Auvray & Spence, 2008; Prescott, 2015; Spence, 2015, 2017, 2020; Spence & Shankar, 2010). Each of our senses plays a role in flavour perception, both individually and collectively (Spence, 2015, 2016; Zampini et al., 2008). The visual system is involved in selecting foods, and the olfactory and gustatory systems make sense of the smell and taste of the food (Spence, 2015). The proprioceptive system assists in identifying textures and shapes of foods, while the auditory system plays a role in the sounds of biting and chewing of foods (Spence, 2015; Verhagen, 2007). In gastronomic sciences, there has been a recent increased focus on this notion of multisensory eating and the multisensory eating framework, and it has been positioned as a novel and improved way to understand gastronomy. Multisensory human-food interaction (MSHFI) has also become a burgeoning field of inquiry as a way to modify and enhance our food-related experiences (Altrarrriba Betran et al., 2019; Nijholt et al., 2018; Velasco et al., 2017; Velasco et al., 2018). Like the multisensory eating framework, the field of MSHFI is dynamic and multidisciplinary and considers how various perspectives and fields interact with food (Altrarrriba Betran et al., 2019). However, the focus of the study is mainly on multisensory eating rather than MSHFI. The author is keen on further exploring this emerging and dynamic field of MSHFI and incorporating this into future studies.

From an anatomical and physiological perspective, multisensory eating can be understood based on the physiological sensory processing systems (refer to studies by Henschke et al., 2015; Macaluso, 2006; Schroeder & Foxe, 2005; Van den Brink et al., 2014). Similarly, the fields of cognitive psychology, cognitive neuroscience, gastronomic sciences, and gastrophysics (merges gastronomy and psychophysics) focus on the mechanisms underlying the complex integration of multiple senses during eating. However, these gastronomic sciences and gastrophysics fields particularly foreground how these sensory processes inform flavour perception (Spence, 2015, 2017; Vi et al., 2020; Wang & Spence, 2018). The field of gastrophysics has shifted its attention from what is occurring in the mouth to emphasise the mind of the individual consuming the food (Spence, 2019). This includes the notion of cross-modal correspondences (i.e. the interaction that occurs when one sense affects another sense), for instance, the widespread olfactory-gustatory

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interaction (Crisinel & Spence, 2009, 2010; Spence et al., 2010; Spence, 2015). This also involves the flavour changes and eating behaviours that are influenced by individual visual, olfactory, gustatory and tactile stimuli, and multisensory stimuli (Spence, 2014, 2021; Spence & Piqueras-Fiszman, 2014; Spence & Shankar, 2010; Spence et al., 2014; Welch et al., 2016).

This study is more inclined to understand multisensory eating from both the physiological and perceptual perspectives discussed above. This will allow this study to encompass various perspectives and promote a more holistic view of the notion of food textural acoustics with regards to multisensory eating and its potential link to the field of dysphagia.

1.5. Research question

How can dysphagia practitioners consider the use of food textural acoustics in the management of individuals with dysphagia?

In light of the existing gaps in the literature across the fields of psychology, gastronomical sciences, marketing and deglutition sciences, the following aim and objectives were established:

1.6. Study aim and objectives

This study aimed to explore the influence of food textural acoustics on swallow responses. The specific objectives were as follows:

- 1.6.1. To develop and test protocols and tools to evaluate the influence of food textural acoustics on physiological and perceptual swallow responses in healthy adults by using modified videofluoroscopic swallowing study (VFSS) protocols, modified surface electromyography (sEMG) protocols, and self-administered perceptual questionnaires.
- 1.6.2. To investigate the sensibility of food textural acoustics as a construct to understand eating for individuals with dysphagia using qualitative evidence synthesis methodologies.
- 1.6.3. To propose a theoretical basis for studying the construct of food textural acoustics concerning dysphagia rehabilitation based on data from a pilot study and qualitative evidence synthesis methodology.

Note. The term “protocols” have been operationalised as guidelines developed and tested to conduct the research study and explore the objectives (Al-Jundi & Sakka, 2016). The term “tools”

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include any item or aspect that allowed and facilitated the collection and analysis of data for the study (Ebrahim, 2016).

1.7. Theoretical framework: Auditory processing of food textural acoustics

This study focuses on developing sensory responsive foods by consideration of food textural acoustics within the field of dysphagia. This section will discuss the theoretical framework of auditory processing of food textural acoustics. This may offer a valuable framework for studying food textural acoustics concerning dysphagia.

Auditory processing refers to how the brain perceives and interprets sounds (Bellis, 2004). This involves the pathway from the inner ear to the brain via the auditory nerve for processing (Price et al., 2005). Auditory processing occurs in the primary auditory cortex, located in the transverse gyrus of Heschl of the brain, which is transmitted up the auditory processing stream (Bellis, 2004; Molholm et al., 2002). Functional neuroimaging studies show that the core areas of the primary cortex are surrounded by the belt and parabelt areas, which are involved in processing more complex aspects of auditory stimuli (Zatorre et al., 2002). Several aspects are involved during auditory processing, such as identification, interpretation, auditory attention, discrimination, memory, and language and temporal processing (Bellis, 2004; Price et al., 2005). Auditory processing may involve two networks; (a) processing of spatial information (“where” or “how”), and (b) processing of acoustic features such as sound recognition and environmental sounds (“what”) (Rauschecker & Tian, 2000).

There is an abundance of research on the auditory processing of linguistic and non-linguistic sounds such as environmental sounds or music (“what”) (Hendrikson et al., 2019; Rassili & Ordin, 2020; Richards & Goswami, 2015) and its two parallel pathways (Møller, 2011, Palumbo et al., 2018). The two parallel pathways, the classical and non-classical auditory pathways are separate ascending sensory pathways (Møller, 2011). The classical auditory pathway is known as the specific system. It responds to only one sensory modality, and the non-classical pathway is the unspecific system as it receives input from other sensory systems such as the visual and somatosensory system, causing cross-modal interactions (Møller, 2011). This study steers away from linguistic and non-linguistic auditory processing to focus on how individuals process body-generated sounds like sounds produced when biting into texturally hard foods (i.e. crispy, crunchy or crackly).

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When exploring the literature neurologically, it was clear that internal or body-generated sounds are processed along the same cortical and subcortical pathways as speech, music and environmental sounds, though the exact process is still unknown (Palumbo et al., 2018). This study, particularly the first paper, has explored the potential link between auditory processing and food oral processing responses (i.e. first bite, mastication and swallowing) of food textural acoustics (see Chapter Two). These internal sounds may also link to the phenomenon of autophony. Autophony refers to self-hearing or our response to internal body-generated sounds such as one's voice, breathing, heartbeat and oral sounds (i.e. lip-smacking, chewing, swallowing) (Harris, 2015; Keidar & Kwartowitz, 2018; Tidball & Fagelson, 2018). This has been researched related to misophonia, an adverse emotional reaction triggered by these sounds (Palumbo et al., 2018). Autophony has been investigated in audiology and otolaryngology, where it has been viewed in the context of pathology or discomfort in the instance of a patulous eustachian tube or superior canal dehiscence syndrome (Johanis et al., 2021; Verrecchia, 2018). At the other end of the continuum, there may be enjoyment and pleasure to these internal body-generated sounds. This study has considered autophony in this way, given the hedonic response to eating sounds of texturally hard foods such as crispy, crunchy and crackly sounds.

1.8. Overview of the study components and methodology

The study involved four main components; namely:

1. conceptual and theoretical exploration,
2. pilot study,
3. exploration of the sensibility of the construct, and
4. exploration of the utility for dysphagia research and practice.

The retrospective review of the study revealed that following the conceptual and theoretical exploration and the pilot study, the next step was the main study. However, as a result of COVID-19, the main study was halted. Despite this disruption, COVID-19 provided an opportunity to relook at the theoretical underpinnings of the study and reflect on the value of the pilot study findings. This led to conducting the exploration of the sensibility of the construct through the revised scoping review and expert consultations and exploration of the utility for dysphagia research and practice. In essence, this may be viewed as innovation in methodology in and of itself as the pilot study represents practice which informed rethinking the theory, rather

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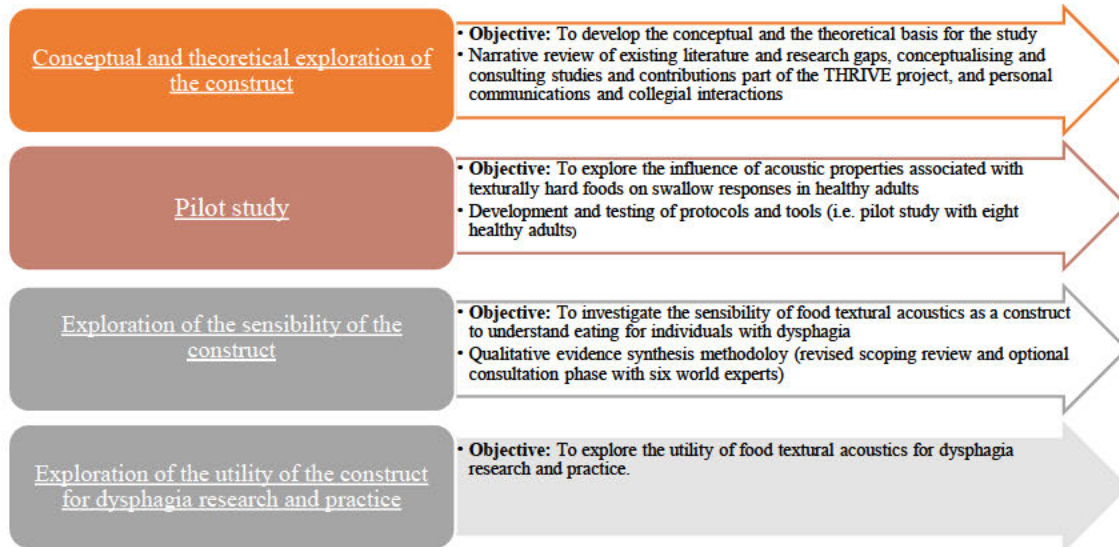
than theory informing practice. The order of the presentation of these study components and their respective papers will follow this sequence.

The overall methodology of this study was predominantly exploratory in nature. Exploratory study designs are used to gain research insights that are still preliminary to formulate questions, develop hypotheses, or clarify concepts (Hallingberg et al., 2018). Due to the novelty of this study, this type of design was utilised to comprehensively explore the phenomenon of food textural acoustics and its related concepts. This study design made use of various data collection methods and a mixed-methods approach. This included qualitative and quantitative methods to effectively address the objectives across the broad four components (Figure 2). The conceptual and theoretical exploration of the construct was mainly qualitative to set up the conceptual and theoretical basis for the study. In chapter two, the pilot study presented utilised a mixed-methods approach using a descriptive-analytical design. This pilot study evaluated the swallow responses using quantitative and qualitative measures. In chapter three, paper two presented the exploration of the sensibility of the construct. This employed a qualitative approach, specifically the qualitative evidence synthesis methodology, to investigate the sensibility of the construct of food textural acoustics. Finally, the third paper in chapter four presented the exploration of the utility for dysphagia research and practice. This largely adopted a qualitative approach and synthesised papers one and two to provide a theoretical basis for studying the construct of food textural acoustics related to dysphagia rehabilitation.

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Figure 2.

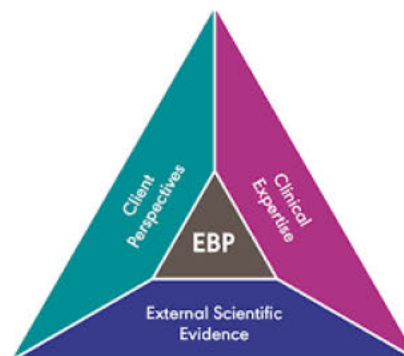
Components of the Broader Study



In essence, the three papers of this study followed principles similar to the evidence-based practice triad, elaborated below (Sackett et al., 1996) (Figure 3). This framework was selected for the knowledge production of a novel construct.

Figure 3.

Evidence-based Practice Triad



Paper one (pilot study) represented the researcher expertise (clinical expertise) employed when testing the pilot study and participant preferences and views (client perspectives) when evaluating the swallow responses of the participants. Paper two involved revised scoping review

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methods through exploring the construct of food textural acoustics in published literature across the fields over 40 years (external scientific evidence). Paper two also conducted an adapted consultation phase using focus group discussions to obtain expert opinions (clinical expertise) regarding food textural acoustics. Thoughts and evidence influence practice. Paper three is a culmination of papers one and two and includes references to all three elements of the evidence-based practice triad to propose a theoretical basis for studying food textural acoustics related to dysphagia rehabilitation. According to American Speech-Language-Hearing Association (ASHA, 2005), when clinicians consider all three components of the evidence-based practice, they can make informed decisions and provide quality services that reflect the needs of the individuals that they serve. This model has been selected to produce knowledge regarding food textural acoustics and apply the construct of food textural acoustics to reimagine dysphagia practice.

1.9. Structure of the study

The study was prepared in line with the guidelines stipulated by the University of KwaZulu-Natal's College of Health Science to present a doctoral thesis by research. This study is presented in the format of a thesis by publication to fulfil these university requirements. This study comprises five chapters; introductory chapter, three chapters in between- consisting of three papers- and a concluding synthesis chapter. The candidate was the prime author of these three original papers. These papers act as distinct papers, one which is published and two under review with local and international journals. The details of the journals and status of the papers are presented in the preamble sections of chapters two, three and four. The preamble section of these three chapters also elaborates on the theoretical constructs and methodology of the paper to provide further clarity. Despite being three independent papers, each paper builds on the previous paper to form a cohesive argument. As a result of this structure, it is essential to note that there is redundancy throughout the study. This ensures that there is coherence and that the study sufficiently covers all areas required by addressing the study aims and objectives.

A summary of the five chapters is described below:

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Chapter one: Introduction and literature review

The introductory chapter provided an overview of the study. The chapter consisted of background and context, conceptual elements undergirding the study and the overarching theoretical framework. The current chapter further presented the research question, aims, objectives and overall study components and design.

Chapter two: Paper one

Title: Swallow responses to acoustic properties associated with texturally hard foods in healthy adults: A pilot study (under review by the American Speech Hearing Association Perspectives- Special Interest Groups, issue 17: *Global perspectives* (ASHA SIG17))

This chapter included a paper designed to explore concepts undergirding food textural acoustics. This paper involved a pilot study which employed two phases; (a) development of protocols and tools, and (b) testing of protocols and tools to evaluate the influence of acoustic properties associated with texturally hard food on swallow responses in healthy adults. This paper presents a proposed method to evaluate the influence of food acoustics on swallow responses to generate research for clinical practice.

Chapter three: Paper two

Title: It's crunch time: Exploring the sensibility of food textural acoustics for individuals with dysphagia (published by the South African Journal of Communication Disorders).

Karani, T. F., & Pillay, M. (2021). It's crunch time: Exploring the sensibility of food textural acoustics for individuals with dysphagia. *The South African Journal of Communication Disorders*, 68(1).

This chapter is presented in the form of a published paper. The paper employed qualitative evidence synthesis methodologies to investigate the sensibility of food textural acoustics as a construct to understand eating for individuals with dysphagia. This involved revised scoping review methods and an adapted consultation phase through online focus group discussions with six world experts from various fields.

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Chapter four: Paper three

Title: “Boom on your palate”: Exploring the utility of food textural acoustics in swallowing rehabilitation (under review by the American Speech Hearing Association Perspectives- Special Interest Groups, issue 13: Swallowing and swallowing disorders (dysphagia) (ASHA SIG13))

The final paper is a theoretical paper in the form of a tutorial. The purpose of this tutorial is to introduce researchers and clinicians to the construct of food textural acoustics in relation to dysphagia rehabilitation based on the results of the two previous papers. This paper proposes four subject areas that may be considered when studying this construct of food textural acoustics. It further explores methods and considerations for researchers to study this construct. This paper concludes by discussing the potential clinical utility of food textural acoustics in clinical dysphagia practice.

Chapter five: Summary, critique and conclusion

The concluding chapter synthesises the significant findings of the study. This chapter provides a critique, exploration of the potential implications of the study, and recommendations for future research and practice.

1.10. Conclusion

Previously the role of audition has been overlooked and referred to as the “forgotten flavour sense” (Spence, 2015). However, the last 15-20 years has seen a renaissance in the study of acoustics. Food acoustics has shown to have a positive influence on behaviour, perception and overall enjoyment across psychology, gastronomical sciences and marketing, with a gap still present across the fields exploring the influence of acoustic stimuli on physiological responses. Given the interconnect nature between textural and acoustic properties and the positive influence of food acoustics, this study is particularly focused on food textural acoustics in relation to dysphagia. Due to limited dysphagia practitioners and food insecurity and food sovereignty challenges (access to suitable foods) in low-to-middle income contexts, diet textural modifications is commonly used as a compensatory strategy. To maximise the effects of diet textural modifications, this study proposes investing in the sensory aspects of diet textural modifications. This involves consideration of food textural acoustics in diet textural modification

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as a way of reimagining global dysphagia practice. This study aspires to promote the change of the rhetoric of sound, which is the “forgotten flavour sense” to the “celebrated flavour sense,” as a way to reimagine dysphagia practice.

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CHAPTER TWO: PAPER ONE

2.1. Introduction

The current chapter presents the second component of the larger study, i.e. the pilot study. The fields of psychology, gastronomical sciences and marketing have studied the influence of food acoustics on behaviour and perception (Carvalho et al., 2016; Demattè et al., 2014; Kantono et al., 2016; Spence, 2016; Spence et al., 2019; Wang & Spence, 2019; Zampini & Spence, 2004, 2005, 2010). Since the influence of food acoustics on physiological responses has still not been sufficiently considered, the paper presented in this chapter explores this gap by detailing a pilot study.

This pilot study aimed to explore the influence of acoustic properties associated with texturally hard foods on swallow responses in healthy adults. Individuals with dysphagia may face challenges to food security and food sovereignty in relation to safe feeding and access to appropriate food (Pillay & Kathard, 2018). As a result, this paper prefaced the need to consider the global crises of food security and food sovereignty when planning dysphagia interventions. As a proposed solution, the pilot study paid particular attention to investigating the food oral processing (FOP) responses to acoustics associated with texturally hard foods. Due to this area not being sufficiently researched, the pilot study is exploratory in nature and used a mixed-methods framework. This exploratory study design aimed to gain insights on preliminary research to inform a future main study (Hallingberg et al., 2018). This paper will further tackle the consideration of acoustic properties of texturally hard foods in global dysphagia management. Additional appendices that have not been included in the paper have been added to the Appendix section at the end of the thesis (see Appendices 1.2 and 2-11).

2.2. Publication details

This chapter includes the paper which has been submitted for publication to the American Speech Hearing Association Perspectives- Special Interest Groups, issue 17: *Global perspectives* (ASHA SIG17). The paper was designed to comply with the journal specifications (style, word count, and page limit) and is currently under peer review. The paper foregrounds the methodology of the pilot study and the preliminary findings. To supplement the paper, the next

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section will further discuss certain theoretical constructs that have guided the development of the methodology of the pilot study.

Title	<i>Exploring the influence of acoustic properties associated with texturally hard foods on swallow responses in healthy adults: A pilot study</i>
Authors	Tasneem Fareed Karani ¹ , Mershen Pillay ²
Journal	American Speech Hearing Association Perspectives- Special Interest Groups, issue 17: <i>Global perspectives</i> (ASHA SIG17)
Status	Under review

2.3. Pilot study

The pilot study involved two phases; (a) development of protocols and tools to evaluate the influence of acoustic properties on the swallow responses, and (b) testing the developed protocols and tools to evaluate the influence of acoustic properties associated with texturally hard foods on the swallow responses in healthy adults. The methodology of the paper (i.e. development of the protocols and tools) was, in part, informed by the component of the conceptual and theoretical exploration. The testing phase employed a descriptive-analytical design with mixed methods and involved eight healthy adults. This phase was conducted at two testing stations to evaluate the two study objectives. Due to the novelty of this pilot study, the methodology has been richly presented in the paper.

2.3.1. Aim and objectives

This study aimed to explore the influence of acoustic properties associated with texturally hard foods on swallow responses in healthy adults and addressed the following two objectives:

- 2.3.1.1. To explore the influence of acoustic properties associated with texturally hard foods on physiological swallow responses using; (a) modified videofluoroscopic swallowing study (VFSS) protocols and (b) modified surface electromyography (sEMG) protocols.
- 2.3.1.2. To explore the influence of acoustic properties associated with texturally hard foods on perceptual swallow responses using self-administered questionnaires.

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2.3.2. Theoretical constructs undergirding the pilot study

This study will elaborate on the physiological and perceptual constructs undergirding the pilot study as per the two study objectives. Below, there will be discussions presented around the specifics of food oral processing responses and cultural-linguistic diversity.

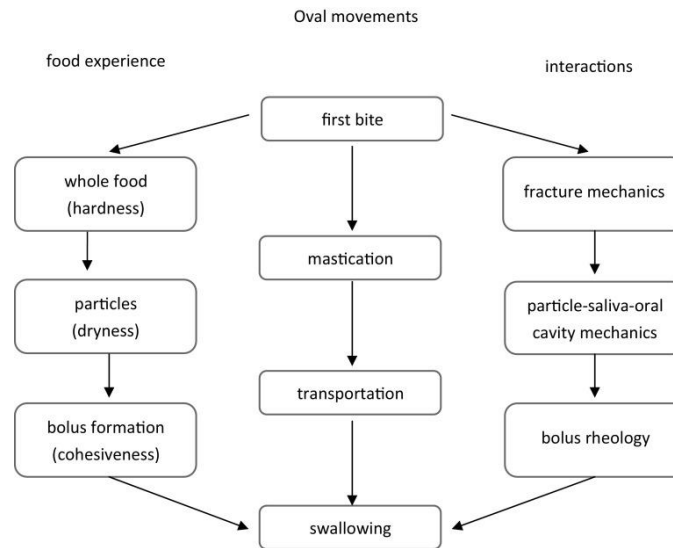
2.3.2.1 Food oral processing (FOP) responses

Food oral processing (FOP) is a highly coordinated and rigorous process (Chen, 2015). The study of FOP has sparked interest, especially since the dawn of ancient society (Nishinari et al., 2019). The subject of FOP is complex and multidisciplinary, involving various disciplines of food physics, psychology and oral physiology (Chen, 2009, 2020; Fiszman & Tarrega, 2020). The construct of FOP is the first phase involved in the breakdown of food and is crucial from nutrition and sensory perspective to appreciate various food textures and flavours (Chen, 2009; Devezeaux De Lavergne et al., 2021; Liu et al., 2017). Hutchings and Lillford (1988) have proposed the FOP model (in-mouth process model). This model represents food trajectory through the breakdown over time and promotes the importance of saliva as a lubricant to assist with swallowing the bolus. The construct of FOP is also a dynamic process that encompasses several oral operations, viz. first bite, mastication, formation, transportation of the bolus and swallowing (Chen, 2015; Duizer, 2019; Liu et al., 2017; Ong et al., 2018; Sharma & Duizer, 2019) (see Figure 1). Cichero (2020) promotes the need for dysphagia clinicians to consider the first bite, early chew down, middle and later chew down, and oral residue post swallow. This paper has engaged with more of the oral physiology perspective to understand the FOP responses given its holistic approach and consideration of all the components involved in eating.

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Figure 1.

Oral Processing Conceptual Framework



Note. Reprinted by permission from Springer Nature: Springer, Journal of Food Science and Technology, Impact of oral processing on texture attributes and taste perception, Liu et al. (2017).

First bite

The first objective of this paper focused on exploring the influence of food acoustics of texturally hard foods on physiological responses. The focal parameter of the study involved understanding the swallowing responses, which is an interconnected event as a result of the first bite. Bite force was used as a critical parameter to evaluate the first bite. The first bite is the starting point of oral processing and refers to when a sample from a food product is acquired and/or the initial chewing cycle of a constant sized sample (Duizer & Winger, 2006; Foster et al., 2011). The first bite is the most significant phase in texture assessment, with studies by Endo et al. (2016), Stokes et al. (2013), and Laguna et al. (2016) and reporting that the first bite is substantial in texturally hard foods. This is the reason for focusing on the first bite in the study to determine the influence of texturally hard foods on the FOP responses.

During FOP, a food sample experiences a change in the structure from the first bite to the bolus formation and swallowing with assistance from the saliva (Liu et al., 2017). The first bite results from the involvement of the masseter, temporalis and pterygoid muscles and can be

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measured using electromyographic recordings of the activity of these muscles (Duizer, 2003). The pilot study has adopted this measure. The muscle activity has shown to be higher during the first bite, the start of the FOP, as the individual requires more significant effort to break down the food (Cichero, 2020). The muscle activity is expected to reduce as the food is broken down. The mechanical properties of the food also influence the force of the first bite. For brittle foods, the biting force is sharp and quick (Duizer & Winger, 2006). Christensen and Vickers (1981) have shown that research has evaluated the crispiness perception during the entire chewing process, and it has depicted that majority of sensations required to perceive crispiness occurs during the first bite. Furthermore, Duizer and Winger (2006) investigated the usefulness of a bite force apparatus to measure the bite force when biting extruded crisp snacks. The results revealed that the maximum bite force was considerably related to the crispiness, hardness and brittleness of the extruded crisp snacks (Duizer & Winger, 2006).

It is important to note that individuals can modify their bite force depending on their prior experience of the biting experience of similar foods and expectations of a food's texture (Duizer, 2003). We can apply this notion to the field of dysphagia. An individual with dysphagia may present with physiological changes such as reduced strength of the muscles of mastication or swallowing. As a result of the reduced lingual control, Cichero (2020) recommends that the dysphagia practitioner suggest an IDDSI Level 4 consistency (pureed). This may be the easiest to manage, given pureed consistencies do not require biting or chewing. In this way, the individual with dysphagia, who has adequate insight, may apply a reduced force when consuming the pureed food. Again, this is based on his or her previous and current sensory perception of the texture of the food and due to the physiological changes resulting from the dysphagia (Cichero, 2020).

Mastication and swallowing

In addition to the first bite, the pilot study evaluated the influence of acoustic properties associated with texturally hard foods on the parameters of mastication and swallowing. Mastication occurs following the first bite. Adequate masticatory function positively influences cognition and is necessary to assist in changing solids into a bolus to promote safe swallowing (Fukushima-Nakayama et al., 2017; Gonçalves et al., 2021; Krishnamoorthy et al., 2018). Gonçalves et al. (2021) published a consensus document on the terminologies and methodologies for masticatory assessment. The main reason for this paper was to limit misuse and ambiguity of terminologies to

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compare various studies on masticatory. The following can be used to assess masticatory function; comminution tests and mixing ability tests (Gonçalves et al., 2021). These researchers further reported that two approaches could be used to evaluate mastication; (a) bolus being examined after a set amount of chews or (b) at the time when the swallow is triggered (Gonçalves et al., 2021). The second approach, known as the mastication test or m-test, was utilised in the pilot study (Bonnet et al., 2019). The function of this approach was to tally the number of masticatory cycles associated with the acoustic properties of the food to get the food ready for swallowing. Chewing assessment tools also include the recent development of the test of mastication and swallowing solids (TOMASS) by Huckabee et al. (2018) and the Karaduman chewing performance scale for the paediatric population (Cichero, 2020). The TOMASS can be used to assess the number of bites, the number of masticatory cycles and swallows per cracker (Huckabee et al., 2018). The pilot study used these principles by considering the number of masticatory cycles per food sample during the various masking conditions and with each individual used as their baseline as prescribed by the test.

Mastication and swallowing are dependent on various characteristics; (a) physical properties of food (size, shape and volume), (b) textural properties of food (hardness and cohesiveness), and (c) an individual's physiological characteristics such as age, mastication force, tongue motility and dentition (Gray-Stuart et al., 2017; Kohyama et al., 2017; Van der Bilt, 2011; Van der Bilt & Abbink, 2017). The relationship between food hardness and chewing cycles has been explored, and the results have portrayed that dry and harder foods, such as the food samples used in the pilot study, require more chewing cycles before swallowing, longer mastication duration and greater muscle force (Chen, 2009; Cichero, 2020; Engelen et al., 2005; Foster et al., 2006; Foster et al., 2011; Gonçalves et al., 2021; Witt & Stokes, 2015; Woda et al., 2006). Furthermore, during the development of the IDDSI framework, Steele et al. (2015) also revealed that solid, hard and adhesive foods require a greater mastication rate and muscle force and longer mastication duration. This is due to the increased time required to break down the food and add sufficient saliva to form a coherent bolus for swallowing (Foster et al., 2011; Gonçalves et al., 2021). To simplify this oral processing, food thickeners and food texture modifications have been used mainly for those individuals with dysphagia (Andersen et al., 2013; Cichero, 2013). It is also essential to note that as a central pattern generator controls mastication in the brain stem, chewing

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frequency is dependent on the individual rather than the food (Gonçalves et al., 2021). Therefore, the pilot study will focus on the evaluation of the FOP responses discussed above.

2.3.2.2. Cultural-linguistic diversity in perception

There are several other associated aspects when considering food textural acoustics, the physics of sound, and the several physiological processes and responses involved (i.e. FOP responses as explained above). This includes perceptual responses. Food and mealtimes are a cultural phenomenon given it plays a significant role in food preferences and engagement in mealtimes (Kenny, 2015). Certain foods are more appreciated and enjoyed by specific cultures. For instance, Asian countries prefer slippery sensations in food such as noodles. In contrast, slurping foods are not considered good manners in western countries, with a preference for more crispy and crunchy foods (Nishinari et al., 2019).

There also exists cultural and linguistic diversity around food textural acoustics. Studies by Szczesniak (1988) and Tunick et al. (2013) depicted that textural terms are dependent on culture and languages. I believe that this is a critical concept to consider, given the various cultures and languages. For example, Chinese and Japanese populations have multiple terms to refer to crispy, crunchy and crackly such as words that translate to rustling and sprinkling (Szczesniak, 1988). While, Italians have only one word, “croccante”, to classify crispy and crunchy foods (Spence, 2015). South Africa is commonly referred to as a rainbow nation as it comprises of diverse cultures, religions and languages. This paper will further explore the construct of cultural-linguistic diversity in perception with South African participants and present this construct as one of the paper's themes.

2.4. Summary of the preamble

This chapter presents the paper currently under review with ASHA SIG17. Due to the word and page limits of the journal, this preamble has further discussed the theoretical constructs (physiological and perceptual responses) undergirding the pilot study to provide the reader with a better understanding of the paper presented below. This includes the theoretical constructs of FOP responses and cultural-linguistic diversity.

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**2.5. Paper one: Exploring the influence of acoustic properties associated with texturally
hard foods on swallow responses in healthy adults: A pilot study**

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Abstract

Purpose: The global prevalence of dysphagia (swallowing disorders) is 590 million. Individuals with dysphagia encounter safety concerns such as aspiration risks and reduced access to dysphagia services and suitable foods. Our study focuses on the need to shift the lens from the practitioner and resources to the food provided to these individuals with dysphagia, thus addressing some of the challenges of food insecurity and food sovereignty that they face. We conducted a pilot study aimed at exploring the influence of acoustic properties associated with texturally hard foods on swallow responses in healthy adults. The pilot study involved two phases; (a) developing the protocols and tools and (b) testing the developed protocols and tools to evaluate the swallow responses.

Method: The pilot study used an exploratory design. The testing phase employed a descriptive-analytical design with mixed methods. The testing phase recruited eight healthy adults using non-probability convenience sampling. Stata 15 and thematic analysis were used for the quantitative and qualitative analysis, respectively.

Results: Phase one involved developing four protocols and tools for use during the testing phase. Phase two, the participants' physiological and perceptual responses were evaluated using five food samples of varying textures in two auditory conditions, i.e. masked or unmasked. The preliminary results revealed the positive influence of acoustic properties of texturally hard foods on physiological and perceptual swallow responses.

Conclusions: Acoustic stimuli are salient. We propose developing and using transitional foods that are safe, pleasurable, and sensory responsive foods, such as transitional foods. We anticipate that this study will inspire more novel approaches for global dysphagia practices such as the consideration of inclusion of acoustic properties. Based on the evaluation of this pilot study, we propose the implementation of the main study with minor amendments.

Keywords: *textural acoustics, swallow physiology, dysphagia practice, multisensory eating, perception, food security.*

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1. Introduction

Food security and food sovereignty are global concerns. Food security refers to food availability, access, utilisation and sustainability (FAO et al., 2015; Webb & Rogers, 2003). Food sovereignty is connected to food politics and a nation's right to develop food that is culturally diverse and socially and economically appropriate (Campesina, 1996; Patel, 2009). According to the Global Report on Food Crises, in 2021, approximately 155 million people suffered from acute food insecurity. The food security and food sovereignty of individuals with disabilities are particularly essential to consider as these individuals have an increased vulnerability when facing these challenges (Quarmby & Pillay, 2018).

According to the World Health Organisation (WHO), over one billion people live with a disability, approximately 15% of the global population and this prevalence is reported to be increasing (WHO, 2021). The prevalence of dysphagia is stated to affect 8% of the world's population, approximately 590 million people worldwide, which is an issue that needs consideration (Cichero et al., 2017). Dysphagia refers to any difficulty or disorder transporting food or drink from the oral cavity to the stomach and is known to lead to myriad consequences such as dehydration, malnutrition, aspiration pneumonia, reduced quality of life and mortality (Abu-Ghanem et al., 2020; Cichero et al., 2017; Malagelada et al., 2015). As a result of the dysphagia, these individuals face concerns with safe feeding and limited access to appropriate foods that may cause food security and sovereignty challenges (Pillay & Kathard, 2018). For instance, commercial food thickeners and suitable foods for individuals with dysphagia are poorly available in low-to-middle income contexts, which may further exacerbate aspiration risks (Andrews & Pillay, 2017). In addition to the reduced access to resources, specific healthcare contexts face a high patient-to-therapist ratio with an unequal distribution of therapists between urban and rural settings, making access to dysphagia intervention problematic (Andrews & Pillay, 2017; Pillay et al., 2020). Due to these challenges, the traditional model of individual dysphagia care, such as direct or rehabilitative interventions of swallowing manoeuvres and sensory stimulation techniques, is not always possible to target the swallow physiology (Easterling, 2017; Mittal et al., 2015). This results in the overreliance on compensatory postures and diet textural modifications (de Villiers et al., 2019; Mittal et al., 2015; Simons & Hamdy, 2017; Swan et al., 2015).

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Use of food acoustics as a way of reimagining dysphagia practice

The Coronavirus Disease 2019 (COVID-19) pandemic has further highlighted the social and economic crises and inequities encountered in healthcare systems across the globe. COVID-19 has also exacerbated rates of food insecurity, with approximately 49 million people entering poverty around the world (Bauer, 2020; Paslakis et al., 2021; Pereira & Oliveira, 2020). Arundhati Roy (2020) argued that the COVID-19 pandemic is a “portal” and a “gateway between one world to the next.” “We can choose to walk through it, dragging the carcasses of our prejudice and hatred...Or we can walk through lightly...ready to imagine another world. And ready to fight for it” (Roy, 2020). A possible solution for these challenges that we face is to consider novel methods to reimagine practice.

This study focuses on re-aligning the lens from the limited access to practitioners and resources to focusing on the food provided to individuals with dysphagia. This study represents one of the four components of the broader project (refer to Appendix A with details of the broader project). These study components are all undergirded by the Tackling Hunger by Research and Innovation in Vulnerable Environments (THRIVE) project, which is driven by repositioning swallowing and feeding in a concerned way with food security sovereignty (Pillay & Kathard, 2018). Based on this tenet, we are inspired to develop novel dysphagia interventions that focus on multisensory eating and investing in the sensory aspects of diet textural modifications such as more accessible and affordable “sensory responsive” foods. This can be achieved using cost-effective processes such as food dehydration and drying. Sensory aspects of diet textural modification and sensory responsive foods may include acoustic properties due to its recognised salience. Evolutionarily, auditory salience has been understood as acoustic properties of food signifying freshness, pleasantness and enjoyment (Spence, 2015, 2017; Tunick et al., 2013; Vickers, 1983). Therefore, we propose the potential use of acoustic properties in the foods for individuals with dysphagia, given the known positive hedonic response to food acoustics and the possible therapeutic benefit for individuals with dysphagia.

1.1. History of the study of food acoustic properties

Historically, the acoustic sense was referred to as the “forgotten flavour sense” (Spence, 2015). However, especially over the last 15-20 years, acoustics have taken the fields of cognitive neuroscience, marketing and gastronomical sciences by storm, becoming one of the central features

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of food science and/or engineering (Höchenberger, & Ohla, 2019; Knöeferle et al., 2015; Spence et al., 2019; Wang & Spence, 2019;). The influence of non-food related acoustics (i.e. music, background sounds and packaging) and food-related acoustics (sound of mastication and drinking) on behaviour and perception have been extensively studied (Carvalho et al., 2016; Demattè et al., 2014; Kantono et al., 2016; Lowe et al., 2018; Spence, 2016; Zampini & Spence, 2004, 2005, 2010). For instance, studies by Kantono et al. (2016) and Lin et al. (2019) have depicted the influence of environmental sounds and music on taste perception. The study by Zampini and Spence (2004) dubbed the “sonic chip” demonstrated that participants rated the same commercial potato crisp as crispier and fresher when the loudness and/or frequency components (>2000Hz) of the auditory feedback was amplified during eating.

Despite the well-researched area on the influence of food acoustics on behaviour and perception, there are insufficient studies on the influence of food acoustic properties on physiological responses. Endo et al. (2016, 2017) investigated the influence of altered auditory feedback of chewing sounds (pseudo-chewing sound) on the perception of food texture. The results revealed that the pseudo-chewing sound positively influenced the perception of the palatability of food, including taste and texture. However, the pseudo-mastication sound did not affect mastication intensity and rhythm, and further exploration is needed.

When we consider acoustic properties, it is necessary to consider it in relation to texture. Textural and acoustic properties of food are interlinked, for example, crispy, crunchy and slurping sounds are produced when consuming food and drink. The physical sciences and engineering fields have recognised this relationship with establishing the notion of acoustic rheology (Peleg, 2017; Zadeike et al., 2018). Given that the field of deglutition sciences has not sufficiently explored this phenomenon, within this study, we explored the influence of acoustic properties associated with texturally hard foods on swallow responses in healthy adults. Similar to other fields such as cognitive neuropsychology, which assumes that understanding typical development or processes will inform our understanding of atypical processes, and vice-versa, this study explored typical swallow responses in order to apply the research to individuals with dysphagia (swallowing disorders) (Graham & Madigan, 2016). This pilot study involved two phases:

1. Development phase: To develop protocols and tools to evaluate the influence of acoustic properties associated with texturally hard foods on the swallow responses in healthy adults.

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2. Testing phase: To test the developed protocols and tools to evaluate the influence of acoustic properties associated with texturally hard foods on the swallow responses in healthy adults.

2. Method

2.1. Objectives

1. To explore the influence of acoustic properties associated with texturally hard foods on physiological swallow responses using (a) modified videofluoroscopic swallowing study (VFSS) protocols and (b) modified surface electromyography (sEMG) protocols.
2. To explore the influence of acoustic properties associated with texturally hard foods on perceptual swallow responses using self-administered questionnaires.

2.2. Study design

The study was exploratory since the relationship between food acoustics and physiological responses is a relatively novel area of inquiry. This exploratory study design was used to explore the phenomenon of food textural acoustics comprehensively. This study design may also assist in informing the future main study (Hallingberg et al., 2018). The testing phase of the study employed a descriptive-analytical design which used a mixed-methods framework. The descriptive-analytical study design described the characteristics of the variables and allowed for a comparison between the two groups (i.e. the absence and presence of the masking condition) to evaluate possible effects of food acoustic on swallow responses (Aggarwal & Ranganathan, 2019; Omair, 2015).

2.3. Participants

2.3.1. *Screening and eligibility criteria*

We first screened the participants to ensure that they strictly fulfilled the inclusion criteria. The inclusion criteria included healthy individuals with hearing within normal limits and no signs of oro-mandibular pathology. This was confirmed by conducting three rigorous screening protocols and/or checklists for health, swallowing and hearing as detailed below:

1. The health screening questionnaire was developed by adapting the World Health Organization International Classification of Functioning, Disability and Health (ICF) checklist (ICF, 2003). The participants' questionnaire was self-administered and included

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two sections; physical, emotional and mental health, and hearing and swallowing abilities. The section on hearing and swallowing abilities included questions relating to any aversions to loud sounds and picky eating.

2. The Eating Assessment Tool (EAT-10), a self-administered outcome instrument for dysphagia, was used to screen the participants' swallow.
3. The hearing screening included otoscopy, tympanometry testing, acoustic reflex testing, and pure tone audiometry. The hearing screening procedures and technical parameters followed standard protocols recommended by ASHA (1997) and/or protocols developed for the study.

We screened a total of 10 participants, however, two participants were excluded from the final sample. The exclusion criteria included the presence of any health conditions and/or failed swallowing or hearing screenings. This criterion was set out to ensure that these conditions do not influence the effect of food acoustics on swallow responses in healthy adults and consequently the overall study findings. The excluded participants were referred to the appropriate health services for rescreening.

2.3.2. Recruited participants

Following the screening, we successfully recruited a total of eight healthy female adults aged between 18 and 25 years old with a mean age of 20 years old. Participants were students from the University of KwaZulu-Natal, South Africa, recruited using non-probability convenience sampling. This sampling technique refers to selecting participants based on meeting the inclusion criteria and their willingness to participate (Etikan et al., 2016). The inclusion and exclusion criteria ensured that the sample chosen was a representation of the population. The choice of this sampling method also allowed the researchers to select participants that were easily accessible and close to the study setting (Etikan et al., 2016).

2.4. Study setting

For the testing phase, we conducted the screening and recruitment phase at the University of KwaZulu-Natal. Following this, we conducted the pilot study at the Radiology department at one of the local hospitals in Durban, South Africa, close to the University of KwaZulu-Natal. The

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Biomedical Research Ethics Committee of the University of KwaZulu-Natal (South Africa) (BF152/19) approved the study. Participants provided informed consent before participation.

2.5. Data collection

The results of the development phase and testing phase tools are the results of the study. However, for the overall flow and ease of understanding of the pilot study, the details of the development phase and the process of the testing phase will be included under data collection. The results section will present the findings from the testing phase (physiological and perceptual swallow responses).

2.5.1 Development phase (protocols and tools)

We developed the following four protocols and/or tools for the pilot study; (a) modified Videofluoroscopic Swallowing Study (VFSS) protocol and modified Surface Electromyography (sEMG) study protocol, (b) food sample selection and development protocol, (c) sensory masking protocol, and (d) perceptual questionnaires. These protocols tools were used to evaluate the physiological and perceptual swallow responses. The conceptual and theoretical exploration of the broader study guided the development of these protocols and/or tools.

(a) Modified VFSS and sEMG study protocols

We conducted Clarke and Braun's (2014) thematic analysis to develop the parameters of interest for the VFSS and sEMG studies to evaluate physiological swallow responses. The initial review explicitly focused on studies on VFSS (Basson, 2015; Boaden et al., 2019; Daniels & Easterling, 2017) and sEMG (Steele et al., 2012; Vaiman & Eviatar, 2009). Derived from the initial review, we generated 12 parameters based on the three swallow phases (oral, oral, preparatory, and pharyngo-oesophageal phase), reviewed and recategorised. After that, we refined these parameters based on the three swallow phases by merging them with parameters from the initial dynamic oral processing (IDOP) framework (Duizer, 2019; Ong et al., 2018; Sharma & Duizer, 2019). A total of ten physiological swallow parameters were finalised through consultations with an expert food scientist to determine whether these parameters adequately address the study focus (L. Duizer, personal communication, August 19, 2019) (Appendix B, Table 2). We used these ten parameters when conducting the modified VFSS and sEMG studies. We also developed the modified VFSS

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and sEMG procedures by adapting standardised VFSS protocols by the American College of Radiology (2014) and Logemann (1993), and sEMG guidelines adapted from Steele et al. (2012).

(b) Food sample selection and development protocol

We carefully selected and developed five food samples; (a) commercial potato chip (or crisp), (b) commercial thin toast, (c) self-developed e-Pap biscuit, (d) self-developed e'Pap soft-semolina, and (e) self-developed e'Pap soft (refer to Table 1 for details). Laboratory trials by e'Pap and the University of Zululand informed the development of food sample c (e'Pap- based biscuit) (deVilliers et al., 2019; Kolanisi et al., 2020). e'Pap is a South African food production company with a humanitarian orientation of improving the nutritional status of African communities using a blend of whole-grain maize, soya beans, vitamins and minerals. This ensured that the food samples were cost-effective and nutritious for potential use in low-to-middle income contexts. All the food samples were according to the International Diet Standardisation Initiative (IDDSI, 2019) framework levels and size dimensions. Food samples a, b and c were texturally hard and classified as Level 7 (regular) food samples (IDDSI, 2019). These three food samples were also classified based on their acoustic and textural properties as crispy, crunchy, or crackly, according to Duizer (2001) and Vickers (1983, 1985) (see Table 1). We confirmed the classification through expert consultations (L. Duizer, personal communication, August 19, 2019). Food samples d and e were classified as IDDSI Level 6 (soft and bite-sized) and used as reference points. Due to the human swallow mechanism variability, no normative reference data exists for sEMG, specifically for acoustic rheology (Steele et al., 2012). Thus, a reference point was required to understand the change in swallow physiology due to acoustic properties associated with texturally hard foods.

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Table 1.

Table with the Textural and the Acoustic Description of the Food Samples Included in the Study

Food sample:	Textural property according to IDDSI levels:	Acoustic property (Vickers, 1983, 1985; Duizer, 2001)
Food sample 1: Commercial potato chip (or crisp)	Regular (Level 7)	Crispy
Food sample 2: Commercial thin toast	Regular (Level 7)	Crunchy/crackly
Food sample 3: Self-developed e’Pap-based biscuit	Regular (Level 7)	Crunchy/crackly
Food sample 4: Self-developed e’Pap soft, coated with semolina	Soft and bite-sized (Level 6)	Course and soft (reference point)
Food sample 5: Self-developed e’Pap soft	Soft and bite-sized (Level 6)	Soft (reference point)

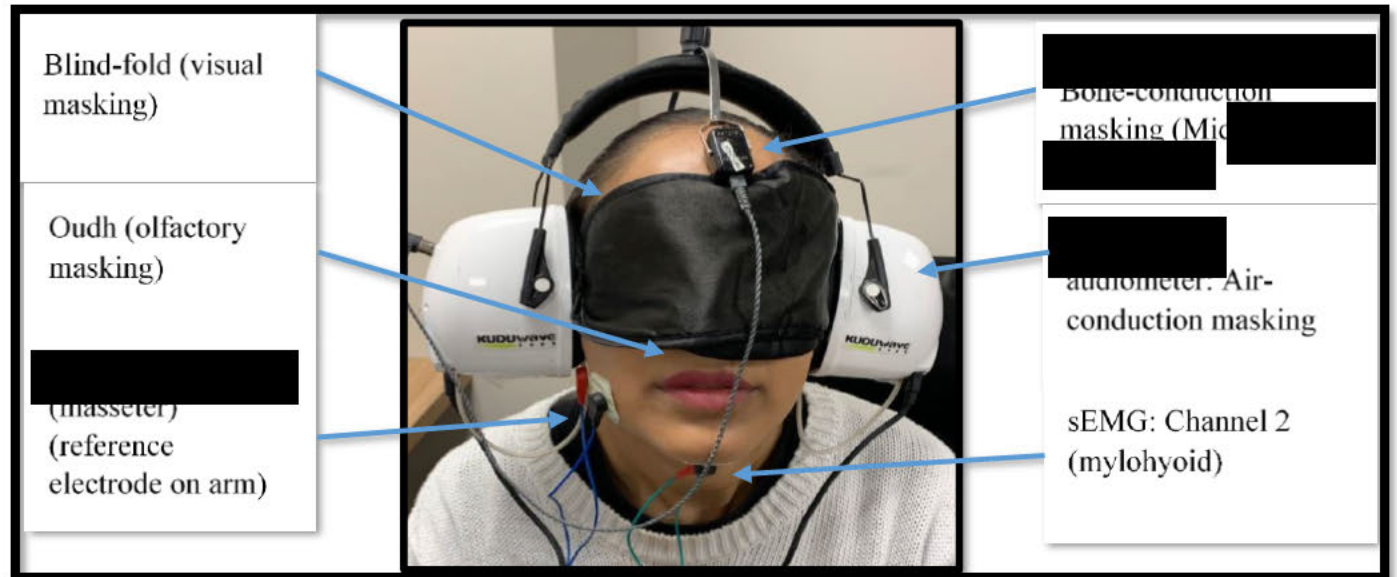
(c) Sensory masking protocol

We developed the sensory masking protocol based on literature evidence synthesis, referring to other undergirded studies by the THRIVE project (Mabaso et al., 2019) and through expert consultations. As eating is a multisensory experience (Spence, 2017, 2020), when developing the sensory masking protocol, we had to account for the other senses (i.e. visual, olfactory, somatosensory, and auditory masking (Figure 1) through sensory masking. This ensured that the auditory sense was isolated to evaluate the influence of food acoustics

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Figure 1.

Sensory Masking Protocol



Note. Researcher pictured in Figure 1 above

The following procedure was developed for sensory masking:

1. Blindfolding for visual masking
2. Distractor scent of Oudh, an Asian and Middle Eastern scent, was applied below the participants' noses as olfactory masking due to its potent fragrance (Gafsou, 2019; Khatoun, 2019; Renner et al., 2016). This scent was carefully chosen. Other scents such as those related to foods (flavourants) or chemical stimulants (e.g., menthol or aromatics) were not selected as olfactory maskers as they influence salivary flow rate, resulting in effects on oral processing responses and possibly the overall swallow responses (i.e. timing of the oral or pharyngeal phases). For instance, black pepper oil has shown to stimulate salivation (Noh et al., 2017).
3. IDDSI Level 6 (soft and bite-sized) food sample coated with semolina was used as somatosensory masking and as a distractor to provide the participants with an initial feel or response of a texturally hard food sample due to its coarse surface, however, then perceived

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as soft when masticated. According to Duizer (2019), the rheological properties of food can be evaluated from a sensory perspective within the first few milliseconds.

4. To evaluate the influence of acoustic properties of texturally hard foods, two masking conditions were used; namely (a) masked, and (b) unmasked.

(a). The masked condition referred to the auditory masking condition. In this condition, the participant was provided with the food sample with the presence of effective auditory masking (air-conduction and bone-conduction), with constant visual and olfactory masking. This ensured that the participant could not hear the acoustic properties of the foods generated when eating, such as crispy, crunchy and crackly sounds (Christensen & Vickers, 1981; Duizer, 2001). Auditory masking was delivered by a diagnostic audiometer (KUDUwave Plus by eMoyo). The auditory masking protocol was developed through consultations with field experts (H. Ramatsoma, personal communication, August 16, 2019) (Appendix C).

(b). The unmasked condition referred to the condition without auditory masking, with constant visual and olfactory masking.

5. During the evaluation of the swallow responses, we signalled the participants to commence self-feeding using a spoon by a tap on their shoulders. This confirmed that the textural and its associated acoustic properties of the food samples were masked before eating.

(d) Perceptual questionnaires

To evaluate the influence of food acoustics on perceptual swallow responses, we developed two perceptual questionnaires. These questionnaires were developed based on consulting another study which was undergirded by the THRIVE project (Lakhi et al., 2019) and considering literature regarding the psychology of hedonic response (perception and liking) to foods (Berridge & Kringelbach, 2015; Cardello, 2017; Kwak & Lee, 2016). The first questionnaire evaluated the participants' perception of their swallow responses to the texturally hard food samples. This included rating their perception of the parameters of bite force, mastication force, duration, and swallow force by comparing the two masked conditions and their review of the food samples based on the two masked conditions. The second questionnaire involved sensory perception by classifying the food samples as either crispy, crunchy, crackly or other.

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2.5.2. Testing phase: The study process

We conducted a pre-pilot study on two healthy adult males before the pilot study. The pre-pilot study was conducted at a local hospital in South Africa and was aimed as a basic mapping exercise for the pilot study and addressed the overall reliability of the study. The function of the pre-pilot study functioned as a first step to guide planning and modification of the pilot study (In, 2017). After that, the data collection tools and methods were revised, and the pilot study was conducted over two testing stations at a local hospital in South Africa. The physiological swallow responses were evaluated at testing station one (VFSS suite), and the second testing station evaluated the perceptual swallow responses. When a participant arrived at the hospital, they were accompanied to a waiting area. We explained the study information, and the participant provided their informed consent.

Testing station one

After providing written informed consent, the participant was accompanied to the first testing station, where the physiological swallow assessments were conducted. Here, we prepared the food samples and donned our radiation aprons while also providing the participants with safety. After palpation, a pair of sEMG electrodes were placed on the right masseter and mylohyoid (channel one and channel two) of the participant to measure their muscle activity. The reference electrode was placed on the participant's arm. The participant preparation required five minutes per participant. The food samples were coated with barium sulphate made into a paste using water according to the guidelines by Steele (Swallowing Rehabilitation Research Lab, 2020) and placed in clear plastic containers to present to the participant. This paste was at the correct consistency to ensure that the food samples retained their textural properties.

The process at testing station one involved two researchers, two radiologists and one research assistant. The participant sat facing forward and upright with their back towards the test screen and the radiologist. We conducted simultaneous modified VFSS and modified sEMG study protocols in the VFSS suite to evaluate the ten swallow parameters developed. We provided the following instructions to the participant before commencing; "bite and chew naturally on the right side of the mouth, and swallow when you are ready", to encourage the most natural way of eating. The sensory masking protocol was administered during the modified VFSS and modified sEMG study protocols (described previously). The effect of food acoustic properties was determined by

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first screening the participant's dry swallow without masking to record a baseline. Thereafter, a total of nine food trials were conducted, i.e. each of the four food samples, except IDDSI Level 6, in a random order in the two conditions, i.e. (a) constant visual and olfactory masking with the presence of auditory masking and (b) constant visual and olfactory masking but without auditory masking. The IDDSI Level 6 food sample was delivered only in the unmasked condition due to its soft texture and no acoustic property of a texturally hard food sample. The protocols and tools were repeated on all eight participants. The process of evaluating the physiological swallow measures for the food samples in the two masking conditions took approximately 25 minutes per participant.

The radiologist captured the VFSS images in real-time in a digital format known as Digital Imaging and Communications in Medicine (DICOM). These VFSS images were stored onto a Siemens Picture Archiving and Communication Software (PACS), an imaging technology used in the medical field for various medical imaging modalities. The sEMG recordings (mean) were stored using two methods (a) electronically recording and saving the results onto a VitalStim® Plus programme installed on a laptop, and (b) a Speech-Language Pathologist (SLP) research assistant documenting the values in real-time. After evaluating the physiological swallow responses at testing station one, the participant was taken to testing station two.

Testing station two:

We evaluated the participant's perceptual swallow responses (including hedonic responses) at testing station two. An SLP research assistant provided instructions and handed out the two questionnaires to each participant to complete. Participants were required to provide a rating and explain their perceptions of bite force, mastication force and duration, and swallow force by comparing the masked to the unmasked auditory conditions. This was based on a 3-point ordinal scale (more effort/duration, less effort/duration, or same effort/duration) and open-ended response. Participants were provided with the same four texturally hard food samples to eat and were asked to classify them based on one of the choices of "crispy", "crunchy", "crackly", or "other". If the participants responded with "other", this was open-ended as they were required to provide another term to classify the food sample in English and/or their home language. Participants were also required to provide a review ("like" or "dislike") with a corresponding motivation to evaluate the hedonic responses to the texturally hard food samples. Each participant took approximately 20 minutes to complete the questionnaires.

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2.6. Data analysis

We retrieved the VFSS images captured at testing station one, which were stored onto PACS. We consulted a radiology Information Technology specialist with any queries regarding the PACS. We analysed the hyolaryngeal complex excursion (HLC) using a co-ordinate system (x-axis and y-axis) commonly used to standardise measurements to determine the level of excursion as a result of the food samples in the two masked conditions (Zu et al., 2011). Testing station one and station two data (physiological and perceptual swallow responses) were collated into separate data collection schedules on Microsoft Excel spreadsheets for statistical analysis. Quantitative data from the physiological and perceptual swallow responses were analysed using Stata 15 (StataCorp, 2017). The descriptive statistics included percentages, means, standard deviations, medians, and interquartile ranges. The paired t-test was used to evaluate any significant differences (using a p-value of <0.05) in the physiological swallow responses between baselines (dry swallow), masked and unmasked conditions.

We used thematic analysis by Clarke and Braun (2014) to analyse the results of the open-ended responses of the two questionnaires. This provided a rich and complex account of the data. The six-step recursive method for thematic analysis was used to guide the analysis. This included familiarisation, generating initial codes, searching for, and reviewing themes, producing final themes, and producing a report. We also used the computer analysis software *NVivo 12* to assist with the data coding processes. In essence, we formulated codes, categories and themes (Clarke & Braun, 2014).

3. Results and discussion

The pilot study yielded preliminary results, including physiological and perceptual swallow responses (including hedonic responses).

3.1. Physiological swallow responses

The results of the masked and unmasked conditions on the physiological swallow responses revealed the following based on the ten swallow parameters (see Table 2):

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Table 2.

Results of the Physiological Swallow Responses to Food Acoustics

Physiological swallow responses	Masked auditory condition		Unmasked auditory condition	
	Median/ Mean	Inter- quartile Range/Standard deviation	Median/ Mean	Inter-quartile Range/Standard deviation
Oral phase timing (ms)	15.13	4.19	13.02	6.26
First bite force (μV)	12.50	10.30	10.75	7.95
Mastication force (μV)	19.35	13.20	18.60	10.40
Mean number of masticatory cycles	15.44	4.17	13.75	5.12
Mean mylohyoid force (μV)	19.55	12.15	16.85	12.50
Duration of palatal elevation (ms)	1.18	0.43	1.12	0.44
Duration from the entrance of the bolus into the hypopharynx until the opening of the UOS (ms)	0.33	0.26	0.33	0.28
Percentage change in HLC excursion (from at rest to elevation (x-value)) (%)	32.88	55.04	31.02	51.00
Percentage change in HLC excursion (from at rest to elevation (y-value)) (%)	43.26	33.40	41.81	20.42
Duration of change in HLC excursion (at rest \rightarrow descent)	1.57	0.62	1.58	0.43
Duration of UOS opening and closing (ms)	0.43	0.40	0.53	0.40

Note. Abbreviations: HLC (Hyolaryngeal Complex); UOS (Upper Oesophageal Sphincter).

Table 2 represents the results of the physiological swallow responses to food acoustics. It shows a higher median for the oral phase timing, first bite force, mastication force and palatal elevation in the masked condition than the unmasked condition. Also shown is a higher mean for

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the mylohyoid force, the number of masticatory cycles and percentage change in HLC excursion (x-value and y-value) in the masked condition than the unmasked conditions. The median for the duration of the bolus entering the hypopharynx until the upper oesophageal sphincter (UOS) opening was the same in the masked and unmasked conditions. However, there was a lower median for the duration of the change in HLC excursion and the UOS opening and closing duration in the masked condition than the unmasked condition. These preliminary results depict that acoustic properties associated with texturally hard food may play a role in the swallow responses. Participants required less force and shorter duration for the first bite, mastication and swallowing when hearing the food acoustic properties. However, an increase in these parameters was recorded when the acoustic properties were masked. These results link to the potential relationship between auditory processing and oral processing that needs further exploration. Despite the results revealing differences between the masked and unmasked conditions, no statically significant differences were shown when hypothesis testing was conducted (p -value < 0.05). This is to be expected with small sample size. However, proving significance was not the aim of this pilot study.

We also analysed the differences in the physiological parameters between the dry swallows (baseline swallows) and five food samples to evaluate the influence of the food texture on physiological swallow responses. The rheological properties of foods are essential to consider as they have been recognised as an influencing factor in affecting the first bite and mastication (Chen, 2015). The results revealed significant differences (p -value < 0.05) with the first bite force, mastication force, mylohyoid force, and duration of palatal elevation for the texturally hard food samples compared to the soft food samples. The results regarding the significance of the first bite for the texturally hard foods are consistent with previous studies (Endo et al., 2016; Laguna et al., 2016; Stokes et al., 2013). Furthermore, the IDDSI Level 6-semolina food sample revealed significance in the first bite and mylohyoid forces, which will be discussed further under Theme 1.

As mastication is a semi-automatic rhythmic movement controlled by the central pattern generator in the brainstem, food hardness has been shown to modulate particular masticatory functions (Morquette et al., 2012). Texturally hard foods increase mastication intensity (i.e. sEMG activity of the masseter and temporalis muscles) (Endo et al., 2016), the number of chewing cycles and increases the duration of the masticatory sequence (De Wijk et al., 2008; Gonçalves et al., 2021; Van der Bilt, & Abbink, 2017; Woda et al., 2006). During the development of the IDDSI

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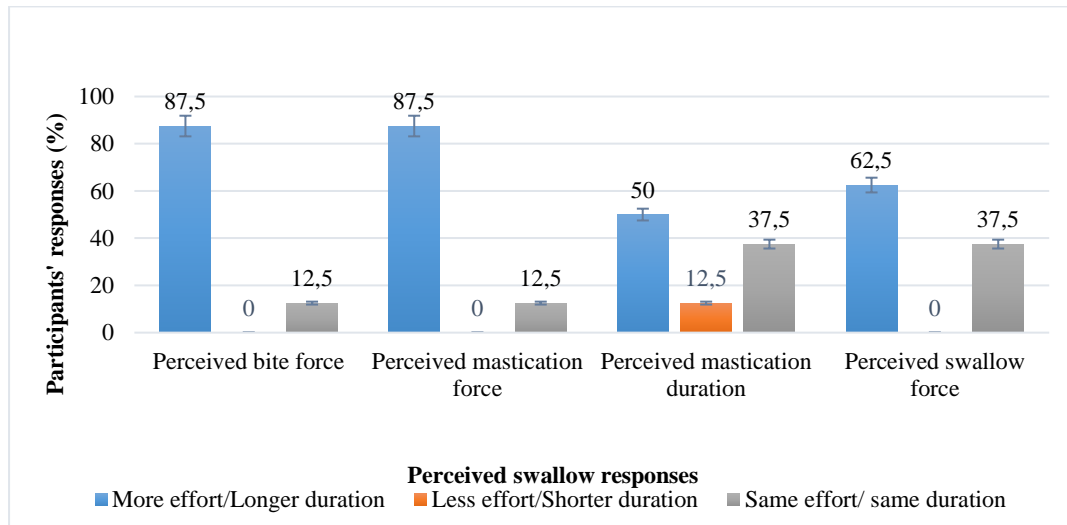
framework, Steele et al. (2015) also revealed that solid, hard and adhesive foods require a greater mastication rate and muscle force and longer mastication duration. This is due to the increased time required to break down the food and to add sufficient saliva to form a coherent bolus for swallowing (Foster et al., 2011). The preliminary physiological swallow responses obtained need to be further explored in the main study with a larger sample to determine whether the findings are replicable and generalisable.

3.2. Perceptual swallow responses

The participants' perceived swallow responses (Figure 2) and the two corresponding themes that emerged from the qualitative responses are presented below.

Figure 2.

Bar Graph Representing the Participants' Perceived Swallow Responses to Acoustic Properties Associated with Texturally Hard Food samples (Masked).



As depicted in Figure 2, the majority of the participants perceived their bite force (87.5%), mastication force (87.5%), and swallow force (62.5%) as requiring more effort when they were unable to hear the acoustic properties of the food samples (masked condition). Furthermore, most of the participants perceived their mastication duration as longer (50%) in the masked condition. Therefore, we can infer that participants perceived their first bite, mastication and swallowing force and duration as requiring less force and/or shorter duration in the presence

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of food acoustic properties. These results correlate with the results from the physiological swallow responses. Some participants also perceived the swallow parameters as requiring the same effort/same duration (i.e. 12.5 % for bite force and mastication force, and 37.5 % for mastication duration and swallow force).

Hedonic responses to acoustic properties associated with texturally hard food samples

There was a consensus regarding the hedonic response to acoustic properties of texturally hard food samples based on the responses to the perceptual questionnaire. The qualitative responses revealed that participants 1, 6 and 7 referred to the texturally hard food samples in the unmasked condition as more “flavourful”, “enjoyable”, and “interesting”. In addition, all eight participants (100%) indicated that they “like/d” hearing the bite sound of the texturally hard food samples during the unmasked condition, which illustrates the positive hedonic responses to acoustic properties associated with texturally hard foods. These results correlate with studies by Tunick et al. (2013) and Vickers (1981) that have reported that crispiness strongly relates to a food’s pleasantness and enjoyment. Similarly, Spence et al. (2011) and Spence (2015, 2017) have highlighted that food acoustics adds value and enhances the overall experience of eating and improves pleasure and enjoyment.

Two main themes emerged from the qualitative responses, namely:

(a) “Trying to dissect whatever was in my mouth”

Participants believed that when the acoustic properties of the texturally hard food samples were masked, their mastication and swallow responses were impacted. One of the participants reported, “When I chewed and could not hear the bite sound, I had to bite with more effort for a longer duration” and “I had to swallow with more effort when I could not hear the bite sound.”

Due to the notion of auditory salience, we rely on acoustic properties to determine food texture. This was clearly depicted in the study as participants described the significance of food acoustics in influencing texture perception. One participant indicated, “I felt more aware of what was entering my body (in the unmasked condition).” The participants further expressed that when the acoustic properties of food were removed during the masked condition, it negatively influenced their “oral feel” or oral somatosensation. When the acoustic properties were masked, it was challenging for the participants to identify the texture and type of food sample presented to

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them. The participants articulated, “I chewed with more effort trying to dissect whatever was in my mouth,” and “It was like the food took longer to go down[...] [The food] felt thick and mushy.” This phenomenon of sensory salience was also observed in studies by Demattè et al. (2014), Endo et al. (2016, 2017), Masuda and Okajima (2011) and Zampini and Spence (2004). Modulation of the acoustic properties of the food while keeping the texture unchanged improved the participants’ “oral feel” or oral somatosensation, i.e. perceiving the foods as harder or crispier (Spence & Zampini, 2006). Our results corroborated with these studies highlighting that the acoustic properties of food do play a role in texture perception.

Auditory salience was also noted during the classification of the food samples. The majority of the participants classified the texturally hard food samples as either “crispy” or “crunchy”, and they did not provide an alternative term (“other”) in English or in their first language to classify these foods. Interestingly for the reference point food sample (IDDSI Level 6-semolina), 62.5% of the participants characterised this food sample as “other”. The participants were mainly bilingual or multilingual, and their first languages were predominantly English and African languages such as isiZulu, isiXhosa, isiNdebele and Sesotho. Participants used various terms such as “soft”, “mushy”, “kuthambile” (in isiZulu to refer to “soft”), “chewy”, and “moist” to describe the food sample. The participants may have classified the reference point food sample based on their total oral processing instead of their initial contact or first bite. We may account for this regarding sensory salience and attentional capture (Zampini & Spence, 2004, 2010). Participants received conflicting information regarding the auditory and oral somatosensory stimuli (i.e. coarse initially, followed by a soft texture when masticated). The oral somatosensory information may have been most salient or reliable and resulted in the dominance of perception of the oral somatosensory modality, perceiving the food sample as soft (Alais & Burr, 2004; Ernst & Banks, 2002; Zampini & Spence, 2004, 2010).

(b) Cultural-linguistic diversity in perception

Culture dictates one’s food preference and engagement in mealtimes (Kenny, 2015). Language also plays a role as there exists linguistic variations or a complete lack of vocabulary in a language for individuals to describe and differentiate crispy, crunchy, and crackly foods (Spence, 2015; Tunick et al., 2013). For instance, Italians only possess a single word, “croccante”, to classify crispy and crunchy foods (Spence, 2015). Similarly, the majority of the participants in this study

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could not provide alternative terms to describe and differentiate the food samples in English or their first language. The participants expressed two significant reasons; a lack of a word/s in their first language to describe the food samples and to have “difficulty thinking in their first language.” The second reason was possibly due to the participants being university students where English is the language of learning and teaching, and the questionnaire was also presented in English. Together these two reasons highlight the need to consider cultural-linguistic aspects in perception. This notion needs to be further explored in the main study to determine its influence on individuals with dysphagia.

4. Recommendations for practice

Acoustic properties in dysphagia rehabilitation: Exploring the potential use of transitional foods

The study results reveal that acoustic properties of texturally hard foods play a role in texture perception, leading to positive hedonic responses. The preliminary data from the physiological and perceptual swallow responses depict that acoustic properties influence the swallow responses, specifically by reducing the force needed and duration of the first bite, mastication and swallowing. This suggests a potential link between oral processing and auditory processing that needs to be explored further. These findings may be beneficial for individuals with dysphagia who present with weakness of the oral and pharyngeal muscles for mastication and swallowing. However, it is challenging to suggest texturally hard foods for individuals with dysphagia due to swallowing safety. To address this, we propose using IDDSI transitional foods and other novel approaches that are both pleasurable and potentially therapeutic for improving dysphagia.

Transitional foods are foods classified as IDDSI Level 5-7. Upon contact with body temperature or moisture, these foods swiftly melt to become easier to chew and swallow, for example, ice chips, wafers, ice cream and shortbread biscuits (Cichero et al., 2017; Cichero, 2020). The use of transitional foods will ensure individuals with dysphagia are provided with foods that possess the visual, olfactory and acoustic properties associated with texturally hard food while being enjoyable and safe when consumed. Hedonic responses to food acoustics are essential to consider for individuals with dysphagia as food palatability increases food intake, appetite and overall nutrition (Endo et al., 2017; McCrickerd & Ford, 2016). Studies by Dovey et al. (2013) and Gisel (1991) have also shown the historic therapeutic benefit of transitional-like solids in the

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paediatric population. This may hold a similar benefit for the adult population with dysphagia. This may also assist in addressing the concerns regarding food security and sovereignty by ensuring swallow safety and improving access to foods suitable to individuals with dysphagia. However, Barewal et al. (2020) highlight the insufficient research available on the behavioural properties and oral processing of these transitional foods. In the forthcoming main study, we aim to address this by exploring the influence of transitional foods on physiological swallow responses.

5. Study critique

There were both strengths and limitations to this study. Firstly, this study revealed that the protocols and tools developed were suitable to evaluate the study constructs. Furthermore, implementing the tools and protocols was feasible regarding the number of personnel and resources required. However, one of the limitations of this study is the small sample size with females only. Given that this pilot study aimed not to consider statistical significance but to evaluate the study methods and the developed protocols and tools, the sample size was appropriate. The primary study should include a larger sample size which consists of both males and females of varying ages, to explore the influence of the gender and age variable. The main study should also employ a quasi-experimental design to determine whether the findings are replicable and generalisable.

Secondly, we acknowledge the possible limitations regarding the study methods. For instance, we could not provide sufficient auditory masking by eliminating the influence of bone-conduction. However, due to the nature of the bone-conduction response, we recognise this poses a major methodological dilemma which needs further investigation. Furthermore, as this study used novel methods that have not been previously studied, the methods can be critiqued. For example, the setup of the order of the physiological testing followed by perceptual testing may have impacted the nature of the study findings due to the relationship between human perception and physiology. The participants may have felt coerced to respond to the perceptual station in a particular manner as the questions were related to the task in the previous testing station one, i.e. swallowing. In addition, the length of time taken between completing testing at station one and testing at station two was not controlled. This was due to the individual variation in the testing time of the physiological responses in testing station one (i.e. increased mastication time or swallowing time). These study limitations need to be carefully considered in the future main study as they may influence the validity of results. We attempted to factor any limitations by ensuring that several

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methods validated the developed protocols and tools of the study; (a) the conceptual and theoretical exploration component of the more extensive study, (b) adapting standardised protocols designed to measure the specific constructs, (c) expert consultations during the development of the protocols and tools, and (d) amendments made following the pre-pilot phase on two healthy adult males (Heale & Twycross, 2015). We also promoted data triangulation to address the validity, particularly the credibility of the study. Finally, we adopted various data collection and analysis methods within the study, such as the two methods to record and corroborate the sEMG recordings (Creswell & Creswell, 2017). Given the novelty of the study, we encourage further suggestions to improve the study methods for the main study.

6. Conclusion

This paper presents a pilot study that details developed protocols, tools, and methods to successfully evaluate the influence of acoustic properties associated with texturally hard foods on swallow responses. The preliminary results are precise; food acoustic stimuli are salient, with changes noted in the oral processing responses due to the acoustic properties of the texturally hard foods. Based on the evaluation of the pilot study, we propose the implementation of the main study with larger sample size and minor amendments to the study protocols and tools. The tenet of this foundational research could have several implications for reimagining global dysphagia practice. This may assist in addressing the food security and sovereignty issues when planning dysphagia interventions by focusing on developing safe, pleasurable, accessible and “sensory responsive” foods like IDDSI transitional foods. We anticipate that this study will inspire the development of more novel ways to reimagine global dysphagia practices because food for individuals with dysphagia should be more than safe; it should be enjoyable too.

Declarations

Ethics approval and consent to participate

This study was approved by the Biomedical Research Ethics Committee of the University of KwaZulu-Natal (South Africa) (BF152/19). Written informed consent was provided by all study participants.

Consent for publication

Not applicable.

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Availability of data and materials

The datasets generated and/or analysed during the current study are available from the corresponding author on reasonable request.

Competing interests

The authors declare that they do not have any conflict of interest.

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Author contributions

T.K and M.P conceptualised the study protocols, tools and methods. T.K collected data, and analysed and interpreted the data as part of her doctoral study under the supervision of M.P. T.K drafted the paper. Both researchers reviewed and approved the final paper.

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Learning outcomes:

1. The reader will describe the preliminary results of the influence of acoustic properties of texturally hard foods on swallow responses in healthy adults.
2. The reader will apply the protocols, tools, and methods to evaluate the swallow responses to acoustic properties of texturally hard foods.
3. The reader will understand the connection between food acoustic properties, swallowing and dysphagia (swallowing disorders).

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Appendix A: Components of the broader study

Conceptual and theoretical exploration of the construct

- **Objective:** To develop the conceptual and the theoretical basis for the study on food textural acoustics
- Narrative review of existing literature and research gaps across the fields of; speech pathology, audiology, rheology, food engineering, gastronomical sciences, cognitive neuropsychology and physiology. This specifically included the work of the following renowned authors across the above fields; Logemann, Steele, Duizer, Vickers, Aguilera, Spence, Hamdy, Ludlow, Dietsch, Pearson, and Zampini.
- Conceptualising and consulting studies and contributions part of the THRIVE project (De Villers et al., 2019; Kolanisi et al., 2020; Lakhi et al., 2019; Mabaso et al., 2018)
- Personal communications and collegial interactions (M. Pillay, personal communication, 2019).

Pilot study

- **Objective:** To explore the influence of acoustic properties associated with texturally hard foods on swallow responses in healthy adults
- **Development phase:** To develop protocols and tools to evaluate the constructs related to acoustic properties associated with texturally hard foods in healthy adults
- **Testing phase:** To test the developed protocols and tools to evaluate the influence of acoustic properties associated with texturally hard foods on the swallow responses in healthy adults

Exploration of the sensibility of the construct

- **Objective:** To investigate the sensibility of food textural acoustics as a construct to understand eating for individuals with dysphagia
- Revised scoping review
- **Optional consultation phase:** Focus group discussion with six world experts from the following fields; mechanical engineering, food science, audiology, speech pathology, cognitive neuropsychology and gastronomy
- Refer to Karani and Pillay (2021) for details

Exploration of the utility of the construct for dysphagia research and practice

- **Objective:** To explore the utility of food textural acoustics for dysphagia research and practice.

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Appendix B: Table of finalised physiological swallow parameters evaluated in the study

Swallowing phases	Initial Dynamic Oral Processing (IDOP)	VFSS	sEMG
Oral and oral- preparatory phases	IDOP (Early, mid and late phases):	Duration of the oral phase (ms)	First bite force (μV) (Channel one: Masseter)
		Number of masticatory cycles	Mastication force (μV) (Channel two: Masseter)
Pharyngo- oesophageal phases	IDOP (Residual phase)	Velopharyngeal closure:	Mylohyoid force (μV) (Channel two: Mylohyoid)
		- Duration of the palatal elevation (ms)	
		Hyolaryngeal complex (HLC) excursion:	
		- HLC excursion at rest, elevation and descent (mm)	
		- Duration of HLC excursion from at rest to descent (ms)	
		Peristalsis:	
		- Duration from the entrance of the bolus into the hypopharynx until the opening of the UOS (ms)	

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- Duration of UOS
opening and closing
(ms)
-

Note. Abbreviations: HLC (Hyolaryngeal Complex); UOS (Upper oesophageal Sphincter).

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Appendix C: Self-developed auditory masking protocol

	Air-conduction masking	Bone-conduction masking
Type of stimulus	White band noise	Bone-conducted tone
Intensity of stimulus	85 dB [†]	50 dB
Placement of headphones/conductor	Right ear	Mid-forehead placement
Frequency of stimulus	500 Hz	500 Hz
Rate of stimulus	20 000 ms [‡]	20 000 ms

END OF PAPER

† dB: Decibels

‡ ms: Milliseconds

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2.6. Summary of the chapter

The paper presented above functioned to provide a pilot study that involved two phases; (a) development of protocols and tools, and (b) testing of the developed protocols and tools to evaluate the influence of acoustic properties associated with texturally hard foods on swallow responses. The results of phase one of the paper yielded the development and/or adaptation of four protocols and tools to evaluate the swallow responses; (a) modified VFSS protocol and modified sEMG study protocol, (b) food sample selection and development protocol, (c) sensory masking protocol, and (d) perceptual questionnaires. This resulted in phase two (i.e. method employed to test these protocols and tools) as per the two study objectives (physiological and perceptual swallow responses).

For objective one, the preliminary results depict that acoustic properties associated with texturally hard food may play a role in the swallow responses. Participants required less force and shorter duration for the first bite, mastication and swallowing when hearing the food acoustic properties, but an increase in these parameters was recorded when the acoustic properties were masked (Figure 2). This finding is particularly important as it demonstrates the possible influence of acoustic properties on FOP responses, and the potential link between FOP and auditory processing (elaborated below). The texture of the food samples has also been shown to influence the physiological swallow parameters, with an increase noted in the first bite force, mastication force and mylohyoid force of texturally hard foods compared to the soft food samples. With regards to objective two, all participants indicated the positive hedonic response to acoustic properties of texturally hard foods (“flavourful”, “more enjoyable” and “more interesting”). Two main themes emerged from the perceptual responses; “Trying to dissect whatever was in my mouth” (auditory salience) and cultural-linguistic diversity in perception.

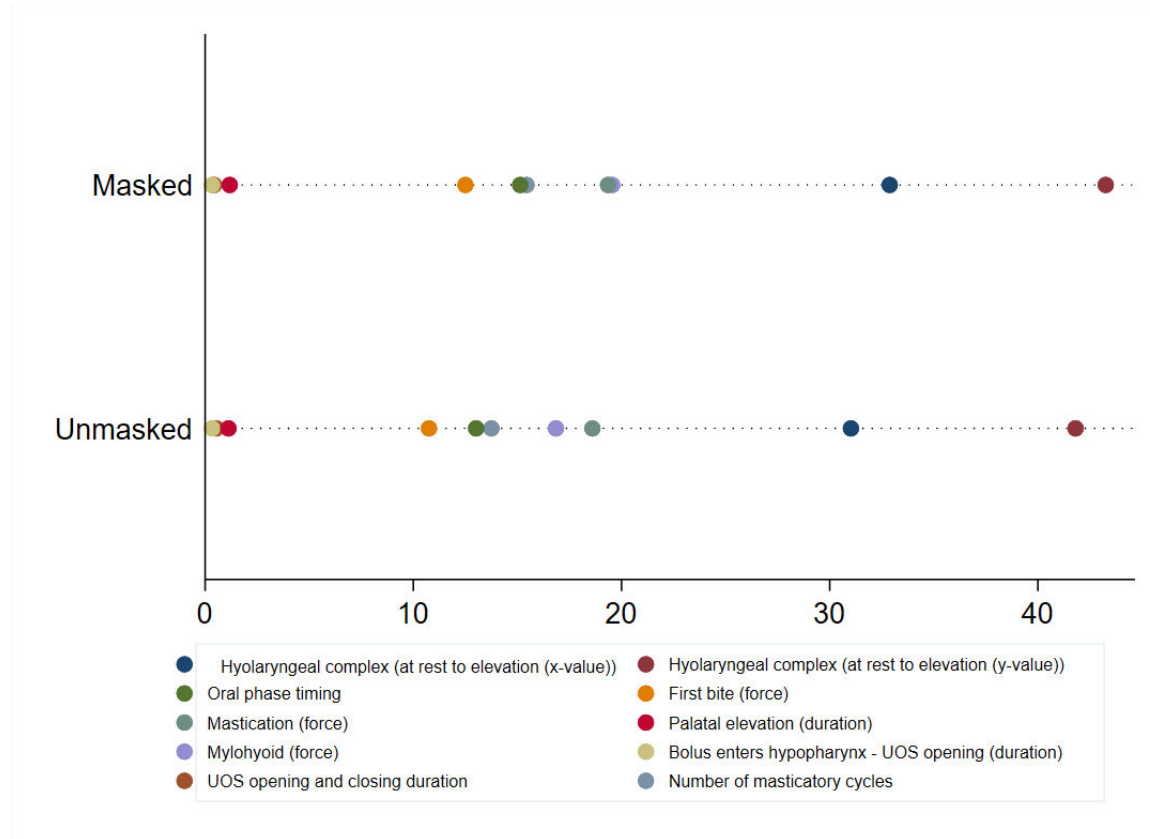
The preliminary results of this pilot study depict the positive influence of acoustic properties of texturally hard foods on swallow responses. This paper also proposes the need to consider food security and sovereignty issues in planning dysphagia interventions such as the development of “sensory responsive” foods and the use of transitional foods based on their safety and hedonic responses that are affordable and accessible for the clients. Based on the evaluation of

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the pilot study, the main study should be conducted with a larger sample size and minor amendments to the study protocols and tools.

Figure 2.

Dot Plot of Mean and Median of Physiological Parameters in the Masked and Unmasked Conditions



Note. Abbreviation: UOS (Upper Oesophageal Sphincter).

Proposed interlinked relationship between auditory processing and food oral processing

This paper focuses on the oral processing of food textural acoustics, focusing on the first bite resulting from texturally hard foods and its associated acoustic properties. Despite this study offering potential implications for dysphagia practitioners, this study may be of interest to engineers and food scientists. This study depicts the dynamic and rapid nature of FOP as a result of the acoustic properties of texturally hard foods. These results may link to the potential interconnected nature between auditory processing and FOP (see Figure 3). The nature of these

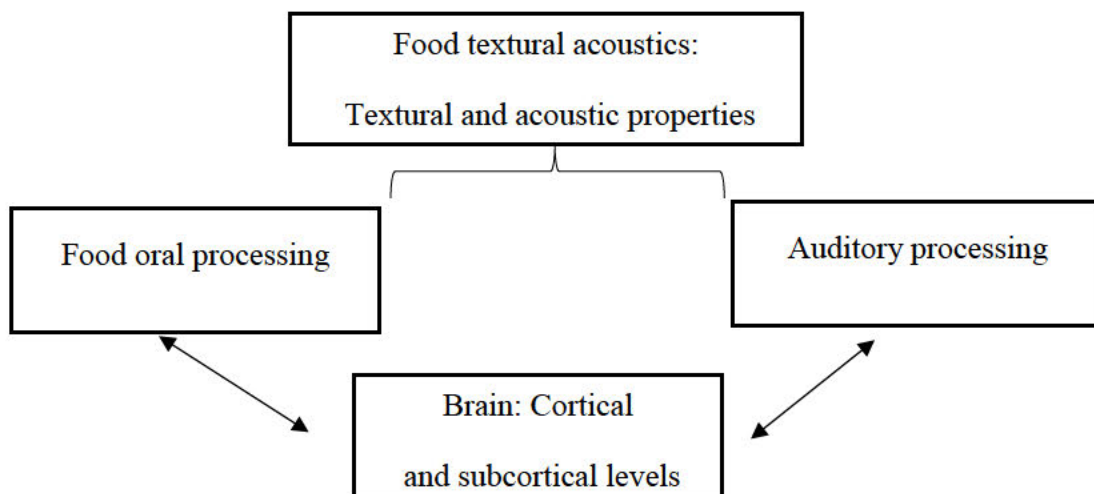
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biomechanics and the transmission of the signals, such as timing aspects, may also be of interest to non-dysphagia practitioners. When we understand food oral processing of food textural acoustics, Figure 2 proposes the need to consider auditory processing. The dynamism of auditory and food oral processing may be depicted through the processes regulated at both cortical and subcortical levels. There appears to be a recurring feedback loop between auditory processing and FOP systems, with signals being continuously transmitted to and from the brain. For instance, during the study, the first bite of a texturally hard food produced crispy, crunchy or crackly sounds that were transmitted to the ear. This is known to be processed in the primary auditory cortex of the brain. As a result, this may have transmitted a signal to the oral processing systems to bite with a greater bite force, as noted in the study.

Conversely, less bite force was applied to a soft food sample. As the texturally hard food sample is processed in the oral cavity, from the bite to mastication to formulation of a bolus, there is a breakdown of the food sample with the texture being reduced. This results in less bite force required as this process progresses. When the bolus is ready for swallowing, the swallow is triggered.

Figure 3.

Proposed Interlinked Nature Between Food Oral Processing and Auditory Processing



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2.7 Conclusion

Acoustic stimuli are salient and have been shown to influence both physiological and perceptual responses. This included changes to FOP responses and positive hedonic responses. This paper presents a pilot study that details developed protocols, tools, and methods to successfully evaluate the influence of acoustic properties associated with texturally hard foods on swallow responses. The main study is the next step to confirm the preliminary results. Transitional foods and the development of more novel ways of approaching this construct of food acoustic properties should be considered as potential ways to reimagine global dysphagia practice.

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CHAPTER THREE: PAPER TWO

3.1. Introduction

This chapter is presented in the form of a published paper. This paper addressed the second objective of the study by exploring the sensibility of the construct of food textural acoustics as a construct to understand eating for individuals with dysphagia. This paper employed a qualitative evidence synthesis methodology design which involved revised scoping review methods and an adapted optional consultation phase with six world experts from various fields. Despite its order as paper two in the overall study, this paper is the basis for papers one and three. My supervisor, Mershen Pillay, conceptualised the notion of food textural acoustics by conducting the conceptual and theoretical exploration of the construct. The conceptual and theoretical exploration involved a narrative review of the literature to identify research gaps, conceptualising and referring to studies part of the THRIVE projects, and personal communications and collegial interactions. Mershen Pillay was unable at the time to establish a framework for studying food textural acoustics, and it was not yet established within the field of dysphagia. This provided me with an opportunity to further explore this construct through the three papers (i.e. pilot study, exploration of the sensibility of the construct, and exploration of the utility of the construct for dysphagia research and practice).

Paper one presented a pilot study that developed and tested the protocols and tools to evaluate the swallow responses to acoustic properties associated with texturally hard foods. Based on the evaluation of this pilot study, the subsequent plan was to conduct the main study using a quasi-experimental design with a larger sample size and minor amendments to the methodology. The main study aimed to validate the several claims around the swallow responses to acoustic properties associated with texturally hard food and determine whether the pilot study findings are replicable and generalisable. However, due to COVID-19, the main study had to be halted. Despite this disruption, COVID-19 provided the primary researcher with an opportunity to rethink the conceptual basis of the construct of food textural acoustics by conducting the exploration of the sensibility of the construct, which will form the primary focus of this paper.

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3.2 Publication details

This chapter includes the published paper, which is the central component of this chapter. This paper has been accepted for publication by the South African Journal of Communication Disorders (SAJCD). However, the methodology details of the paper have not been fully presented to comply with journal specifications (style, word count, and page limit). The additional information will be discussed in the next section to augment the methodology presented in the paper.

<i>Title</i>	<i>It's crunch time: Exploring the sensibility of food textural acoustics for individuals with dysphagia</i>
<i>Authors</i>	Tasneem Fareed Karani ¹ , Mershen Pillay ²
<i>Journal</i>	South African Journal of Communication Disorders (SAJCD)
<i>Status</i>	Published
<i>Year</i>	2021
<i>Volume number</i>	68 (1)
<i>DOI number</i>	https://doi.org/10.4102/sajcd.v68i1.806

3.3. Exploration of the sensibility of the construct

This preamble section will elaborate on the theoretical and methodological basis of the paper. The focus will explain the specifics of conducting the revised scoping review and the adapted optional consultation phase.

3.3.1. Objective

To investigate the sensibility of food textural acoustics as a construct to understand eating for individuals with dysphagia.

3.3.2. Theoretical understanding of the notion of sensibility

The notion of sensibility has been foregrounded in this paper. This paper essentially explores the construct validity of food textural acoustics, i.e. the extent to which the measures are

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used to test the theory being evaluated (Ginty, 2013). However, the term sensibility has been selected rather than the traditional use of construct validity to highlight the complexity and marginality of the construct of food textural acoustics under investigation. In this paper, the term sensibility has been operationalised concerning plausible knowledge, the judgment of the plausibility of a concept (Strati, 2007).

3.3.3. Understanding the methodology

Qualitative evidence synthesis (QES) methodology

The underlying theory of this paper originates from qualitative evidence synthesis (QES) methodologies, also referred to as systematic reviews of qualitative research (Ames et al., 2019). This methodology aims to understand a complex phenomenon by collating and synthesising data from various sources (Tufanaru et al., 2017; Ames et al., 2019). The QES methodology was chosen carefully to generate evidence to inform knowledge and practice on the construct of food textural acoustics, which is not a well-researched area (Tufanaru et al., 2017). Traditionally in healthcare, researching the theoretical basis of a construct and using the evidence from the scientific research has led to the development of clinical practices (Dodd, 2007). Essentially, this paper argues that informed thoughts (theory) determine our practice (clinical practice). This QES methodology involved two interconnected data sources; (a) published peer-reviewed articles, which were obtained via seven databases, and (b) online focus group discussions with six world experts from numerous fields.

3.3.3.1 Revised scoping review methods

Scoping review methods have been proposed first by Arksey and O'Malley (2005), and further proposed by Levac et al. (2010). Scoping reviews are a form of QES that aims to identify knowledge gaps and map existing evidence (Arksey & O'Malley, 2005; Tricco et al., 2016). Scoping reviews present a broad overview of the evidence, particularly useful for novel areas, whereas a systematic review focuses on specific questions (Peters et al., 2015). The nature of the scoping review method allowed the researcher to broadly explore this area of food textural acoustics across fields of study (Colquhoun et al., 2014). This also enabled the exploration of the bibliographic coverage of the findings and yielded core constructs and considerations when studying food textural acoustics.

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This paper did not strictly follow the Preferred Reporting Items for Systematic Reviews and Meta-analyses extension for Scoping Reviews (PRISMA-ScR) framework (Tricco et al., 2018). The revised scoping review was mainly guided by the PRISMA-ScR framework, with input from Arksey and O'Malley (2005), Levac et al. (2010), Schultz et al. (2018), and Tricco et al. (2018). Schultz et al. (2018) promote the scoping review's iterative and reflexive process, which allowed adaptations throughout the scoping review process. The revised scoping review involved three core steps; (a) pilot study, and (b) main study, which involved a blind review by two reviewers, and (c) conflict resolution to finalise the selection of the full-text articles. Due to the journal's word limit, details of the pilot study and main review process are not presented in detail in the published paper. This preamble section will further elaborate on these details.

Pilot study: Process and outcomes

Firstly, the researcher developed the search protocols for the electronic search and the screening protocols to ensure standardisation (Tricco et al., 2018) (refer to Appendix 13 and Appendix 14 for the search and screening protocols, respectively). Thereafter, before the main review, a pilot study of the revised scoping review was conducted. The pilot study was conducted to assess and refine the protocols developed to improve the overall internal validity of the study (In, 2017). The pilot study involved an external reviewer who trialled and assessed the search protocols, screening protocols and screening tools using the evaluation tool (Appendix 12). The external reviewer scored the evaluation form two out of three and three out of three for the majority of the categories. Her overall comment was, "The tools and protocols were found to be quick, easy to use and effective." The reviewer provided valuable recommendations regarding the search terms and ways to improve the search protocols, data collection tools and protocols. For instance, in addition to "food" AND "sound" AND "eating" as search terms, the reviewer suggested the use of "food" AND "sound" AND "perception". This search yielded relevant results. According to Schultz et al. (2018), the iterative and reflexive nature of the scoping review process allowed the initial search terms to be modified as needed. This iterative process also ensured that every decision was rigorously applied (Schultz et al., 2018). Following this step, adjustments were made to the protocols as per the reviewer's suggestions, and the main review was conducted.

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Main review: Data collection and data analysis

The following inclusion and exclusion criteria and search strategy parameters were considered for the main review (Figure 1).

Figure 1.

Parameters of the Scoping Review

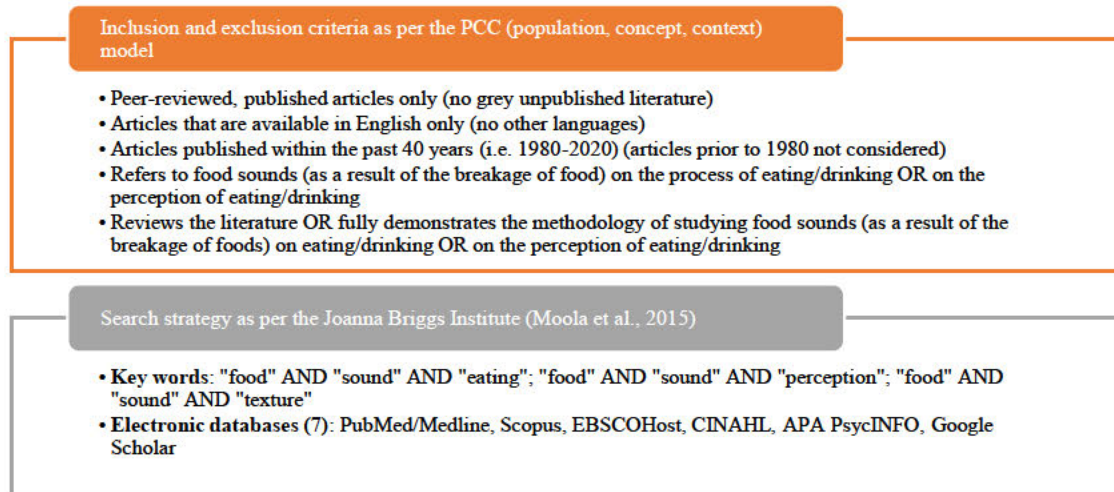


Figure 1 above depicts the parameters applied in the main review. Two reviewers conducted an independent blind review to screen the articles' abstracts, titles, and full-texts (refer to Appendix 15 for the screening forms). Once the independent review was completed, these two reviewers met to confirm the eligibility of the articles. Where consensus was not reached regarding the inclusion of a specific article, the two reviewers held conflict resolutions through discussion to finalise the selection of the full-text articles for further analysis. The researcher used *Mendeley with Covidence* for data management of the articles retrieved from the review. Interestingly, only a total of 11 studies regarding food textural acoustics were retrieved for final analysis. These 11 articles were analysed by the researcher using the following methods; (a) thematic analysis by Clarke and Braun (2014), (b) bibliographic coverage of the included articles by charting the data by frequency analysis of author names, year, location, knowledge fields and affiliation (journal), and (c) basic content analysis to identify and tabulate the frequently occurring constructs, methodologies used and overall findings. Refer to Appendix 3 in the published paper for the PRISMA-ScR results and bibliographic findings. Of the 11 finalised articles that were analysed, it was surprising to note that food textural acoustics was shown to be

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predominantly researched in the field of psychology. It was expected that other knowledge fields such as Food Engineering, and nutrition and dietetics would have appeared on the list of articles.

3.3.3.2. Adapted optional consultation phase: Data collection and data analysis

Following the scoping review, a consultation phase was conducted (Colquhoun et al., 2017). According to Arksey and O'Malley (2005), the consultation phase can be used in various forms depending on the study aim. In this case, the consultation phase was adapted and expanded by further exploiting the process by more closely engaging with selected experts across mechanical engineering, food science, speech pathology and audiology, cognitive neuropsychology, and gastronomical sciences. Due to the novelty of the area of study, a hermeneutic paradigm was promoted. Hermeneutic or constructivist paradigms facilitate knowledge generation using the interaction between the investigator and respondents (Guba & Lincoln, 1994; Pillay & Kathard, 2018). Experts from these various fields were purposefully selected to contribute constructively and collaboratively to the study. The hermeneutic paradigm promoted the diverse perspectives and opinions from the experts (Guba & Lincoln, 1994). This approach acknowledged and celebrated that multiple realities and subjectivities exist (Guba & Lincoln, 1994; Pillay & Kathard, 2018).

The six world experts were contacted via email with an information sheet and an informed consent form (Appendix 16 and Appendix 17). Consent was required for both audio and video recording. Once consent was obtained, a brief PowerPoint presentation using the three-minute thesis (3MT) format was sent to the experts to provide a background of the study and broad areas to consider for the consultation phase. Before the focus group discussions, the researcher developed a general interview protocol (Appendix 18) and utilised interview schedule strategies (Appendix 19) to guide the expert consultations. The researcher set up three focus group discussions on the online teleconferencing Zoom, which was password-protected. The times of the focus group discussions were carefully selected and confirmed by considering the time zones of the world experts. The focus group discussions were approximately 45 minutes to 60 minutes each, and they included self-developed semi-structured open-ended questions to promote dialogue between the experts. The questions posed during the expert consultations followed an ethnographic method. This method aimed to encourage open discussion regarding the field experts' views of the construct of food acoustics based on their personal and

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professional backgrounds (Ejimabo, 2015). The first question included an open-ended question (“Tell me your general thoughts around food acoustics/texture and eating”). The follow-up questions were also open-ended but more structured. The questions focused on the experts’ opinions regarding food textural acoustics, relevance to their respective fields and discussion on some of the published literature and scoping review findings. Details of the methodology and results of the second component of the broader study (pilot study) were also discussed.

The primary researcher transcribed the data verbatim from the consultation phase to analyse the online focus group discussions. The transcripts and the audio recordings were sent out via email to the experts. Member checking was conducted to improve the trustworthiness and validity of the data (Birt et al., 2016). The experts confirmed that the transcripts were a fair reflection of the focus group discussions. After that, the computer-assisted qualitative data analysis software *NVivo 12* was used to upload the raw data and assist with data extraction and coding. The researcher adopted thematic analysis by Clarke and Braun (2014) to analyse the 11 included articles and the focus group discussions. The analysis involved substantive and axial coding to reveal codes, followed by the recursive steps of formulating categories, concepts and themes (Clarke & Braun, 2014). Furthermore, the critical theory, ideology critique framework and interrogative framework by Guba and Lincoln (1994), adapted by Pillay (2003) and Pillay and Kathard (2018), were used. A total of three interconnected themes were developed, which are presented as three core arguments in the paper.

3.4. Summary of the preamble

This chapter presents the published paper by the SAJCD journal. Due to the word and page limits of the journal, this preamble section of the chapter has further elaborated on the theoretical and methodological background of the study. This will provide the reader with a better understanding of the paper presented below. This included details regarding the QES methodology implemented in the study (i.e. data collection and data analysis of the scoping review and consultation phase).

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**3.5. Paper Two: It's Crunch Time: Exploring the Sensibility of Food Textural Acoustics for
Individuals With Dysphagia**

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It's crunch time: Exploring the sensibility of food textural acoustics for individuals with dysphagia



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Background: Various fields of study have alluded to food textural, and its associated acoustic, properties (i.e. food textural acoustics). However, because of the challenging nature of the inclusion of acoustic properties in diet textural modifications in dysphagia (swallowing disorders), this construct has not been sufficiently considered in the field.

Objective: To investigate the sensibility of food textural acoustics as a construct to understand eating for individuals with dysphagia.

Method: The study design was based on qualitative evidence synthesis methodologies. This involved revised scoping review methods (peer-reviewed published articles from 1980 to 2020 over seven databases), with an adapted consultation phase through online focus group discussions with six world experts. The data was analysed using frequency and thematic analysis, and ideology critique.

Results: A total of 11 articles were included in the revised scoping review analysis (seven research studies and four review articles). The analysis of these articles revealed a lack of diversity in geography, discipline and perspective exploring the construct of food textural acoustics. A total of three themes with three associated core arguments emerged from the revised scoping review and the consultation phase. These arguments highlighted (1) the need to study food textural acoustics because of its salience and pleasure responses, (2) possible methodological dilemmas in studying food textural acoustics due to the complexity of eating, and (3) considerations with regard to the approach and positioning adopted when studying the construct.

Conclusion: Food textural acoustics may be a sensible construct to understand eating for individuals with dysphagia. As eating is a complex process, there is a need to challenge the methods we use when studying this construct of food textural acoustics. We hope that this article inspires researchers and practitioners to think differently by using textural, and its associated acoustic, properties as a way to reimagine dysphagia practice, especially for those from low- to middle-income contexts such as South Africa and Brazil.

Keywords: food acoustics; texture; perception; physiology; multisensory eating; dysphagia.

Background

Eating is one of the most multisensory human experiences (Spence, 2017, 2020). The visual system is involved in the selection of foods, and the olfactory and gustatory systems make sense of the smell and taste of the food. The proprioceptive system assists in identifying textures and shapes of foods, while the auditory system plays a role in the sounds of biting and chewing of foods (Spence, 2015; Verhagen, 2007). Practitioners in the field of dysphagia (swallowing disorders) primarily consider sensory stimuli such as chemical, tactile and thermal properties in the management of individuals with dysphagia (Steele & Miller, 2010; Steele et al., 2015). Despite the multisensory nature of eating, acoustic stimuli are not predominately used. This is due to the challenging nature of selecting the appropriate food textures, that have robust and consistently replicable acoustic properties, yet still safe for consumption for individuals with dysphagia. Auditory properties are also not sufficiently foregrounded in comparison to the remaining senses in other fields such as cognitive neuropsychology and are often regarded as the neglected or 'forgotten flavour sense' (Spence, 2015).

The coronavirus disease 2019 (COVID-19) pandemic has highlighted the vital role of the senses in eating. Anosmia and ageusia (i.e. loss of the sense of smell and taste) are symptoms of the COVID-19 virus, which can lead to diminished pleasure in eating (Coppin, 2020; Menni et al., 2020; Parma et al., 2020). Can one still eat and survive with the disabling effects of the loss of smell

and taste? Regardless of the temporary loss of these senses, an individual may rely on the role of texture and its associated acoustic properties for their hedonic or pleasure response when eating. This is as a result of the notion of auditory salience. Evolutionarily, auditory salience has been understood as acoustic properties of food signifying freshness, pleasantness and enjoyment (Spence, 2015; Tunick et al., 2013; Vickers, 1983).

Indeed, textural properties and acoustic properties are intimately connected. For instance, the force applied to a texturally hard food sample when biting into the food results in the production of vibrations that are transmitted to the ear as a wave via two pathways, namely, air-conduction and bone-conduction (Duizer, 2001; Vickers & Bourne, 1976). We perceive these vibrations as sounds. For the purpose of this study, we will refer to the textural, and its associated acoustic, properties involved during eating as food textural acoustics. There are several fields of enquiry that have alluded to food textural acoustics. This includes the well-established fields of engineering and physical sciences, gastronomic sciences, cognitive neurosciences and dysphagia sciences (see Appendix 1 for a review of the established fields that have made reference to food textural acoustics). This undeniable marriage of texture and acoustics was first recognised within the fields of engineering and physical sciences with the establishment of the notion of acoustic rheology (Peleg, 2017; Zadeike, Jukonyte, Juodeikiene, Bartkiene, & Valatkeviciene, 2018). We have borrowed from these fields and have chosen to use the term food textural acoustics. Although it is well-known in the aforementioned fields that texturally hard foods produce auditory stimuli, for example, crispy or crunchy sounds, dysphagia studies of diet textural modifications tend to marginalise how texture and acoustic properties are closely connected. It is necessary to note that textural properties cannot be divorced from its acoustic properties when recommending the commonly used compensatory strategy of diet textural modifications in dysphagia rehabilitation (Cichero, 2018; Cichero et al., 2017; Swan, Speyer, Heijnen, Wagg, & Cordier, 2015).

Other fields that are more recent and burgeoning such as the multisensory human-food interaction (MSHFI) and multisensory eating frameworks have also alluded to food textural acoustics. The field of cognitive neuroscience has studied acoustic stimuli by foregrounding music and the environment and its influence on behaviour and perception (Callan, Callan, & Ando, 2018; Carvalho, Wang, Van Ee, & Spence, 2016; Höchenberger & Ohla, 2019; Kantono et al., 2018; Spence, 2015, 2017). However, there is still a gap present in the fields at large exploring the influence of acoustic stimuli on physiological responses. We have not sufficiently considered the physiological responses such as the notion of autophony. Autophony refers to how the body generates and responds to internal sounds, for instance, sounds produced when eating and hearing one's voice and breathing (Harris 2015; Mabaso, Malinga, & Paruk, 2018; Tidball & Fagelson, 2018). The various fields that have alluded to this construct of food textural acoustics, discussed above, speak to

its overall construct validity or sensibility. We have chosen to use the notion of sensibility because of the complexity and marginality of the construct that we are studying. We have defined sensibility with reference to sensible knowledge and the judgement of the plausibility of a concept (Strati, 2007).

This study is part of a larger cluster of research projects under the THRIVE programme. THRIVE is an acronym for 'Tackling Hunger by Research and Innovation in Vulnerable Environments' (Pillay, 2013; Pillay & Kathard, 2018). The THRIVE programme strives to reposition swallowing and feeding in a way that promotes transformative practitioners who are concerned with the food security and sovereignty of their patients. Individuals with disabilities such as those with dysphagia may encounter difficulty in accessing food that is affordable and safe for consumption (Pillay, 2013; Pillay & Kathard, 2018). This is prevalent particularly in low- to middle-income contexts such as South Africa and Brazil. Low-to-middle income contexts may present with limited access to healthcare professionals, resources and equipment, where one can only target and invest in the food provided to these individuals. There is a specific THRIVE project that is motivated to develop more novel dysphagia interventions (Pillay & Kathard, 2018). In this study as part of this project, we would like to propose a transformation of the diets for patients with dysphagia (refer to Appendix 2 for a history of the study that includes three phases). We would like to conceptualise alternative methods of developing foods that consider the multisensory nature of food and the potential therapeutic benefits of acoustic properties. This may drive us to connect diet textural modifications to food security from the perspective of food safety and the appropriate food textures. This includes developing and investing in more 'sensory responsive' foods that in addition to having a hedonic response, we hope that these foods will have a therapeutic benefit for individuals with dysphagia. It is vital to highlight that despite the documented research on the hedonic response to food textural acoustics, certain individuals may dislike or have unpleasant experiences to textural acoustic properties. Sensory aversions and misophonia (i.e. a negative emotional reaction and dislike triggered by particular sounds such as eating and breathing) may also occur in both typical and atypical individuals (Little, Dean, Tomchek, & Dunn, 2017; Palumbo, Alsalman, Ridder, Song, & Vanneste, 2018).

Objective

To investigate the sensibility of food textural acoustics as a construct to understand eating for individuals with dysphagia.

Methods

Study design

The underlying theory of this study originates from qualitative evidence synthesis (QES) methodologies with regard to creating evidence for a form of knowledge and practice. Traditionally in healthcare, researching a theoretical

basis of a construct and using the evidence from the scientific research may lead to the development of clinical practices (Dodd, 2007; Sackett & Rosenberg, 1995). Essentially, we are arguing that thoughts (theory) determine our practice (clinical practice). We used this broad QES methodologies framework in a way that engaged us reflexively as researchers. Reflexivity refers to providing 'attention to the complex relationship between the processes of knowledge production and the various contexts of such processes, as well as the involvement of the knowledge producer' (Alvesson & Sköldbberg, 2009:8). This QES methodology study design involved scoping review methods by Arksey and O'Malley (2005) and Levac, Colquhoun and O'Brien (2010) with an optional adapted consultation phase through online focus group discussions (Colquhoun et al., 2017). According to Arksey and O'Malley (2005), the consultation phase can be used in a variety of forms depending on the study aim. In this case, we have adapted and expanded the consultation phase by further exploiting it and more closely engaging with expert practitioners in the field. This has been used to dialogue the experts' opinions with the published literature and scoping review findings regarding the construct of food textural acoustics in eating for typical adults. Similar to other fields of enquiry, this information may be applied to individuals with dysphagia.

Data sources

This study involved two main interconnected data sources: (1) published, peer-reviewed articles obtained via seven databases, detailed below, and (2) online focus group discussions with six world experts. We reviewed the published articles over a 40-year period (1980–2020). We also conducted focus group discussions with six world experts from several fields to gather their opinions on the construct of food textural acoustics in eating. This method will be expanded on in the next section. We hoped that this would inform a novel way of understanding the construct and its potential clinical application to the field of dysphagia. We have intentionally revealed the identities of the world experts, with their permission, to initiate a conversation and to develop a community of practice from a variety of fields regarding the construct of food textural acoustics.

Data collection

We used the following methods to design the revised scoping review methodology; Preferred Reporting Items for Systematic Reviews and Meta-analyses extension for Scoping Reviews (PRISMA-ScR) framework (Schultz et al., 2018; Tricco et al., 2018), and guidelines by Joanna Briggs Institute (Moola et al., 2015) for the search strategy. These methods were used to systematically and comprehensively map concepts and the distribution across the fields (Levac et al., 2010). The revised scoping review included the following: (1) a pilot study that was conducted by an external reviewer to assist in planning the main study and analysing its validity (In, 2017), (2) a main study which involved a blind review by two reviewers to screen the titles and abstracts to ensure inter-rater consistency,

and (3) conflict resolution through discussions between the two reviewers to finalise the selection of the full-text articles. Figure 1 depicts the parameters used in the revised scoping review.

We consulted six world experts through online focus group discussions following the scoping review. The world experts represented various disciplines of study: (1) mechanical engineering (Associate Prof. Ben Hanson; University College London); (2) food science (Prof. Lisa Duizer; University of Guelph, Canada); (3) audiology (Prof. Wayne Wilson; University of Queensland, Brisbane); (4) cognitive neuropsychology (Prof. Massimiliano Zampini; University of Trento, Italy); (5) a sommelier, (Chef Ferran Centelles; Director of BulliPedia Drinks eBullifoundation, Barcelona), and (6) speech pathology and audiology (Associate Prof. Mershen Pillay; University of KwaZulu-Natal, South Africa). These experts were purposefully selected based on their respective fields of expertise and the knowledge of them contributing collaboratively and constructively to the development of the study. Pillay co-author of the article, was included in the study as he is an expert who has developed the THRIVE framework and provided a perspective from a low- to middle-income context on the matter. The expert consultations included self-developed semi-structured open-ended questions to promote dialogue between the experts. The questions focused on the experts' opinions regarding food textural acoustics, its relevance to their respective fields and discussion relating to some of the published literature and scoping review findings. We also shared details of the methodology and results of phase 2 of our study. Our analysis yielded core constructs and considerations when studying food textural acoustics, which will be presented under the 'Results and discussion' section.

Data analysis

We conducted two main data analyses: (1) frequency analysis and basic content analysis of the 11 included articles, and (2) thematic analysis of the 11 articles and the focus group discussions. We used *Mendeley* with *Covidence* for data management of the articles retrieved from the

Inclusion and exclusion criteria	Search strategy
<ul style="list-style-type: none"> • Peer-reviewed, published articles only (no grey unpublished literature) • Articles that are available in English only • Articles published within the past 40 years (i.e. 1980–2020) • Refers to food sounds (as a result of the breakage of food) on the process of eating/drinking OR on the perception of eating/drinking • Reviews the literature OR fully demonstrates the methodology of studying food sounds (as a result of the breakage of foods) on eating or drinking OR on the perception of eating or drinking 	<ul style="list-style-type: none"> • Key words: 'food' AND 'sound' AND 'eating'; 'food' AND 'sound' AND 'perception'; 'food' AND 'sound' AND 'texture' • Electronic databases: PubMed/Medline, Scopus, EBSCOHost, CINAHL, APA PsycINFO, Google Scholar

FIGURE 1: Parameters of the revised scoping review.

review. We identified the bibliographic coverage of the 11 included articles by conducting frequency analysis of author names, year, knowledge fields and affiliation (journal). We also conducted a basic content analysis to identify and tabulate the frequently occurring constructs, methodologies used and overall findings. The primary researcher transcribed the data verbatim from the consultation phase. We conducted member checking to improve the trustworthiness and validity of the data (Birt, Scott, Cavers, Campbell, & Walter, 2016). This was performed by sending out the audio recordings and transcripts of the online focus group discussions to the experts via email. All the experts confirmed that the transcripts were a fair reflection of the focus group discussions. We employed thematic analysis by Braun and Clarke (2006) to analyse the 11 included articles and focus group discussions. Thematic analysis was used to provide a rich account of the data and to develop themes. As per the process of thematic analysis, we conducted substantive and axial coding of the raw data using the computer analysis software *NVivo 12* to reveal codes. Subsequently, we formulated categories, concepts and developed themes.

Ethical considerations

This study was approved by the University of KwaZulu-Natal Biomedical Research Ethics Committee (BREC). Ethical clearance number: BF152/19.

Results and discussion

In relation to the stated objective, to investigate the sensibility of food textural acoustics as a construct to understand eating for individuals with dysphagia, the results and discussion will be presented under the following two headings: (1) PRISMA-ScR results and bibliographic coverage findings of the 11 included articles, and (2) overview of core concepts and considerations related to food textural acoustics and eating.

Preferred Reporting Items for Systematic reviews and Meta-analyses extension for Scoping Reviews (PRISMA-ScR) results and bibliographic coverage findings of the 11 included articles

There were 1439 articles identified in the initial search across the seven databases. After 741 duplicates were removed, both reviewers independently screened 228 articles. Appendix 3 depicts the results of the PRISMA-ScR and the bibliographic information of the 11 included articles. The results revealed that there were seven research studies and four narrative reviews. The studies were conducted over 2004–2017, with the majority of the studies (seven out of 11) conducted in the United Kingdom and the remaining studies conducted in Italy, Japan and Netherlands. Of the 11 articles, only one article was conducted in the field of speech and swallowing. Spence (field of experimental psychology) conducted a majority of studies (six out of 11) independently or with other

researchers specifically from the fields of psychology. These findings depict that food textural acoustics has predominantly been researched in the field of psychology, denoting that in addition to the lack of diversity in geography, there is a lack of diversity in discipline and perspective exploring this construct.

Overview of core concepts and considerations related to food textural acoustics and eating

To understand these results and discussion, it is essential to note that in addition to the thematic analysis, we analysed the revised scoping review and focus group discussions data using the critical theory and ideology critique framework. We used the interrogative framework by Guba and Lincoln (1994), adapted by Pillay (2003), and Pillay and Kathard (2018). This involved three assumptions that we used to formulate our three core arguments:

- **Ontological assumption:** Ontology is the nature of reality. Realities are subjective and it is dependent on each person (Parahoo, 2014). Realities are shaped by social, political, cultural and economic values (Guba & Lincoln, 1994).
- **Epistemological assumption:** Epistemology is truth bases. This refers to how knowledge is created and communicated (Denzin & Lincoln, 2017).
- **Methodological assumption:** This represents the research strategies used by researchers to confirm what they believe can be known (Denzin & Lincoln, 2017).

The analysis of the revised scoping review and the online focus group discussions revealed the following three interconnected themes, which we will discuss as three core arguments:

- The sensibility of the acoustic sense.
- It does the 'boom' on your palate.
- The measurement texture-lemma.

The sensibility of the acoustic sense

Eating involves multiple senses (Velasco, Carvalho, Petit, & Nijholt, 2016). However, acoustic properties are often overlooked and neglected in contributing to flavour perception (Spence, 2015). There were three references made in the included articles (A) (Article 5 (A5), A6 and A7) and four references during the focus group discussions regarding the neglect of the acoustic properties in comparison to the other senses. Participant 1 (P1), Hanson (a chemical engineer), referred to the auditory sense as the 'hidden sense'. P4 (Zampini, a cognitive neuropsychologist) also described the acoustic sense as 'one of the most neglected modalities when it comes to food perception'. This correlates with the literature that depicts that there is a lack of focus on food textural acoustics and the common reference to the auditory sense as the 'forgotten flavour sense' (Spence, 2015). There has been a recent renaissance of interest over the past 15–20 years in studying the acoustic sense in cognitive psychology, cognitive neuroscience, food science and gastronomic sciences (A5, A6, A7; Spence, Reinoso-Carvalho, Velasco, & Wang, 2019).

P4 further expressed that acoustic properties of food are rarely considered as influencing flavour perception. He believes that acoustics should be considered as the acoustic sense is a 'relevant part of flavour experience' and flavour involves more than smell and taste. Articles 2, 3 and 4 and article 9 made reference to auditory salience. When the acoustic properties of the food were modified and the texture remained unaltered, participants of these studies reported that the auditory information was more salient to them. This improved the participants' 'oral feel' or oral somatosensation, perceiving the foods as harder or crispier (Spence & Zampini, 2006). This phenomenon was also depicted by a study by Masuda and Okajima (2011). These studies highlight the possible sensible nature of food textural acoustics in eating through the need to foreground the auditory sense. This should not be surprising as evolutionary, food acoustics has always served as a highly salient cue of freshness and pleasantness of food (A6; Tunick et al., 2013; Vickers, 1983). This notion of auditory salience is a critical factor to consider in the overall experience of eating for individuals with dysphagia.

It does the 'boom' on your palate

The analysis of the expert consultations and the 11 articles demonstrates six main codes that highlight the hedonic responses to food textural acoustics (i.e. enjoyment, positive feelings, intraoral sounds, food enhancement, freshness and texture perception). These references to the hedonic response to food textural acoustics were made mainly by P5 (Centelles, a sommelier). P5's perspective predominantly focused on the need to build a dish that consists of auditory elements. He conveyed that this is needed as it 'enhances' the dish, 'adds another dimension', 'flavours get more intense' and is 'something magical' (Figure 2). The positive hedonic responses to food textural acoustics correlate with what is evident in the literature (Tunick et al., 2013; Vickers, 1983). These studies have reported that the characteristic of crispiness most strongly relates to a food's pleasantness and enjoyment. A6 and Spence (2017) also depict that food acoustics improve the experience, pleasure and enjoyment of eating.

There are differing views and methods embraced to consider the hedonic influence of food acoustics. The analysis of the 11 articles and the vast literature shows that food textural acoustics has been focused on using a quasi-experimental orientation (A3, A4, A9 and A10; Masuda & Okajima, 2011). This involves subjectively evaluating hedonic responses related to the influence of food sounds on taste, freshness, feelings and texture perception using questionnaires (A3 and A4) and visual analogue scales (A1, A2 and A9). Conversely, P5 admitted that his perspectives are based purely on considering the feedback from his restaurant customers and their pleasure experiences. He further declared that this is 'not scientific at all'. In the real world, cooks and chefs are known to be driven by this intuition and the need to foreground hedonic interests to food acoustics for consumers' food experience, as shown in Figure 2. This is also present in

the creative dishes such as the *sound of the sea* by one of the world's famous chefs Heston Blumenthal.

The above argument depicts that similar to cooks and chefs, experts affiliated with the scientific fields also express the significance of the hedonic responses to food textural acoustics. P3, Duizer (a food scientist), added that from a sensory perspective, sounds produced when eating indicates the freshness of food. Despite experts from the scientific fields expressing the importance of the hedonic responses, their focus is more closely aligned with the literature related to how the construct of food textural acoustics can be studied rather than solely based on intuition. Thus, a disparity exists between the varying perspectives of experts in the field, as well as the literature that portrays the reductionist nature adopted in the scientific fields. The reductionist approach does not admit into its purview sound because it is difficult to measure. There is also the opposing view that there is a need to focus on the body's response and the hedonic value that sound has on the experience of eating. In relation to dysphagia management, in addition to considering the body's response to food textural acoustics, it is essential to take into account premonitory food preferences and hedonic responses. Food palatability or positive hedonic response to foods are known to increase food intake, appetite and overall nutrition (A4; McCrickerd & Ford, 2016).

The measurement texture-lemma

Dysphagia practitioners view food and drink using a textural or rheological lens when recommending diet textural modifications. Traditionally in dysphagia science, dysphagia management has perpetuated a biomedical perspective. This perspective predominantly focuses on down modifications to make food safer for consumption to prevent choking and aspiration risks (i.e. moving from Level 6 or 7 to Level 3 or 4 based on the International Dysphagia Diet Standardisation Initiative framework) (Cichero et al., 2013; Cichero et al., 2017; IDDSI, 2019). This is possibly to prevent litigation issues arising from patient fatalities. Furthermore, the literature on dysphagia assessment and practice was mainly produced in the global north, promoting specific ontological viewpoints (nature of realities). This makes it difficult for the global south to adopt these viewpoints in practice as these contexts may be confounded by economic and social challenges such as reduced access to practitioner expertise and these assessment and management measures (Andrews & Pillay, 2017; Ostrofsky & Seedat, 2016).

'I have selected a dish that we serve in our restaurant that is quite influenced by these sounds ...at that time we used to do a dessert called "chocolate in textures" and crunchiness was there and was the main factor driving the palatability of this dish ... you know, when you eat something and it just explodes on your palate ... but it is quite interesting, this sound of something exploding – doing the "boom" on your palate ... The coffee was (also) crunchy, the creaminess ... (it) had this sort of explosion on your palate ... very complex.' (P5)

FIGURE 2: Box display of an excerpt from the consultation with participant 5 depicting hedonic response to food textural acoustics.

We acknowledge that rheology is vital to foreground in diet textural modification as rheological properties of food contribute to swallowing. For instance, studies by Newman, Vilardell, Clavé and Speyer (2016) and Hadde, Cichero, Zhao Chen and Chen (2019) have depicted that rheological properties influence lingual pressure patterns, flow rate of the bolus, timing of the pharyngeal phase and swallow safety. Despite the documented benefits of diet textural modification, it should be noted that when texture or rheological properties of food are modified, the sensory and proprioceptive properties (i.e. visual, olfactory, tactile and acoustic properties) are also modified. This may lead to reduced enjoyment of the overall experience of eating. This makes it necessary to consider the holistic and complex nature of eating (i.e. textural and its associated acoustic properties), even in the management of individuals with dysphagia. This will be further elaborated on below.

Multisensory and cross-modal nature of food: Articles 2–11 and the expert consultations with P1, P4, P5 and P6 revealed two codes related to the complex nature of eating (i.e. multisensory and/or cross-modal integration) (Knöferle & Spence, 2012). Argument one (sensibility of the acoustic sense) points to the sensibility of food textural acoustics as a construct to understand eating. Due to the complex nature of eating, it poses a methodological dilemma of measuring a specific sense like acoustics. P1, P4, P5 and P6 expressed that it will be challenging to study food acoustics as a single construct as ‘sound does not come alone...very tightly and close to texture and some other sensations...really complex topic’ (P5). P2, Wilson (an audiologist), also highlighted the intricacy of the processing of auditory stimuli. He described, ‘*It (auditory processing) is not linear or unidirectional*’, and it involves complex processes (i.e. various pattern matching and neural responses). The articles and the experts are in agreement with the literature that promotes the ontological appreciation of the notion of the complexity of eating as multisensory. A total of five articles (A2, A5, A6, A7 and A9) and two experts (P3 and P4) stated that acoustic properties of food have both air-conduction and bone-conduction influences, which further compounds this methodological dilemma (Christensen & Vickers, 1991; Dacremont, 1995; Dacremont & Colas, 1993; Duizer, 2001) (Figure 3).

Despite the acknowledgment of the complexity and interconnectedness of eating, empirical science and reductionist approaches have been adopted to study the auditory sense by isolating it (Endo, Ino, & Fujisaki, 2016, 2017; Masuda, Yamaguchi, Arai, & Okajima, 2008). This includes the use of data collection tools such as microphones with headphones (A2, A3, A4, A8, A9 and A10) and surface electrodes to detect mastication behaviours (A3 and A4). This reductionist science pulls out and manipulates the auditory cues in terms of its components (i.e. pitch, loudness and/or frequency and temporal factors) and it utilises such methods to gather information regarding the body’s responses. P6, Pillay (a speech pathologist and audiologist), expressed that isolating a sense is ‘artificial and sanitised that it actually

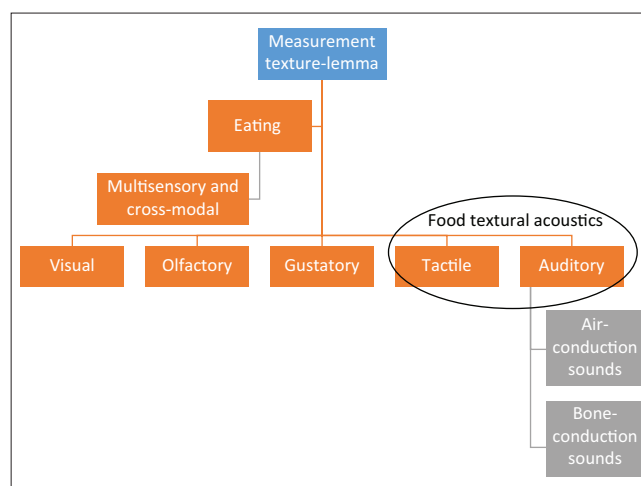


FIGURE 3: Diagram showing the complexity of eating and studying food textural acoustics.

takes away from the natural event (of eating) itself’. He further reported that using this type of approach becomes less pragmatic and less implementable in our work as practitioners. By virtue of the fact that eating is both multisensory and cross-modal, eating needs to be understood holistically. Studying eating by isolating the various senses may be of value (such as those conducted by the studies described above); however, it is counteractive. We need to acknowledge this blind spot and rethink this paradigm when studying the construct. P6 voiced that he believes that the difficulty in measuring the construct ‘comes from the methodology we use, the science we use’. This will be discussed further below.

The soundness of positioning: The results of the expert consultations exposed three primary codes related to positioning of food textural acoustics (i.e. bias, variety of perspectives and knowledge fields, and the culture of the science that we follow). Varying perspectives emerged from the expert consultations and this illuminated the notion of memetics. Memetics theoretically originates from the central concept of a meme (unit of cultural evolution and selection), conceptualised by Richard Dawkins in 1977 (Tyler, 2011). We have operationalised the notion of memetics in this study as the way in which ideas have been generated across time and space (Castaño Díaz, 2013; Dawkins, 1977). P4 stated that he felt ‘comfortable’ with the science that he uses. P2 and P6 had an overt discussion of the science. P2 indicated at the onset that his thoughts reflect his biases of understanding auditory processing from more of a bottom-up perspective (‘that goes from outer ear to middle ear to inner ear to cochlear nerve, to cochlear nucleus... station by station up the pathway’). This was because of his profession and retreat to topics that he is more comfortable with. This bottom-up perspective correlates with A5 and A7 which reviews highly controlled laboratory-based studies, and the literature that acknowledges more epistemological variations that come from quasi-experimental or positivistic frameworks (Endo et al., 2016, 2017; Masuda et al., 2008). Despite P2’s stated professional bias, he questions certain scientific basis and encourages that auditory processing be understood from a more top-down perspective.

This includes consideration of the influence of higher-order functions such as expectation and memory (Spence, 2015; Piqueras-Fiszman, 2020; Sakai, 2020). Similarly, we need to consider these higher-order functions during eating and also for those with dysphagia (i.e. premorbid food preferences, and anticipation for consumption and subsequent memories of food experiences) (A6).

It is crucial to acknowledge the methodological dilemma (i.e. the complexity of eating because of its multisensory and cross-modal nature) and approach used when studying the construct of food textural acoustics. This may assist in conceptualising and developing innovative methods of studying the construct. Isolating a sense may not be the most ideal approach. P6, a South African-based practitioner proposed, 'our mission is to look at inventing or imagining a new science that can help us take this (construct) forward'. The multisensory nature of eating with the consideration of the textural, and its associated acoustic, properties should be foregrounded in the assessment and management of individuals with dysphagia. P6 further expressed:

'We work in a low socio-economic context. And a lot of the people we work with (individuals with dysphagia) do not have enough healthcare services to help... So we want to invest in developing foods that are in and of themselves maximally therapeutic... for its impact on the swallow mechanism. If sound is one of the other ingredients we can put into it (dysphagia diets), then that is why we want to develop it.' (P6, Pillay, Speech Pathologist and Audiologist)

'Illuminators' and implications for the field of dysphagia

The above three intersecting arguments illustrate that the construct of food textural acoustics may be sensible to investigate as it is supported from both a practice and theoretical perspective and from the focus of empirical-based and ecological studies. Why have we not sufficiently researched and factored food textural acoustics and its potential therapeutic and hedonic benefits into dysphagia practice? We are more focused on diet textural modifications such as recommending softened foods and the use of commercial food thickeners. This often results in undernutrition, reduced quality of life, poor compliance and frequent hospitalisations because of recurrent aspiration pneumonia (O'Keeffe, 2018; Shune & Namasivayam-MacDonald, 2020; Swan et al., 2015). Are we solely concerned with food safety, rather than with rehabilitating swallowing and improving overall quality of life? Are we treating the condition of dysphagia instead of the whole individual?

The research across the fields of psychology, cognitive neuroscience, gastronomic sciences and marketing has depicted the influence of food acoustics on behaviour and perception (Callan et al., 2018; Carvalho et al., 2016; Höchenberger & Ohla, 2019; Kantono et al., 2018; Spence, 2015, 2017). How can we understand the influence of food

textural acoustics on the body's physiological response for dysphagia management? A few illuminators exist to connect this construct of food textural acoustics to dysphagia. However, two will be discussed below.

Studies by Endo et al. (2016, 2017) have investigated the influence of altered auditory feedback of chewing sounds, which resembled a crunchy sound on the perception of food texture. The results revealed that in addition to positively influencing palatability and taste, this pseudo-chewing sound had an influence on the perception of food texture (i.e. perceiving the texture as stiff and rougher). This influence was present even in the absence of the actual crunchy oral sensation. This technique may be used to improve the texture perception and hedonic responses to texturally modified foods for individuals with dysphagia, without changing the actual texture of the foods. A second illuminator is the possible therapeutic benefit of 'up-modifications' (i.e. moving from lower Level 4 to Level 6 on the IDDSI framework) (refer to Pillay [2013] for further explanation). This involves the use of transitional foods for individuals with dysphagia. Transitional foods (also known as solid meltable foods) refer to foods that change rapidly by melting when it comes into contact with body temperature, becoming easier to chew and swallow (Cichero et al., 2017). An example in the South African context is the Bakers Blue Label® Marie Biscuit. The most recent version of the IDDSI framework includes transitional foods that span across the pyramid. Research has shown the benefit of transitional foods in the paediatric populations, especially for those with less mature or underdeveloped sensorimotor systems for mastication (Dovey, Aldridge, & Martin, 2013; Gisel, 1991). This offers some promise for the adult population. A study by Barewal, Shune, Ball and Kosty (2020) demonstrated that it is necessary to consider the use of transitional foods like *Savorease* and the *EAT-Bar*, which are two commercially available transitional foods. These transitional foods may provide improved eating pleasure and nutrition for individuals on texturally modified foods (Barewal et al., 2020). Snack foods and finger foods like the *Savorease* require minimal chewing that may benefit masticatory muscle strength and cognition for individuals with dysphagia (Barewal et al., 2020). These studies described above provide a strong evidence to support the development of more 'sensory-responsive foods', as per the THRIVE programme, because of their improved pleasure and potential therapeutic benefit.

Study critique

We used multiple data sources (i.e. revised scoping review, online consultation phase and reference to published data) and data analysis methods. This was used as a means of triangulation to improve the credibility and trustworthiness of the study. The inclusion of a pilot study and a blind review prior to and during the scoping review aided with establishing data credibility. We acknowledge the limitations associated with the scoping review methodology. For instance, the search terms and databases chosen might have resulted in

some relevant articles being overlooked. However, we used a rigorous method for data collection to alleviate this potential limitation. The co-author of this study acted as a supervisor and as an informant during the expert consultations. While this may appear to be bias, he was included as this study followed a hermeneutic paradigm (Guba & Lincoln, 1994). This involved including individuals' opinions as a way of acknowledging that multiple realities exist and foregrounding and celebrating subjectivities (Guba & Lincoln, 1994; Pillay & Kathard, 2018). Following the expert consultations, we also conducted member checking to promote trustworthy and credible data (Birt et al., 2016; Cope, 2014).

Conclusion

This study has synthesised the literature, especially from 1980 to 2020, and views from world experts from various fields. The results of this study depict the possible sensibility of food textural acoustics as a construct to understand eating for individuals with dysphagia. We have highlighted auditory salience numerous times throughout the article with the need to change the rhetoric of sound the 'forgotten flavour sense' (Spence, 2015) to the 'celebrated flavour sense'. Thoughts influence practice. We hope that this article inspires researchers and practitioners to think differently by using texture, and its associated acoustic, properties such as the use of transitional foods as a way to reimagine dysphagia practice. This study may drive us to develop novel ways of approaching this construct and to explore its potential clinical applicability for individuals with dysphagia. This may be particularly contextually responsive to those individuals with dysphagia from low- to middle-income contexts such as South Africa and Brazil, where food security and food sovereignty are a concern.

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Competing interests

The authors declare that they have no financial or personal relationships that may have inappropriately influenced them in writing this article.

Authors' contributions

T.K. drafted this manuscript. T.K. collected, analysed and interpreted the data under the supervision of M.P. Both researchers reviewed and approved the final manuscript.

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Data availability

The data that support the findings of this study are available from the corresponding author, T.K., upon reasonable request.

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Appendices starts on the next page →

Appendix 1

TABLE 1-A1: Established fields that have alluded to food textural acoustics.

Fields	Reference
Engineering and physical sciences (Chemistry)	Acoustic Rheology: (Peleg, 2017; Zadeike et al., 2018)
Food science	Drake (1965) was the pioneer in investigating and noting the relationship between the auditory sense in texture perception and described this as textural acoustics. Duizer (2001): Food acoustic classification system (crispy, crunchy and crackly)
Gastronomical sciences	Food marketing and packaging (Spence, 2016; Wang & Spence, 2019)
Cognitive neurosciences	Music: (Carvalho et al., 2016; Kantono et al., 2016; Kantano et al., 2018) Background sounds: (Callan, Callan, & Ando, 2018; Lowe, Rigler, & Haws, 2018; Rahne, Köppke, Nehring, Plontke, & Fischer, 2018; Trautmann, Meier-Dinkel, Gertheiss, & Mörlein, 2017)
Dysphagia sciences	Textural modifications: (Cichero, 2018; Cichero et al., 2017; De Villiers et al., 2019; IDDSI, 2019; Swan et al., 2015)

Appendix 2

History of the study

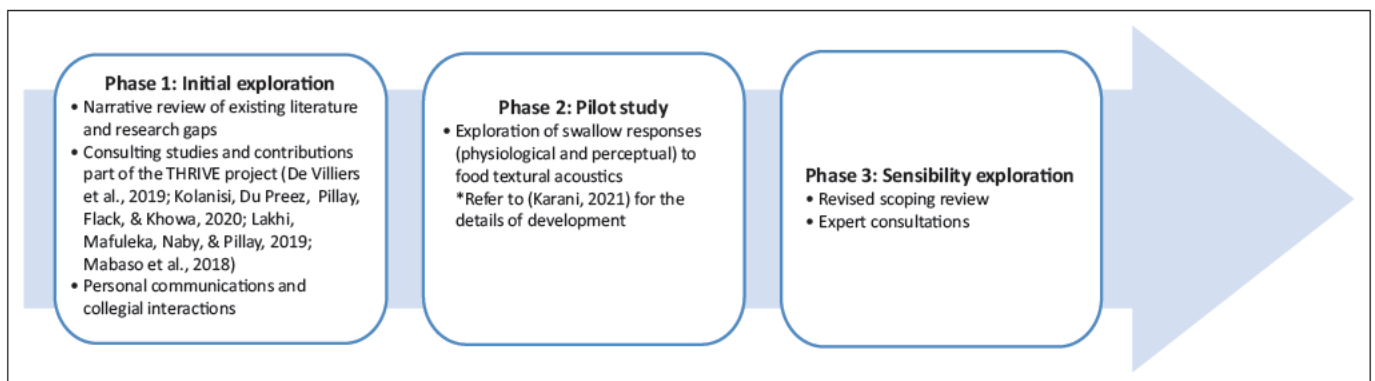


FIGURE 1-A2: The broader study involved three main phases (initial exploration, pilot study and sensibility exploration). Phase 3 formed the primary focus of this article.

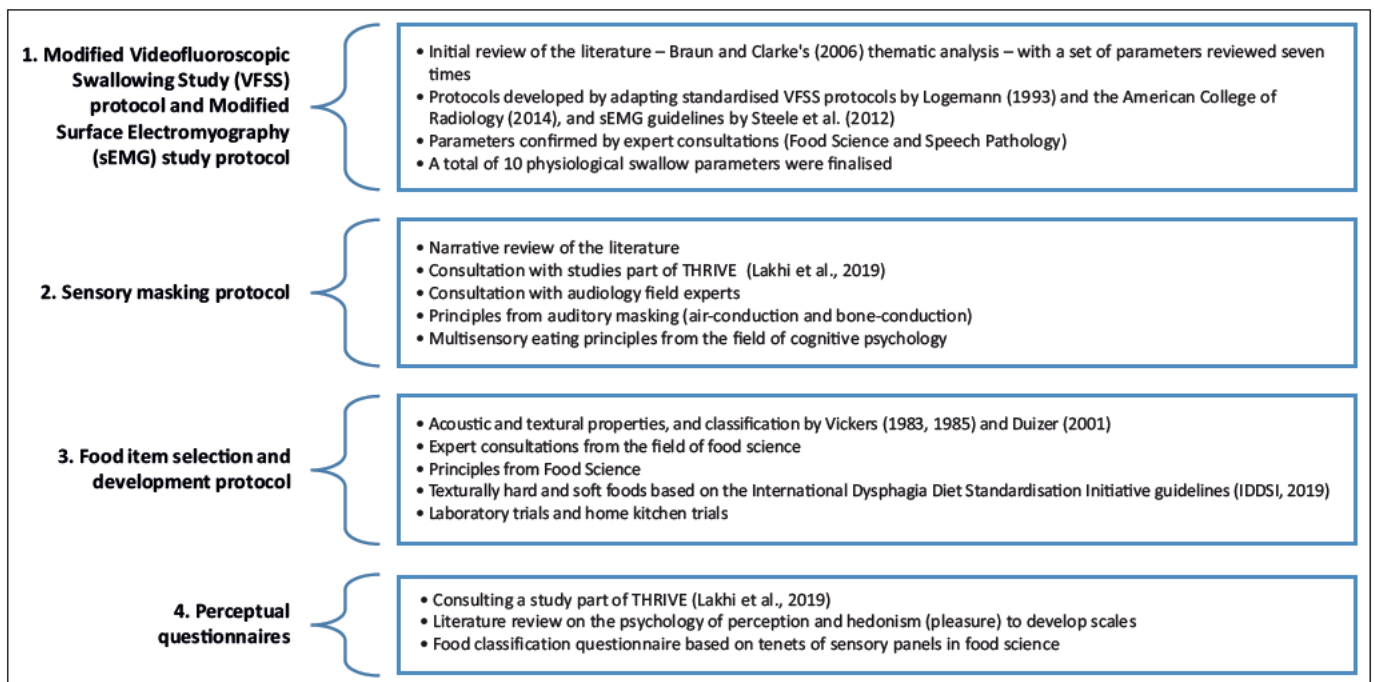


FIGURE 2-A2: Self-developed protocols and tools associated with phase 2.

Appendix 3

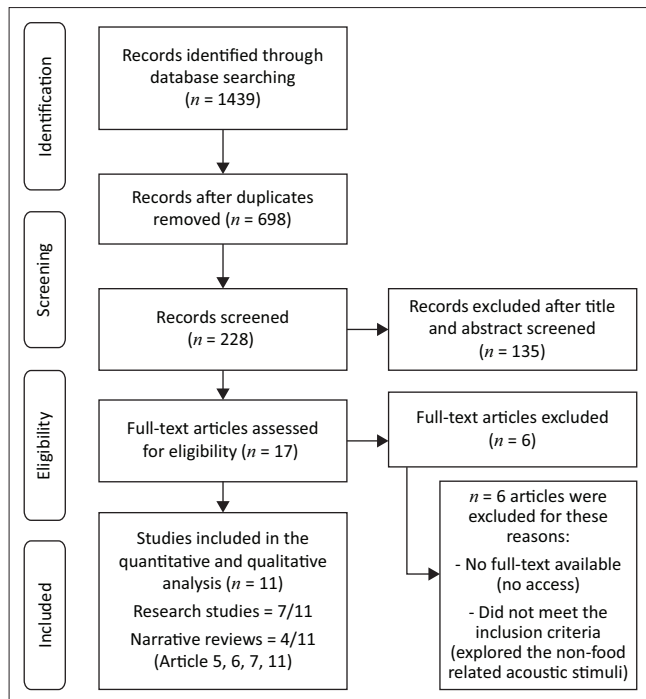


FIGURE 1-A3: Preferred Reporting Items for Systematic Reviews and Meta-analyses extension for Scoping Review (PRISMA-ScR) flow diagram results.

Appendix 4

TABLE 1-A4: Bibliographic data of the 11 included articles.

Article number	Title	Author/s	Year	Location in which the study was conducted	Knowledge field	Affiliation (Journal)
1	Does listening to the sound of yourself chewing increase your enjoyment of food?	Amos et al.	2006	United Kingdom	Speech and Swallowing Research	<i>Annals of General Psychiatry</i>
2	Effects of the sound of the bite on apple perceived crispness and hardness.	Demattè et al.	2014	Italy	Psychology and Cognitive Science	<i>Food Quality and Preference</i>
3	The effect of a crunchy pseudo-chewing sound on perceived texture of softened foods.	Endo et al.	2016	Japan	Industrial Science and Technology	<i>Physiology & Behavior</i>
4	Texture-dependent effects of pseudo-chewing sound on perceived food texture and evoked feelings in response to nursing care foods.	Endo et al.	2017	Japan	Industrial Science and Technology	<i>Appetite</i>
5	Auditory contributions to flavour perception and feeding behaviour.	Spence	2012	United Kingdom	Experimental Psychology	<i>Physiology & Behavior</i>
6	Eating with our ears: assessing the importance of the sounds of consumption on our perception and enjoyment of multisensory flavour experiences.	Spence	2015	United Kingdom	Experimental Psychology	<i>Flavour</i>
7	The influence of auditory cues on the perception of, and responses to, food and drink.	Spence and Shankar	2010	United Kingdom	Experimental Psychology	<i>Journal of Sensory Studies</i>
8	The influence of auditory and visual information on the neuromuscular control of chewing crispy food.	Van der Bilt, Pocztauruk, Frasca, Van der Glas, and Abbink	2011	Netherlands Brazil	Oral-Maxillofacial Surgery, Prosthodontics and Special Dental Care Faculty of Dentistry	<i>European Journal of Oral Sciences</i>
9	The role of auditory cues in modulating the perceived crispness and staleness of potato chips.	Zampini and Spence	2004	United Kingdom	Experimental Psychology	<i>Journal of Sensory Studies</i>
10	Modifying the multisensory perception of a carbonated beverage using auditory cues.	Zampini and Spence	2005	United Kingdom	Experimental Psychology	<i>Food Quality and Preference</i>
11	Assessing the role of sound in the perception of food and drink.	Zampini and Spence	2010	United Kingdom Italy	Experimental Psychology Cognitive Sciences	<i>Chemosensory Perception</i>

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3.6. Summary of the chapter

The published paper presented above explores the sensibility of the construct of food textural acoustics for dysphagia. COVID-19 has prevented the main study from exploring the influence of food acoustic properties on swallow responses using mixed methods. However, COVID-19 provided an opportunity to more thoroughly develop the conceptual basis of the study through a more systematic review of the published literature and to dialogue with world experts across the fields openly. This paper employed a QES methodology (revised scoping review and expert consultations). This QES methodology proved valuable for the overall study of the exploration of food textural acoustics and its potential link to dysphagia.

This study highlighted the value and power of QES methods. Within this study, the expert consultations promoted a hermeneutic paradigm by meaningfully engaging world experts with diverse perspectives and from various fields of study using the format of open dialogue (Guba & Lincoln, 1994). This dialogue with interprofessionals used an ethnographic method that promoted complex discussions regarding the field experts' views of the construct of food textural acoustics based on their personal and professional backgrounds (Ejimabo, 2015). This allowed the experts to freely dialogue to generate rich information that contributed to a more holistic and deeper understanding of food textural acoustics. For instance, three themes with three associated core arguments emerged from the analysis of the expert consultations (refer to the published paper above). First, dialogic interactions and dialogic learning and its associated positive outcomes have been focused on from the perspective of education (Mercer & Dawes, 2014; Haneda, 2017; Resnick et al., 2018). Second, traditionally, the educator's knowledge was valued (Pillay & Kathard, 2015). However, this study used this theory of dialogic learning and adapted it by collectively valuing all the views and perspectives of the world experts and the published literature to make sense of the construct of food textural acoustics (Pillay & Kathard, 2015). These expert consultations also involved critical discussions and "cross-talk" as strategies to allow for debate to contribute to the conceptual basis of food textural acoustics (Brydon & Dvořák, 2012).

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3.7. Conclusion

How can we use food textural acoustics as a way to reimagine dysphagia practice? Our thoughts and evidence influence practice. This paper acts as a basis for considering the construct of food textural acoustics in relation to individuals with dysphagia. There are methodological dilemmas of studying this construct of food textural acoustics highlighted in this paper. However, through dialogue between the experts and with reference to the published literature, this paper has highlighted and acknowledged that subjectivities and multiple realities exist across the fields through the notion of memetics and the hermeneutic approach. This promotes the need to consider these subjectivities and propose alternative and novel ways of approaching food textural acoustics in relation to dysphagia. This may act as a way to reimagine dysphagia practice through the exploration of food textural acoustics.

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CHAPTER FOUR: PAPER THREE

It's crrr...time! So why is it that we find crispy chips and snack foods so satisfying? Why do we gravitate towards crisp lettuce and crunchy carrots and find ourselves salivating when we hear the sizzling sounds of stir-fried vegetables? Does it have anything to do with how our bodies are wired to understand food sounds and respond physiologically? Can we use this basis to manage individuals with dysphagia (swallowing disorders) as a way to reimagine practice? (Tasneem Karani, author)

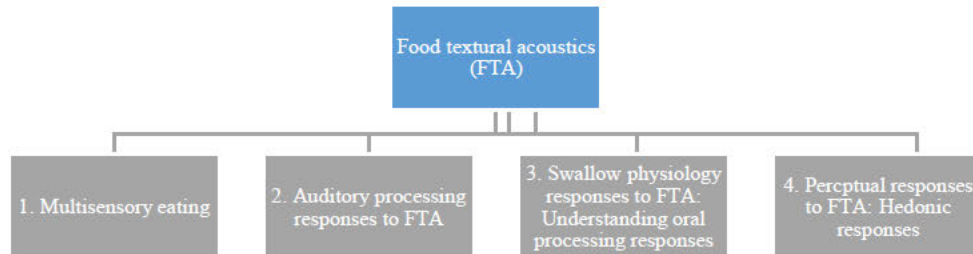
4.1. Introduction

This chapter presents the third paper, which explores the utility of food textural acoustics for dysphagia research and practice. This third paper is a theoretical paper written as a tutorial to culminate the study. The purpose of this tutorial is to introduce researchers and clinicians to the construct of food textural acoustics concerning dysphagia rehabilitation by drawing on the results of the three components of the broader study (i.e. conceptual and theoretical exploration of the construct, pilot study, and exploration of the sensibility of the construct). Within this paper, four subject areas that may be considered when studying this construct of food textural acoustics are proposed (Figure 1). This paper further discusses how these four subject areas constitute the foundational constructs of a methodology to assess food textural acoustics in a research setting and highlights the considerations (theoretical-methodological issues) related to the study of this novel construct. Finally, as this construct provides preliminary research in the field of dysphagia, this paper discusses the potential clinical utility of food textural acoustics in clinical dysphagia practice, given the results of the other components of the broader study. This paper concludes by inviting and encouraging further inquiry into improving food enjoyment and swallowing therapeutic outcomes for dysphagia management.

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Figure 1.

Proposed Subject Areas Undergirding Food Textural Acoustics



4.2. Aim

To explore the utility of food textural acoustics for dysphagia research and practice.

4.3. Publication details

This chapter includes the paper submitted as a tutorial for publication to the American Speech Hearing Association Perspectives- Special Interest Groups, issue 13: Swallowing and swallowing disorders (dysphagia) (ASHA SIG13). The paper was designed to comply with the journal specifications (style, word count, and page limit) and is currently under peer review. The paper details the theoretical basis of the construct of food textural acoustics by presenting the subject areas that underpin the construct, discussing the methods to study the construct further, and exploring its potential use in dysphagia practice.

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<i>Title</i>	<i>“Boom on your palate”: Exploring food textural acoustics in relation to swallowing rehabilitation</i>
<i>Authors</i>	Tasneem Fareed Karani ¹ , Mershen Pillay ²
<i>Journal</i>	American Speech Hearing Association Perspectives- Special Interest Groups, issue 13: Swallowing and swallowing disorders (dysphagia) (ASHA SIG13)
<i>Status</i>	Under review

4.4. Summary of preamble

This chapter presents the final paper currently under review with ASHA SIG13. The paper details the theoretical basis for studying the construct of food textural acoustics regarding the other components of the broader study. This paper presents the preliminary data on food textural acoustics. This tutorial calls for further research to develop and refine the novel construct of food textural acoustics concerning the field of dysphagia. As this paper is a culmination of the study, the main findings of the overall study will be discussed further in the next chapter (conclusion).

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4.5. Paper Three: “Boom on Your Palate”: Exploring Food Textural Acoustics in Relation to Swallowing Rehabilitation

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Abstract

Purpose: This paper focuses on exploring textural and its associated acoustic properties, i.e. food textural acoustics (FTA), regarding the data from our two previous studies (i.e. pilot study, scoping review and expert consultations). This tutorial aims to introduce researchers and clinicians to the construct of FTA concerning swallowing rehabilitation. This paper discusses four proposed subject areas that undergird FTA; (a) multisensory eating, (b) auditory processing responses, (c) swallow physiology responses, and (d) perceptual responses- to FTA. Finally, we propose methods and considerations for researchers to further study this construct of FTA and explore its potential utility for dysphagia practice.

Conclusion: This paper has provided a theoretical basis for the need to consider FTA in deglutition sciences. As a result of our research, we propose using the International Dysphagia Diet Standardisation Initiative (IDDSI) transitional foods. As the construct of FTA provides preliminary research in the field, we invite further research. We anticipate that this paper will inspire inquiry into FTA and its potential use in global dysphagia practice.

Keywords: *textural acoustics, multisensory eating, swallow physiology, auditory processing, dysphagia practice, clinical utility.*

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1. Introduction and background

Eating is one of the most multisensory experiences (Piqueras-Fiszman & Spence, 2016; Spence, 2015, 2017, 2020; Velasco et al., 2016). Previously, the role of audition has been briefly explored compared to the other senses and has been commonly referred to as the “forgotten flavour sense” (Spence, 2015). However, there has been a renaissance of interest in the study of the audition, particularly in the last 15-20 years. This includes the fields of cognitive neuroscience (Callan et al., 2018; Kantono et al., 2018; Lowe et al., 2018), gastronomic sciences (Knöferle et al., 2015), food marketing (Spence, 2016; Wang & Spence, 2019) and beyond (Spence et al., 2019). Furthermore, due to the salience of auditory stimuli, non-food related sounds such as music and background sounds, and food-related sounds (i.e. crispy, crunchy, crackly, squeaky and carbonation), have been shown to have a positive influence on behaviour, perception and overall enjoyment of food (Carvalho et al., 2016; Demattè et al., 2014; Kantono et al., 2016; Spence, 2015, 2016, 2017; Trautmann et al., 2017; Zampini & Spence, 2004, 2005, 2010).

Despite these well-researched effects, a gap exists across the fields exploring the influence of audition on swallow physiology, with only two studies conducted that have focused on the influence of altered auditory feedback (pseudo-mastication sound) on the perception of food texture and effect on mastication (Endo et al., 2016, 2017). The results revealed that the pseudo-mastication sound positively influenced the perception of food texture, palatability, and taste of the soft nursing food, even in the absence of the oral sensation. However, the pseudo-mastication sound showed no effect on mastication intensity and rhythm. These physiological effects are the focus of the paper.

1.1 Review of the literature on acoustics in the field of dysphagia (swallowing disorders)

This paper is concerned with the influence of acoustic stimuli on physiological responses. In deglutition sciences, various sensory modalities such as visual, olfactory, gustatory and tactile senses influence swallow physiology and contribute towards dysphagia rehabilitation (Loret, 2015; Nagy et al., 2014; Wahab et al., 2010, 2011). We have explored the impact of the senses on swallowing and dysphagia management by conducting a narrative review of the dysphagia literature from 1991-2021. The following parameters were used; peer-reviewed published articles; databases: EBSCOHost, Google Scholar and CINAHL; keywords: “senses” OR “sensory

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modalities” AND “swallowing” OR “dysphagia”. The search was restricted to the first 40 relevant studies located. The review revealed that of the 40 articles retrieved, three articles were concerned with the effect of the visual sense, five olfactory, eight gustatory, 24 tactile, and none with the auditory sense (see Appendix A with the review findings).

Interestingly, the review indicated that similar to psychology, gastronomy and marketing, dysphagia literature had not been sufficiently explored in the auditory sense. Out of the 24 references on the effect of the tactile sense, nine articles explored the influence of texture. Our literature review further revealed that diet textural modifications, explicitly focusing on altering the rheological parameters of foods, are what dominate research in dysphagia management (Cichero et al. 2017; Cichero, 2020; de Villiers et al., 2019; Steele et al., 2015; Swan et al., 2015).

Fields such as engineering, physical sciences and food science have all supported the interconnected nature between texture, and its associated acoustic, properties, with the construct of “acoustic rheology” being established over 50 years ago (Drake, 1965; Peleg, 2017; Swan et al., 2015; Zadeike et al., 2018). In light of this, it was surprising that studies of diet textural modification in dysphagia tend to marginalise how texture and acoustic properties are intimately connected. It is well-established that textures such as hard foods produce auditory stimuli during mastication, for example, crispy or crunchy sounds. We have borrowed from these fields and refer to textural properties of food and their associated acoustic properties as “food textural acoustics” (FTA). As textural properties and acoustic properties of food are closely linked, and texture has been studied extensively in the field of dysphagia, why have dysphagia practitioners not adequately considered the role of audition in eating and dysphagia management? The purpose of this tutorial is to explore the construct of FTA by presenting the following:

1. proposed subject areas undergirding the construct of FTA
2. proposed methods and considerations when studying and/or researching the construct
3. discussing the potential utility of FTA for dysphagia research and practice

1.2. The genesis of the study of FTA concerning dysphagia

The conceptual basis of this paper has been shaped by our broader study, which involved three other components, all of which are underpinned by the Tackling Hunger by Research and

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Innovation in Vulnerable Environments (THRIVE) project (Pillay & Kathard, 2018). The THRIVE project endeavours to reposition management of swallowing and feeding to develop transformative practitioners that foreground food security and sovereignty (Pillay & Kathard, 2018). Food security and sovereignty issues are especially prevalent in low-to-middle income contexts where there is reduced availability, access, utilisation, and sustainability of culturally diverse, socially and economically appropriate food (FAO et al., 2015; Patel, 2009; Webb & Rogers, 2003). This is further compounded by the limited access to healthcare professionals, equipment, and resources such as commercial food thickeners and foods suitable for these individuals (Andrews & Pillay, 2017; Pillay et al., 2020). Second, the THRIVE project strives to improve food security for individuals with disabilities such as dysphagia by ensuring that food is accessible, culturally appropriate, affordable, and suitable for safe swallowing (de Villiers et al., 2019; Pillay & Kathard, 2018). As part of this project, we are inspired to conceptualise more novel methods that target the foods that can be provided globally to individuals with dysphagia. Our focus is on investing in more “sensory responsive” foods for individuals with dysphagia. Sensory responsive foods consider the multisensory nature of eating, particularly the potential use of FTA. This will promote swallow safety, food pleasure and overall enjoyment for individuals with dysphagia.

Textural properties are a fundamental criterion for food preference and recognition (Chen, 2009; Engelen & Van Der Bilt, 2008), and sensory acceptance and rejection by consumers (Chen & Engelen, 2012). Studies by Álvarez et al. (2020), Tunick et al. (2013), and Vickers (1981) have also portrayed that crispiness is one of the auditory descriptors that most strongly relates to a food’s appreciation, freshness, pleasantness and enjoyment. Similarly, due to their salience, acoustic properties add value to the experience of eating and improves overall pleasure and enjoyment (Spence et al., 2011; Spence, 2015, 2017). We anticipate that in addition to the known positive hedonic responses to texture and acoustic properties, these foods may have a therapeutic benefit for individuals with dysphagia and improve their quality of life. It is paramount to ensure that dysphagia practitioners consider the cultural diversity of their patients and recommend foods that are culturally appropriate, safe for swallowing, affordable, accessible, enjoyable and potentially therapeutic for individuals with dysphagia from diverse contexts.

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1.2.1. Study components

Our broader study involved the following three components; (a) conceptual and theoretical conceptual exploration of the construct of FTA, (b) pilot study, and (c) exploration of the sensibility of the construct of FTA. These three components provide the conceptual basis of this paper, which forms the fourth component of the study, i.e. exploration of the utility of FTA for dysphagia research and practice. The conceptual and theoretical exploration of the construct of FTA involved conducting a narrative review of existing literature, identifying research gaps, and conceptualising and referring to other studies undergirded by the THRIVE project to develop the construct further. These studies include; De Villiers et al. (2019), Kolanisi et al. (2020), Lakhi et al. (2019), and Mabaso et al. (2018). This also involved personal communications and collegial interactions with audiology, food science, mechanical engineering, and speech therapy experts. The results of the conceptual and theoretical exploration, in part, influenced the methodology of the pilot study.

The pilot study involved developing and testing protocols and tools to evaluate the swallow responses to FTA. This pilot study involved eight healthy adults and four proposed protocols and tools to evaluate the influence of acoustic properties associated with texturally hard foods on swallow responses (see Karani, 2021). The pilot study results reveal that acoustic properties of texturally hard foods play a role in texture perception, leading to positive hedonic responses. In addition, the preliminary data from the physiological and perceptual swallow responses depict those acoustic properties influence the swallow responses, specifically by reducing the force needed and duration of the first bite, mastication and swallowing. Based on the evaluation of the pilot study, the main study is recommended to incorporate a larger sample size and minor amendments to the pilot study protocols and tools.

The study on the exploration of the sensibility of the construct of FTA investigated and depicted the potential sensibility of considering FTA as a construct to further comprehend the eating for individuals with dysphagia. This study utilised revised scoping review methods and an adapted online consultation phase with six world experts (refer to Karani and Pillay (2021) for further details). This study revealed the lack of diversity, geography and discipline exploring this construct of FTA. Given the salience of food textural acoustics and its associated hedonic responses, food textural acoustics may be a sensible construct to understand eating for individuals

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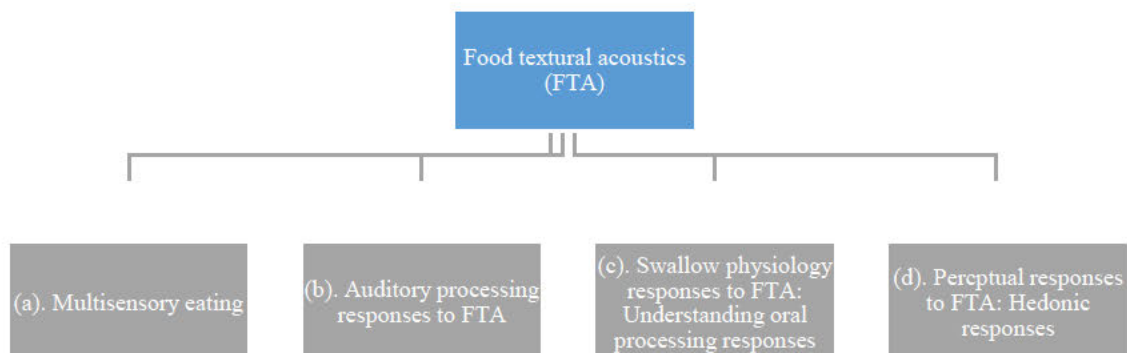
with dysphagia. Based on the findings of these three components, we would like to promote the need to study FTA and its potential utility for dysphagia management as the fourth component of the broader study (see supplementary material 1). This will be further explored in the current paper.

2. Subject areas undergirding FTA

As previously stated, a gap exists in deglutition science related to exploring the swallow physiology responses to food acoustic properties. We propose four subject areas to consider when studying FTA in relation to swallowing and swallowing rehabilitation. This includes; (a) multisensory eating, (b) auditory processing responses to FTA, (c) swallow physiology responses to FTA, and (d) perceptual responses to FTA (see Figure 1). A fifth core subject that underpins FTA is the food composition of texturally hard foods, such as the rheological and mechanical properties (Aguayo-Mendoza et al., 2019). We acknowledge that food composition influences oral processing; however, at present, we are more focused on an individual's responses to FTA (refer to Chen (2015), Liu et al. (2017), and Quo (2021) for studies on the oral processing of foods).

Figure 1.

Proposed Subject Areas Undergirding Food Textural Acoustics



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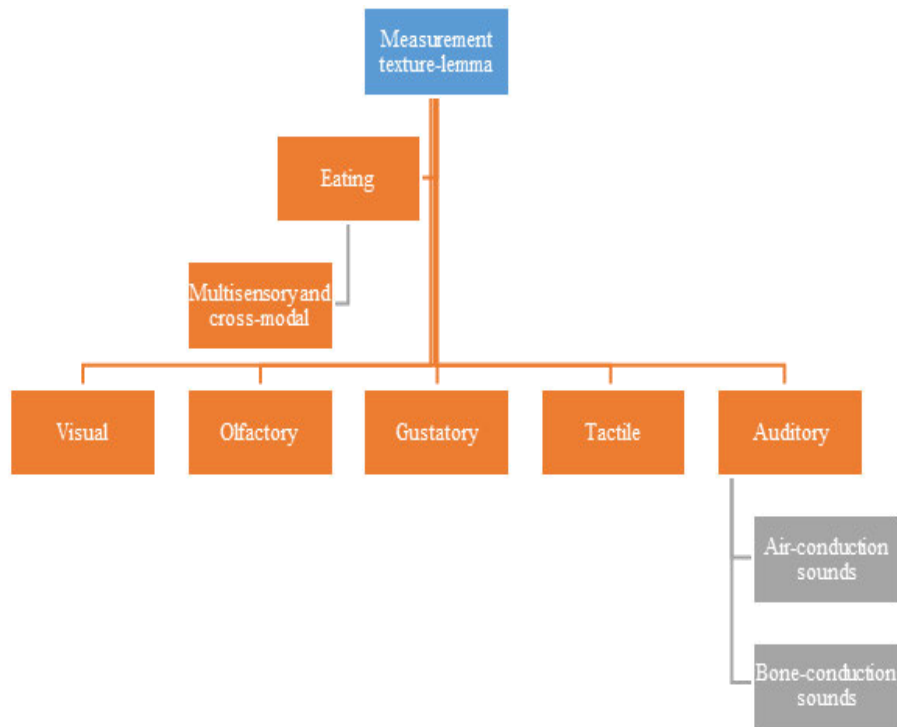
a. Multisensory eating

The ontological appreciation of the complexity of eating as multisensory and cross-modal has been recognised in published literature and by perspectives of world experts (Karani & Pillay, 2021; Piqueras-Fiszman & Spence, 2016; Spence, 2017, 2020; Velasco et al., 2016) (Figure 2). For example, while the visual system is involved in selecting foods, the proprioceptive system identifies food texture, size, and shape (Spence, 2015; Verhagen, 2007). Other senses such as the olfactory and gustatory systems are also involved in making sense of the smell and taste of the food, while the auditory system plays a role in the sounds of biting and mastication of foods (Spence, 2015; Verhagen, 2007). The body is a dynamic and complex organism that can simultaneously focus on these multiple sensory processes (Verhagen, 2007). Traditionally it was believed that initially, these senses are processed in sensory-specific areas in the brain, and these signals are integrated to form the multisensory event (Henschke et al., 2015; Macaluso, 2006). For instance, sensory-specific cortices in the superior temporal gyrus respond to auditory stimuli, and the post-central regions are involved in touch (Macaluso, 2006). However, in recent years, research has shown that these multisensory interactions are not only localised in multisensory convergence zones in the association cortex. They occur at a cortical information processing level such as the primary sensory cortex and include the involvement of subcortical structures (Van den Brink et al., 2014; Van der Burg et al., 2011). Due to the multisensory nature of eating, it is challenging to isolate and study the acoustic sense, and this will be discussed further under proposed methods and considerations.

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Figure 2.

Diagram Showing the Complexity of Eating and Studying Food Textural Acoustics (from Karani & Pillay, 2021).



b. Auditory processing responses to FTA

We proposed the need to consider acoustic properties as other sensory modalities have shown to influence swallowing and dysphagia rehabilitation. There is an abundance of research on the auditory processing of linguistic and non-linguistic sounds such as environmental sounds or music (Hendrikson et al., 2019; Rassili & Ordin, 2020; Richards & Goswami, 2015) and its two parallel pathways (i.e. classical and non-classical auditory pathways) (Møller, 2011; Palumbo et al., 2018). The two parallel pathways, the classical and non-classical auditory pathways, are separate ascending sensory pathways (Møller, 2011). The classical auditory pathway is known as the specific system. It responds to only one sensory modality, and the non-classical pathway is the unspecific system as it receives input from other sensory systems such as the visual and somatosensory system, causing cross-modal interactions (Møller, 2011). This paper will focus on how individuals process body-generated sounds, a phenomenon called autophony.

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Autophony refers to self-hearing or our response to internal body-generated sounds such as one's voice and chewing sounds (Harris, 2015; Keidar & Kwartowitz, 2018; Tidball & Fagelson, 2018). Autophony has been researched in audiology and otolaryngology, where it has been viewed in the context of pathology or discomfort in the instance of a patulous eustachian tube or superior canal dehiscence syndrome (Johanis et al., 2021; Verrecchia, 2018). At the other end of the continuum, there is enjoyment and pleasure. This has not been considered and researched. This study has approached autophony in a novel way to consider the eating sounds of texturally hard foods such as crispy, crunchy and crackly foods. Acoustic properties are a powerful stimulus for processing. Evolutionarily, acoustic properties of food have been known to be salient and denote freshness, pleasantness and food enjoyment (Spence, 2015; Tunick et al., 2013; Vickers, 1983). How can we explore and use autophony as a tool in understanding FTA and its impact on swallow physiology responses? This needs to be further explored.

c. Swallow physiology responses to FTA

When considering the influence of FTA on physiological responses, we are concerned with the food oral processing responses. Food oral processing is a dynamic and complex process that involves various oral operations: first bite, mastication, formation and transportation of the bolus and swallowing (Chen, 2015; de Lavergne et al., 2017; Liu et al., 2017). Our primary interest is to understand the swallowing response resulting from the first bite, specifically the bite force. As the study explores texturally hard foods and their associated acoustic properties, the rheological properties of the food highly influence the first bite and mastication (Chen, 2015). According to studies by Endo et al. (2016), Laguna et al. (2016), and Stokes et al. (2013), the first bite is significant in texturally hard foods. The need to focus on the first bite with the food texture has also been promoted in a study by Cichero (2020).

To date, there does not appear to be studies that have explored the relationship between FTA and swallowing physiology. As this is a novel area of research, our pilot study involved developing and testing protocols and tools to evaluate the swallow responses to FTA. The parameters to evaluate the swallow responses to FTA were developed by merging the food oral processing framework with the three swallow phases (oral phase, oral- preparatory phase and pharyngo-oesophageal phase). The following ten parameters were finalised and evaluated:

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1. oral phase timing;
2. first bite force;
3. mastication force;
4. mean number of masticatory cycles;
5. mean mylohyoid force (i.e. a predictor of swallow force (Steele et al., 2012));
6. duration of palatal elevation;
7. duration from the entrance of the bolus to into the hypopharynx until the opening of the upper oesophageal sphincter (UOS);
8. percentage change in hyolaryngeal complex (HLC) excursion from at rest to elevation (x-value);
9. percentage change in hyolaryngeal complex (HLC) excursion from at rest to elevation (y-value) (predicts functional swallowing (Barikroo et al., 2015); and
10. duration of change in HLC excursion (at rest to descent).

The timing and force parameters were evaluated simultaneously using videofluoroscopic swallowing study and surface electromyography study, respectively. The process of evaluating these parameters will be discussed under the proposed methods and considerations.

d. Perceptual responses to FTA

In addition to the auditory processing and swallow responses to FTA, perceptual responses to FTA need to be considered. This involves one's perceived swallow responses and taste and flavour perception. Eating is a subjective experience dependent on personal preference and social, economic and cultural factors (Kenny, 2015). Food preference and palatability are essential to consider, increasing food intake, appetite, and overall nutrition (McCrickerd & Ford, 2016). Psychology research on sensation and perception depicts that other perceptual processes occur after transmitting and processing sensory information at a cortical level (Privitera, 2018). This involves the brain connecting with other cortical and subcortical areas, such as the hippocampus, to access memories and the mesocorticolimbic circuitry for enjoyment (Berridge & Kringelbach, 2015; Privitera, 2018). For instance, eating texturally hard food such as a crispy potato chip or biscuit involves the anticipation of consumption (i.e. expected crunch sound) and subsequent memories, which determines whether it is a hedonic (pleasurable) or unpleasurable experience (Berridge & Kringelbach, 2015; Sakai, 2020; Spence, 2015; NIDCD, 2020).

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The English term “hedonic” is derivative from the ancient Greek word for pleasure (ἡδονή; *transl. hédoné*), which originated from the word sweet (ἡδύς, *transl. hēdús*) (Berridge & Kringelbach, 2010). Conversely, emotional food experiences are not limited to pleasantness as individuals may dislike or have unpleasant experiences with textural acoustic properties. This may include misophonia, picky eating and sensory aversions in typical and atypical individuals (Little et al., 2017). Misophonia refers to an adverse emotional reaction and dislike triggered by particular sounds such as eating, breathing and repetitive sounds (Edelstein et al., 2013). It results from heightened autonomic and limbic responses without abnormal heightening of the auditory system (Palumbo et al., 2018). Individuals with misophonia and sensory aversions may also display behavioural responses which involve avoidance or escape from trigger sounds, e.g. missing meals with family members and avoiding noisy spaces like cafeterias (Taylor, 2017).

3. Studying FTA: Proposed methods and considerations

We have proposed four subject areas that we believe undergird FTA. This section will explain how these four subject areas constitute the foundational constructs of a methodology to assess FTA in a research setting, and we will highlight the considerations (theoretical-methodological issues) related to FTA.

a. Multisensory eating: sensory masking

Firstly, it is essential to consider the multisensory nature of eating when considering the notion of FTA. To evaluate the influence of acoustic properties associated with texturally hard foods, we considered sensory masking in our pilot study (refer to Karani (2021) for further details). This involved using visual, olfactory and somatosensory masking. Participants were blindfolded (Renner et al., 2016), and a distractor scent was applied below the nose. Oudh, primarily Asian/Middle Eastern scent, was used for its potent fragrance for olfactory masking (Gafsou, 2019; Khatoon, 2019). This was selected in comparison to other olfactory maskers such as food related ones which may influence the salivary flow rate and the overall oral processing responses (Noh et al., 2017). We also used a distractor food sample as somatosensory masking. Eating texturally hard foods produces both air-conducted and bone-conducted sounds, making it necessary to deliver effective air-conduction and bone-conduction auditory masking when

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evaluating the influence of acoustic properties (i.e. in the masked auditory condition) (Christensen & Vickers, 1981; Duizer, 2001).

The intimate connection between air-conducted and bone-conducted sounds raises the methodological dilemma of dissociating the two auditory properties. This has also been noted as a methodological issue in a study by Zampini and Spence (2004) and raises the question: are individuals who have a severe hearing impairment able to perceive the crispiness of food even though they cannot hear it? This was answered by referring to Christensen and Vickers (1981), who investigated this phenomenon by giving participants an auditory block when eating different crispy foods. The results revealed that the participants did not have difficulty differentiating between crisp products due to crispy foods' vibratory and acoustic sensation (Christensen & Vickers, 1981). During the expert consultation in our previous study (Karani & Pillay, 2021), expert food scientist Duizer confirmed this phenomenon. She mentioned, "I had a Deaf student... She could perceive textures. So there is more to it than just your hearing. And I think it [air-conduction and bone-conduction] is a very complex area."

When we presented the process of our pilot study to the experts during the consultation phase, expert cognitive neuropsychologist Zampini inquired about the possibility of manipulating the bone-conducted sound (Karani & Pillay, 2021). He suggested that we modulate the level of masking (i.e. 100%, 50% and 0%). We acknowledge that this suggestion is valid and should be explored in our main study and future research.

Due to the multisensory nature of eating, isolating and assessing a specific sense may not be the most appropriate approach and may be counterproductive (Karani & Pillay, 2021). Using this type of approach adopts principles from empirical and reductionist sciences, with the "principle of separation" underpinning reductionism (i.e. an oversimplification of complex constructs) (Holst, 2020). The consultation held between Hanson (expert mechanical engineer) and Pillay (expert speech pathologist and audiologist) described issues that we understand might stem from this approach. These experts highlighted that using this reductionist approach may result in "unnatural responses". Pillay expressed the concern that isolating a sense is "artificial and sanitised that it takes away from the natural event (of eating) itself." This may risk causing the results to be "less pragmatic" and "less implementable" (Karani & Pillay, 2021). Thus, further

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research and the development of alternative methods are required to address this methodological dilemma.

b. Auditory processing responses to FTA: screening and assessment of hearing ability.

The literature clarifies that neurologically internal or body-generated sounds are processed along the same cortical and subcortical pathways as speech, music and environmental sounds, though the exact process is still unknown (Palumbo et al., 2018). We acknowledge that auditory processing is still a complicated field of inquiry. Literature dating back to the 1950s depicts that auditory processing and auditory processing disorder have been recognised as controversial areas with debates ranging from the definition, neural basis and existence as a disorder (McFarland & Cacace, 2009). The complexity of auditory processing was also highlighted by Wilson, the expert Audiologist in the focus group discussion (Karani & Pillay, 2021), “The term auditory processing has become such an umbrella term, that it means everything and nothing at the same time... It [auditory processing] is not linear or unidirectional.”

Even the theoretical formulation of auditory processing has been laden with reservations. The theoretical formulation of auditory processing involved a silo approach, such as disregarding the influence of the co-occurring visual processing in auditory processing (Cacace & McFarland, 2005). Comprehensively addressing these controversies is beyond the scope of this paper. During the previous expert consultations, Wilson emphasised the multisensory nature of eating and co-occurring processes and parameters to consider when exploring the auditory processing of FTA, such as the influence of other senses (Karani & Pillay, 2021).

Despite understanding the processes involved in processing acoustic stimuli, we should also consider how auditory deficits such as hearing impairment or auditory processing disorder may confound this process. If we were to consider the auditory processing of FTA in a research setting, in addition to central processing, we would need to pay attention to peripheral hearing. We can focus on screening and assessing an individual’s hearing ability as a measure of their peripheral hearing because we hypothesise that it would influence understanding and evaluating overall processing.

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Screening and assessment of hearing ability

When screening and assessing hearing ability, the nature of the test stimulus is vital to consider. This includes attention to the type of stimulus, frequency, intensity and duration. A variety of modalities such as conventional audiometry, special testing and electrophysiological measures can be used to assess and screen hearing ability. However, as the sound produced when biting into texturally hard food is complex, high in frequency, loud in intensity and short in duration, we propose that the stimulus signal be complex and brief, covering the narrow bandwidth and frequency range.

Screening of hearing ability

Conventional audiometry measures such as the use of otoscopic examination, tympanometry, acoustic reflex testing, and pure-tone audiometric screening (1000, 2000, 4000Hz @ 30dB) may be used (Karani, 2021). This is useful as it screens the individual's hearing ability and considers the auditory system from the outer ear to the inner ear. The high frequencies used for the pure-tone audiometric screening are also appropriate as this correlates with the frequency properties of the texturally hard foods (i.e. crispy, crunchy and crackly). According to the classification system proposed by Duizer (2001), the frequency of crispy foods range from 5000 Hz to 12 800 Hz, whilst crunchy and crackly foods have a lower frequency range of 1250 Hz to 2000 Hz. Whilst conventional audiometry measures might be helpful; we believe electrophysiological measures such as Distortion Product Otoacoustic Emission testing (DPOAE) would be a more suitable modality. This non-invasive modality is quick to conduct, and due to its objective nature, it works better for both typical and difficult-to-test populations (Hall, 2016; Soh & Chan, 2015). Like the pure-tone audiometric screening, which focuses on high frequencies, DPOAE is frequency-specific and can also be used to assess hearing sensitivity at higher frequencies than other Otoacoustic Emission measures (Soh & Chan, 2015).

In addition, the DPOAE signal possesses a short temporal property and a loud intensity similar to the brief duration of a bite and the loud property of the sounds produced when biting into the texturally hard foods (Soh & Chan, 2015). Despite the value of Otoacoustic Emission testing, this tool possesses limitations. The Otoacoustic Emissions results are sensitive to middle ear dysfunction and require a quiet setting due to their sensitivity to the level of noise in the

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environment (Ganesan et al., 2018). So, it would be helpful to include an otoscopic examination and tympanometry testing before the DPOAE testing to rule out any pathologies in the outer and middle ear (Soh & Chan, 2015).

Assessment of hearing ability

Following the screening, we require a stimulus comparable to crisp, crunch or crackle sounds to assess the auditory processing of FTA and to measure the response. Various tests such as conventional audiometry or special testing may be used and measured in-situ in auditory sciences. However, after careful research, we assert that electrophysiological measures of auditory brainstem response (ABR) may best understand the auditory processing of these complex food sounds. Despite the widespread use of click and tone burst stimuli to estimate auditory thresholds and neurodiagnostic assessments, this type of stimulus is inappropriate. Traditionally, click and tone stimuli did not account for the behaviourally relevant and complex sounds we encounter in everyday settings such as speech, environmental sounds and music (Skoe & Kraus, 2010). This led to the development of complex ABR (cABR).

We trust that cABR using the proxy stimulus of a chirp stimulus is more apt to capture a complex crunch, crisp or crackle sound and is advantageous due to its objective and non-invasive nature (Skoe & Kraus, 2010). However, the use of ABR as a measure involves a lengthy testing time and is sensitive to artefacts and alternation in the stimulus parameters (Çelik et al., 2016). This can be addressed by conducting the ABR during natural sleep. Nevertheless, cABR may be a valuable and objective tool to assess the auditory function in typical and atypical populations such as auditory processing disorder (Chandrasekaran et al., 2009; Skoe & Kraus, 2010). Careful research and consideration have resulted in these proposed auditory processing screening and assessment procedures for potential use in all populations. Aside from the auditory processing of air-conducted signals discussed, the bone-conducted signals also need to be considered, as discussed under the section of multisensory eating.

c. Swallow physiology responses: evaluating food oral processing responses

Our pilot study explored food oral processing to understand the body's response to FTA (Karani, 2021). In developing and implementing the protocols and tools, we focused specifically on understanding and measuring the parameters of the first bite, mastication and swallow (oral

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and pharyngo-oesophageal phase) in terms of force and temporal properties. If one were to design and conduct an assessment protocol to evaluate the swallow physiology responses to FTA, there are specific parameters, tools and methods that we would propose. These ten proposed parameters are based on a review of the literature of various swallow assessments (Basson, 2015; Boaden et al., 2019; Daniels & Easterling, 2017; Steele et al., 2012) and confirmed by expert consultations (L. Duizer, personal communication, August 19, 2019). We also recognise that there are numerous possible tools and methods to evaluate the swallow physiology responses. We will present our proposed tools and methods below, including references to other tools.

The Clinical Swallow Evaluation (CSE) is a commonly used method in dysphagia assessment that can assess swallow physiology. The CSE is non-invasive and low cost and time-efficient (Virvidaki et al., 2018). As CSE is a subjective measure, debate exists surrounding its use as an exclusive measure in deglutition science (Riquelme, 2015). We propose using a combination of CSE or observational swallow, with videofluoroscopic swallowing study (VFSS) and surface electromyography (sEMG) as tools and methods best suitable to explore this construct of FTA. These protocols have been modified for use in the pilot study (Karani, 2021). One can use VFSS or Fibre-Optic Endoscopic Evaluation of Swallowing (FEES) because they are both “gold-standard” and have high sensitivity and specificity (Fattori et al., 2016). However, we believe that VFSS is more applicable in this case as it can be used to assess swallow parameters in real-time, and the data can also be saved and reviewed later for further analysis. Despite the costly nature, exposure to radiation and time involved, VFSS provides information regarding structural and temporal data of all three swallow phases. We further suggest using sEMG in combination with and during VFSS given that it measures muscle activity associated with swallowing and augments the temporal data with force data (i.e. mastication and swallow) (Beckmann et al., 2015; Steele et al., 2012). The use of FEES may cause discomfort and requires a topical anaesthetic or nasal spray that might not agree with some individuals (Miller & Willging, 2020). FEES is additionally tool not encouraged as it does not cover the oral processing responses in their entirety by missing out on the oral phase, which is crucial to consider for the construct of FTA.

The preliminary results from the pilot study indicate that acoustic properties associated with texturally hard food may play a role in the swallow responses (Karani, 2021). There were

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significant differences noted with the first bite force, mastication force, mylohyoid force, and duration of palatal elevation for the texturally hard food samples compared to the soft food samples. Participants also required less force and shorter duration for the first bite, mastication and swallowing when hearing the food acoustic properties (unmasked), with an increase in the values of these parameters recorded when the acoustic properties were absent (masked) (Karani, 2021). This may depict a potential link between auditory processing responses and food oral processing responses to FTA. Despite the results revealing differences between the masked and unmasked conditions, no statistically significant differences were shown when hypothesis testing was conducted. However, this was not the aim of the pilot study (Karani, 2021).

It is essential to note that foods traditionally used during VFSS evaluations cannot be used to assess the discreet oral processing responses to FTA. Foods selected and/or developed must have robust textural and acoustic properties of crispiness, crunchiness and/or crackliness, which occur along a spectrum (Duizer, 2001; Vickers, 1983, 1985). We also recommend that a reference point food sample be used to note the responses and changes resulting from textural and acoustic properties. The International Diet Standardisation Initiative (IDDSI, 2019) guidelines are suggested to ensure uniformity of food samples between trials and safety during consumption. In our pilot study, we developed and selected a reference point food sample - IDDSI Level 6 (soft and bite-sized) and three commercially available or self-developed IDDSI Level 7 (regular and easy to chew) food samples (i.e. toast, potato chips and biscuit) (Karani, 2021). We coated the food samples with barium sulphate made into a paste using water according to the guidelines by Steele (Swallowing Rehabilitation Research Lab, 2020). This was done to ensure that the food samples retained their textural and associated acoustic properties.

These parameters, tools and methods proposed above provide a starting point to understand the oral processing responses to FTA. As physiological and perceptual processes (i.e. pleasure or displeasure responses) are involved and interact with each other when eating, the evaluation of these perceptual responses will be elaborated on below.

d. Perceptual responses: hedonic responses

Individual perceptual responses can be evaluated using several methods such as food science scales, perceptual questionnaires and trained sensory panels (Cardello, 2017; Kwak & Lee, 2016; Sharma et al., 2017). In our previous study, we used a two-point scale of “like” or

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“dislike”, and participants were required to provide a brief motivation for their choice regarding hedonic responses to food samples. All participants in our pilot study indicated that they “like” hearing the bite sound of the texturally hard food samples and referred to it as “flavourful”, “more enjoyable”, and “more interesting”. During one of our expert consultations, the Spanish chef and sommelier Centelles promoted the use of acoustic properties when creating dishes. He has confidence that food acoustics “enhances” the dish, “adds another dimension”, “flavours get more intense”, is “something magical”, and described the experience of eating foods with acoustic properties as “it does the boom on your palate”. This notion of “adds another dimension” is worth exploring in future studies. The findings of the earlier studies by Karani (2021) and Karani and Pillay (2021) correlate with the literature that depicts the hedonic response to food acoustics with regards to pleasure, experience and enjoyment (Spence 2015, 2017; Tunick et al., 2013). However, as perceptual responses include more than hedonic responses, such as enjoyment and pleasure, future studies should expand on this by evaluating the perceived sensory properties of the food samples (i.e. intensity of crispiness). Future studies should consider collating the results of the perceived sensory properties with the respective hedonic responses, in order to provide a justification for the hedonic responses noted.

In addition to hedonic responses to FTA, our pilot study evaluated the participants’ perceived swallow responses to FTA. This focused on their perceived bite force (first bite), mastication force and duration, and swallow force by rating them on a 3-point ordinal scale (more effort/duration, less effort/duration, or the same effort/duration). In the presence of food acoustic properties, most of the participants perceived their first bite, mastication and swallowing force and duration required less force and/or was of shorter duration. These results correlate with the results from the swallow physiological responses. In future studies, the perceived sensory properties of the food, such as the intensity of the crispiness, should also be considered as this may explain the perceived and objective swallow responses that were noted.

There also exists cultural-linguistic diversity in the perception of food (Karani & Pillay, 2021). For instance, there are linguistic variations or a complete lack of terms that individuals use to describe crispy, crunchy and crackly foods (Spence, 2015). For example, Italians only possess a single word, “croccante”, to classify crispy and crunchy foods (Spence, 2015). Similar findings were also noted in our pilot study. The majority of our participants reported no terms in their first

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language, which were predominantly English and African languages (i.e. isiZulu, isiXhosa, isiNdebele and Sesotho), to refer to and differentiate between the different texturally hard food samples (Karani, 2021). This was an important finding that needs further exploration as it may influence dysphagia management due to difficulties in standardisation.

Having comprehensively discussed the proposed methods and considerations when studying the four subject areas underlying FTA, the following sub-section will explore the potential clinical utility of FTA in dysphagia rehabilitation regarding IDDSI transitional foods.

4. The potential influence of FTA in swallowing and dysphagia management

We propose an additional perspective in deglutition sciences by considering FTA and its potential influence for adults with dysphagia. Individuals with dysphagia require optimal food texture to prevent life-threatening aspiration risks and malnutrition due to limited food intake (Cichero, 2020). As a result, we turn to the use of IDDSI transitional foods and other novel methods. The potential clinical utility of these methods may involve swallow safety, enhanced texture perception, positive hedonic responses, improved quality of life and potential therapeutic outcomes.

4.1. IDDSI Transitional foods

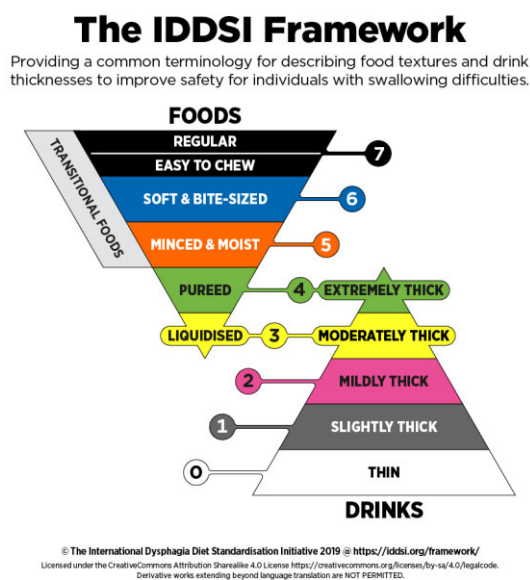
Transitional foods, also known as solid meltable foods, are foods that on contact with body temperature or moisture, swiftly melt to become easier to chew and swallow (Cichero et al., 2017). These foods may include ice chips, wafers, ice cream and shortbread biscuits (Cichero, 2020). The inclusion of transitional foods as part of the IDDSI framework was prompted by clinicians who specifically work with children and those with developmental disorders (Barewal et al., 2020). These transitional foods have been classified by IDDSI guidelines as Level 5-7 (minced and moist to regular), suggesting that these foods are hard in texture and soften with the moisture and heat in the oral cavity (see Figure 3 <https://iddsi.org/framework>). Studies by Gisel (1991) and Dovey et al. (2013) have portrayed the benefit of transitional foods in the paediatric population, specifically those with less mature or underdeveloped sensorimotor systems for mastication. This is encouraging for the potential use in the adult population with dysphagia. A recent study by Barewal et al. (2020) aimed to understand the extent of the breakdown of five transitional foods. The results revealed that using these transitional foods might be beneficial for

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improving masticatory muscle strength and cognition for individuals with dysphagia (Weijenberg et al., 2011). However, due to insufficient research available on the behavioural properties and oral processing of these transitional foods, there is a call for further research (Barewal et al., 2020).

Figure 3.

International Dysphagia Diet Standardisation Initiative (IDDSI) Framework



Note. © The International Dysphagia Diet Standardisation Initiative 2019 Note.

@ <https://iddsi.org/framework/> licensed under the Creative Commons Attribution Sharealike 4.0 License <https://creativecommons.org/licenses/by-sa/4.0/legalcode>. Derivative works extending beyond language translation are NOT PERMITTED.

We propose that “up-modifications” be used in dysphagia management through promoting the use of transitional foods. This involves transitioning an individual with dysphagia from a Level 4 (pureed) “up” to a Level 6 (soft and bite-sized) on the IDDSI framework (refer to Pillay (2013) for further explanation). This will allow the individual with dysphagia to consume texturally hard foods upon initial contact and produce associated acoustic properties such as crispy, crunchy or crackly sounds during the first bite. Following the first bite, these foods will transition to become safer to swallow given their prescribed IDDSI level. Based on the

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preliminary results noted in our pilot study that depicts that texturally hard foods play a role in texture perception (Karani, 2021), we anticipate the safety and hedonic response of these textural acoustic properties in transitional foods. Thus, these foods may provide a therapeutic benefit. The preliminary data also showed that acoustic properties of texturally hard foods influence the swallow responses, specifically by reducing the force and duration of the first bite, mastication and swallow (Karani, 2021). This may be particularly useful for individuals with dysphagia who present with weakness of the oral and pharyngeal muscles for mastication and swallowing, making it easier and safer to consume food. A main study is proposed in the future to validate these results. We also aim to explore the influence of transitional foods on physiological swallow responses, specifically its food oral processing responses.

4.2. Alternative methods to consider

During our expert consultations, Hanson (expert mechanical engineer) suggested an alternative way of incorporating the benefits of acoustic properties for individuals with dysphagia. He proposed investigating the possibility of applying auditory cues of an IDDSI Level 7 food (i.e. incorporating the sounds of hard or crunchier foods) without the harder textures. This refers to foods that are soft and safer for consumption based on the individual's IDDSI recommendations but possess the auditory cues of harder food such as an IDDSI Level 7 food (e.g. melt in the mouth potato chips). Hanson expressed that this suggestion may be an interesting way to try and enhance the auditory side of the response without affecting the food mechanics. He further explored this suggestion by stating, "Try enhancing the natural sounds... If there is a way to provide biofeedback to enhance those crunching sounds [of these foods] ... using a microphone and an amplifier... or a hearing aid [for those who are hearing impaired]."

Studies by Endo et al. (2016, 2017) have investigated the above suggestion by evaluating the influence of altered auditory feedback of chewing sounds ("pseudo-chewing sounds") on the perception of food texture. The results revealed that the altered auditory feedback had a positive influence on the perception of food texture, palatability and taste of the soft nursing food (i.e. perceived as stiff and rougher), even in the absence of the actual oral sensation of a texturally hard food. This is explained by reference to the principle of cross-modal integration (i.e. the association or interaction between senses) (Ernst & Bühlhoff, 2004; Prescott, 2015). With regards

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to physiological responses, the pseudo-mastication sound showed no effect on mastication intensity and rhythm.

Similar to Hanson's suggestion, modifying and enhancing the auditory cues while providing soft food may be a potentially helpful technique for individuals with dysphagia. We also believe that it may be a way to improve texture perception, overall quality of life and hedonic responses to texture-modified foods for individuals with dysphagia while ensuring swallow safety. However, we believe that IDDSI transitional foods may be a better strategy than introducing auditory cues while eating as a way to improve food intake of individuals with dysphagia. Despite both strategies offering swallow safety and positive hedonic responses, IDDSI transitional foods may influence the oral processing responses and affect the overall swallow mechanism. This is due to the actual hard textural properties possessed by IDDSI transitional foods, specifically during the first bite, which makes them more visually and acoustically appealing to be consumed. These suggestions that promote food acoustic properties, both through the use of IDDSI transitional foods and the introduction of auditory cues, should be explored further as potential methods in dysphagia rehabilitation.

5. Conclusion

This paper has provided a theoretical basis for the need to consider FTA in deglutition sciences based on the results from the other three components of the broader study. We have proposed four subject areas undergirding FTA: (a) multisensory eating, (b) auditory processing responses, (c) swallow physiology responses, and (d) perceptual responses – to FTA, and methods and considerations when studying FTA. Through our research, we propose the importance of considering FTA in dysphagia management, such as the use of IDDSI transitional foods and other novel methods. In addition to the safety and hedonic response to these IDSSI transitional foods, dysphagia practitioners need to ensure that these foods address the food security and sovereignty challenges. Furthermore, these foods should be accessible, affordable and culturally appropriate for individuals with dysphagia from diverse contexts. As the construct of FTA is still in the preliminary stages of research in the field, there are still gaps present. Therefore, we are inviting your thoughts and calling for future research to develop further and refine the construct of FTA. We anticipate that this paper will generate further inquiry and research into FTA and its potential use in global dysphagia practices.

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Declaration of interest statement

The authors report no declarations of interest.

Author's contributions

T.K and M.P conceptualised the paper. T.K drafted the paper as part of her doctoral study under the supervision of M.P. The findings presented in this study were based on T.K and M.P's previous studies. Both researchers reviewed and approved the final paper.

Ethical considerations

N/A

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Data availability statement

No new data was produced for this study.

Disclaimer

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Learning outcomes:

1. The reader will be able to describe the four proposed subject areas undergirding food textural acoustics.
2. The reader will be able to describe and discuss optimal methods to be employed when researching food textural acoustics.
3. The reader will be able to understand the potential connection between food textural acoustics, swallowing, and dysphagia (swallowing disorders).

Appendix A: Table with the review findings on the swallow responses to various sensory modalities

<i>Type of sensory modality</i>	<i>Source</i>
1. Visual/ visual biofeedback (3)	(Humbert & Joel, 2012; Kawai et al., 2009; Kober et al., 2019)
2. Olfactory (5)	(Ebihara et al., 2006; Munakata et al., 2008; Wahab et al., 2010, 2011; Welge-Lusse et al., 2009;
3. Gustatory (8) (i.e. Sour, sweet)	(Babaei et al., 2010; Chee et al., 2005; Kajii et al., 2002; Leow et al., 2007; Mistry et al., 2006; Miyaoka et al., 2006; Nagy et al., 2014; Pelletier & Steele, 2014)
4. Tactile/somatosensory (24)	
- <i>Bolus volume (3)</i>	(Ergun, & Facchini, 1993; Kahrilas et al., 1996; Kahrilas & Logemann, 1993)
- <i>Texture and viscosity (9)</i>	(Barewal et al., 2020; Cichero et al., 2013; Cichero et al. 2017; Cichero, 2018; Cichero, 2020; de Villiers et al., 2018; Lazarus et al., 1993; Steele et al., 2015; Swan et al., 2015)
- <i>Thermal (3)</i>	(Chi-Fishman et al., 1994; Kaatzke-McDonald et al., 1996; Kawamura et al., 2004)
- <i>Carbonated (5)</i>	(Bülow, Olsson, & Ekberg, 2003; Loret, 2015; Michou et al., 2012; Miura et al., 2009; Sdravou et al., 2012)
- <i>Electrical (4)</i>	(Barkmeier et al., 2000; Fraser et al., 2002; Humbert et al., 2006; Yamamura et al., 2010).

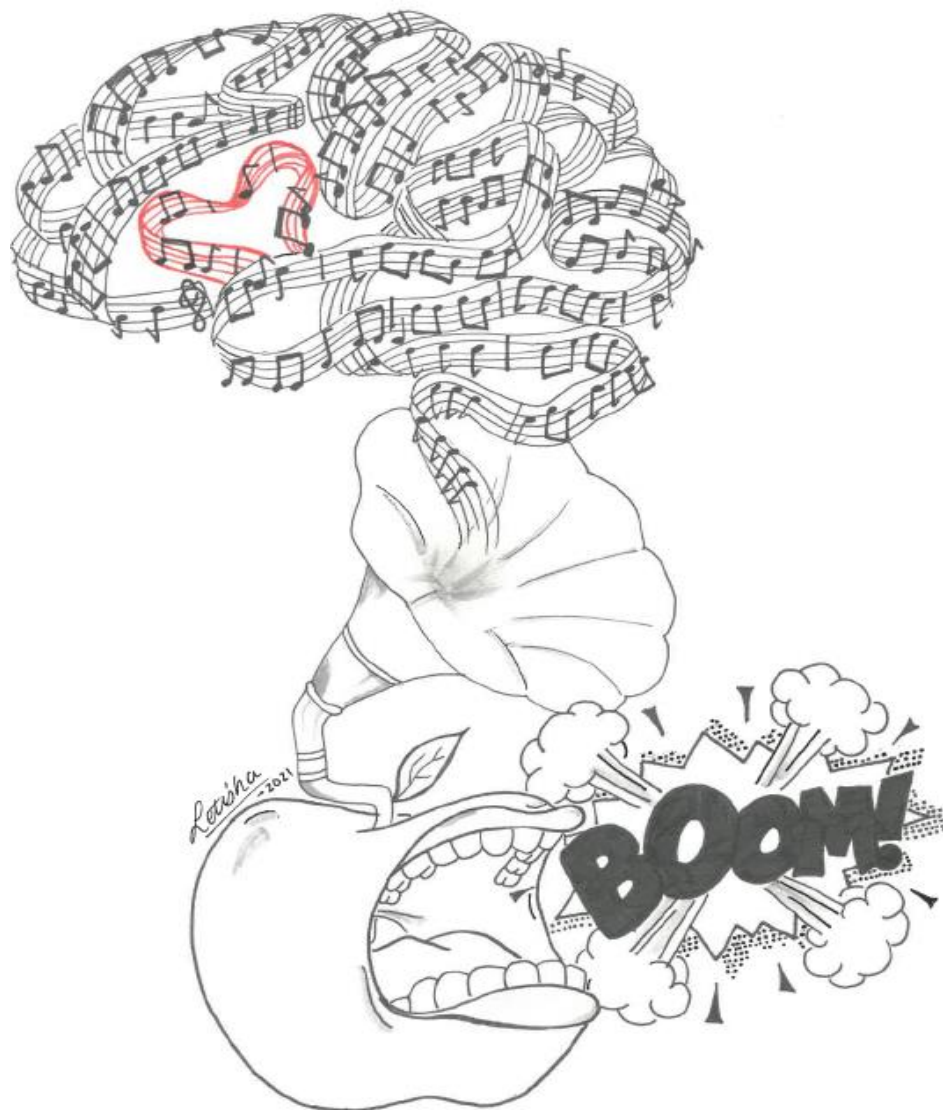
5. Auditory (0)

/

Note. The search was restricted to the first 40 applicable references located.

Supplementary material 1: Illustration: Listen to the crunch, it makes my brain go boom!

(Latchman, 2021)



Note. Description of supplementary material 1: Illustration done by Ms Letisha Latchman, a colleague of the first author. It provides an overall depiction of our study on food textural acoustics in the form of a sketch.

From bottom to top:

- *Apple mouth:* Mouth in the shape of a bitten apple to express food oral processing and the properties of the food being studied (i.e. texturally hard foods that are crispy, crunchy and/or crackly)
- *“Boom!”* Explosion of sounds produced when biting into texturally hard foods- like “boom on your palate.”
- *Music horn/trumpet:* Depicts the ear and the salience of acoustic stimuli (“amplified”), and how sound is transmitted to the brain for processing
- *Musical notes shaped like a human brain, with a heart at the centre:* Potential physiological responses to food textural acoustic sounds. The heart depicts the notion that food sounds are like music to the ears/brain- pleasurable and enjoyable

.....

END OF PAPER

4.6. Summary of the chapter

This paper has provided the theoretical basis for the need to consider food textural acoustics in deglutition sciences based on the results from the other three components of the broader study. This paper has proposed four subject areas undergirding food textural acoustics; (a) multisensory eating, (b) auditory processing responses, (c) swallow physiology responses, and (d) perceptual responses – to food textural acoustics and methods and considerations when studying food textural acoustics. This research invites further research and points to the potential importance of the use of food textural acoustics in dysphagia management.

Despite the extensive exploration of the influence of the construct of food textural acoustics on the swallow mechanism across the four components of the study, the word “potential” has been carefully selected to depict the tentative nature of the construct of food textural acoustics for dysphagia. However, given the pilot results, revised scoping review, and expert consultations, the construct of food textural acoustics possesses the potential to be important for the field of dysphagia. Similar to cognitive neuropsychology, this study uses the assumption that understanding typical development or processes will inform our understanding of atypical processes and vice-versa. This study explored typical swallow responses to apply the research to individuals with dysphagia (swallowing disorders) (Carmazza & Coltheart, 2006; Graham & Madigan, 2016). Table 1 below presents a summary of the research (“illuminators”) that currently exist in the field of dysphagia and a corresponding link to the potential value of food textural acoustics for the field.

Table 1.

Summary of Key Illuminators for the Field of Dysphagia and the Link to the Potential Value of Food Textural Acoustics

Illuminators for the field of dysphagia	Potential value of food textural acoustics
Benefit of transitional foods noted in the paediatric population, especially those with less mature sensorimotor systems for mastication (Dovey et al., 2013; Gisel, 1991).	Use of “up-modifications” (i.e. moving from a lower Level 4 to Level 6 on the International Dysphagia Diet Standardisation Initiative (IDDSI) framework) through suggesting transitional foods such as <i>Savorease</i> and the <i>EAT-Bar</i> (Barewal et al., 2020). This promotes safety and hedonic response to these textural acoustic properties and potential therapeutic benefit for adults with dysphagia (masticatory muscle strength and cognition) (Barewal et al., 2020; Weijenberg et al., 2011).
Studies by Endo et al. (2016, 2017) regarding the positive influence of altered auditory feedback of chewing sounds on the perception of food texture	Modify and enhance the auditory cues while providing soft food. This can improve texture perception, overall quality of life and hedonic responses to texture-modified foods for individuals with dysphagia while ensuring swallow safety.

4.7. Conclusion

The paper presented in this chapter explores the utility of the construct of food textural acoustics for dysphagia research and practice. First, this paper presented the theoretical basis for studying food textural acoustics regarding the other three components of the larger study. The consideration of food textural acoustics for dysphagia management appears to be promising; however, further research is required. The next chapter will present the synthesis of the study, critique, implications and recommendations for future research.

CHAPTER FIVE: CONCLUSION

5.1. Introduction to chapter

This final chapter will provide a summary, critique and overall conclusion to this doctoral study. This chapter will make specific reference to the study aim and objectives set out in the first chapter and discusses the respective significant findings. Following this, the chapter will critique and discuss the novelty of the study. Finally, this chapter will discuss the potential implications of this study for research and practice and recommendations for future research.

5.2. Alignment of the doctoral dissertation with the study aim and objectives

The overarching aim of the study was to explore the influence of food textural acoustics on swallow responses. Like other fields of inquiry, such as cognitive neuropsychology that uses the assumption that understanding typical development or processes will inform the understanding of atypical processes, and vice-versa, this study explored typical swallow responses to apply the research to individuals with dysphagia (swallowing disorders) (Carmazza & Coltheart, 2006; Graham & Madigan, 2016). Across the three papers, this study evaluated three main objectives.

5.2.1. Paper one (*objective one*)

Objective one, which was to develop and test protocols and tools to evaluate the influence of food textural acoustics on swallow responses in healthy adults, this was achieved using a pilot study with eight healthy adults. This study employed a descriptive-analytical design with mixed methods. The pilot study developed and tested four protocols and tools to evaluate the influence of acoustic properties associated with texturally hard foods on the physiological and perceptual swallow responses. The preliminary results based on piloting these four protocols and tools show that acoustic properties associated with texturally hard foods influence the swallow responses, specifically by reducing the force needed and duration of the first bite, mastication and swallowing. The results also revealed that acoustic properties of texturally hard foods play a role in texture perception and leads to positive hedonic responses. Based on the evaluation of the pilot study, the researcher proposed the implementation of the main study with larger sample size and minor amendments to the study protocols and tools. A plan to conduct the main study was the next step; however, due to COVID-19, this was not possible and halted the

main study for future implementation. Despite this disruption, COVID-19 provided an opportunity to rethink the conceptual basis of the construct of food textural acoustics by conducting the exploration of the sensibility of the construct (i.e. objective two of the study).

5.2.2. Paper two (objective two)

The published paper interrogated the study's second objective by investigating the sensibility of food textural acoustics as a construct to understand eating for individuals with dysphagia using qualitative evidence synthesis methodologies. This published paper employed rigorous revised scoping review across the fields and an adapted consultation phase with six world experts. The findings illustrated the lack of diversity, geography and discipline exploring this construct. Nevertheless, based on the literature and views from world experts and given the salience of food textural acoustics and its associated hedonic responses, food textural acoustics may be a sensible construct to understand eating for individuals with dysphagia.

5.2.3. Paper three (objective three)

The second objective revealed the potential sensibility of the construct of food textural acoustics to understand eating for individuals with dysphagia. The first objective provided a pilot study with proposed protocols and tools to evaluate the influence of acoustic properties associated with texturally hard foods on swallow responses. As a result, to create a link between the three papers of the study, the third objective set out to propose a theoretical basis for studying the construct of food textural acoustics for dysphagia rehabilitation based on data from the pilot study and qualitative evidence synthesis methodology (i.e. paper one and paper two). Given that this study of the construct of food textural acoustics is novel and presents preliminary research in the field, the purpose of this paper was to propose subject areas undergirding food textural acoustics. This paper was presented as a tutorial and synthesised the findings from the two previous papers. This tutorial proposed four subject areas undergirding food textural acoustics; (a) multisensory eating, (b) auditory processing responses, (c) swallow physiology responses, and (d) perceptual responses – to food textural acoustics. This tutorial further discussed the methods and considerations when studying food textural acoustics. It concluded by proposing an additional perspective in deglutition sciences by discussing the potential utility and importance of food textural acoustics for adults with dysphagia to fulfil the study's primary aim. This chapter will further discuss these significant findings.

5.3. Main findings

Several findings emerged from the study; however, this section will elaborate on three significant findings.

5.3.1. Acoustic properties are salient

Despite the common reference to sound as the “forgotten flavour sense”, this study highlighted the importance of the acoustic sense (Spence, 2015). In the pilot study, the theme of “Trying to dissect whatever was in my mouth” emerged. Based on the participants’ perceptual swallow responses, food acoustics are found to influence texture perception. For instance, during the masked condition, it was challenging for the participants to identify the texture and type of food sample presented. The participants articulated, “I chewed with more effort trying to dissect whatever was in my mouth” and “It was like the food took longer to go down [...] [it] felt thick and mushy”. The published literature also revealed studies that confirmed that when the acoustic properties of the food were modified and the texture unchanged, participants expressed that the auditory information was more important as it influenced their oral somatosensation (i.e. perceiving the foods as harder or more crispy) (Spence & Zampini, 2006; Masuda & Okajima, 2011). Zampini (expert neuropsychologist) also emphasised the significance of acoustic properties in the consultation phase and expressed that acoustics is a “relevant part of the flavour experience.” This finding makes it necessary to consider the influence of acoustics on eating, focusing on flavour experience and texture perception and its potential application for individuals with dysphagia.

5.3.2. “Boom” on your palate: Hedonic responses to food textural acoustics

Another core study finding that emerged from the published literature, expert consultations, and pilot study results is the hedonic response to food textural acoustics. Evolutionarily, the acoustic properties of food signified freshness, pleasantness and enjoyment (Spence, 2015; Tunick et al., 2013; Vickers, 1983). In the pilot study, all the participants also indicated that they “like/d” hearing the bite sound of the texturally hard food samples and referred to it as being more “flavourful”, “enjoyable”, and “interesting”. Experts also expressed the hedonic response to food textural acoustics in the consultation phase, predominantly the chef who believed that acoustics “enhances” the dish and “adds another dimension”. These sentiments

all illustrate that hedonic responses are associated with food textural acoustics. Hedonic responses to foods need to be accounted for in dysphagia management by considering premorbid preferences given that food palatability increases food intake, appetite, and overall nutrition (McCrickerd & Forde, 2016; Endo et al., 2017).

5.3.3. Complexity of eating: Methodological dilemmas of studying food acoustics

Eating is a complex experience as it is multisensory and cross-modal (Spence, 2017, 2020). Therefore, multisensory eating was a vital tenet to foreground as it influenced the study of the construct of food acoustics. Both papers one and two expressed this finding. Experts in the focus group discussions and the exploration of the published literature reported that this complexity of eating poses a methodological dilemma (referred to as measurement texture-lemma) of measuring a specific sense like acoustics. In the pilot study, the researcher conducted sensory masking of the various senses (visual, olfactory, somatosensory, and auditory masking) to account for the multisensory nature of eating. This allowed the isolation of the auditory sense to evaluate its influence. In addition, both papers noted the complexity of auditory processing. This made it necessary to deliver effective air-conduction and bone-conduction auditory masking when evaluating the influence of acoustic properties during the masked condition in the pilot study (Christensen & Vickers, 1981; Duizer, 2001). Despite acknowledging the complexity of eating, studies have adopted empirical science and reductionist approaches to evaluate the auditory sense by isolating it. This study has also adopted this approach. However, paper two revealed that although this approach may be of value, it may be counterproductive. Therefore, there is a need to rethink this method when studying the construct of food textural acoustics.

5.4. Dissemination of study findings

The findings of this study have been disseminated through various mediums. The study findings have been presented as oral, poster and panel presentations at national and international conferences (see research outputs before chapter one). These presentations have generated extensive discussion between dysphagia researchers and practitioners. This study has also produced three papers, one published and two currently under review with peer-reviewed journals. The published paper in chapter three has also been sent to the study's research participants (i.e. world experts from various fields). Some of these experts have sent positive responses to the published paper. The published paper has also been posted on social networking

accounts such as ResearchGate, LinkedIn and Twitter to increase readability and reach. There are plans to further disseminate the findings through workshops with dysphagia practitioners and the public at local communities to ensure that the research is incorporated into practice.

5.5. Critique of the study

Despite the strengths of this study, there are several limitations throughout the individual papers. Therefore, this section provides the main critiques of the study concerning the theoretical, methodological and contextual limitations and weaknesses.

5.5.1. Theoretical limitations

One can concede that a significant theoretical limitation of this study is the approach adopted by artificially attempting to isolate and study the acoustic properties of food separately other sensory components. This approach may be contrary to multisensory eating and the principles of cross-modality. This approach also minimises the overall complexity of the construct. The consultation with the experts further emphasised this point as a limitation. The experts believed that isolating a specific sense “creates artifice responses” and is “artificial and sanitised that it [isolating a sense] takes away from the natural event [of eating] itself.” However, this study has chosen to privilege the acoustic properties of food above other senses as the literature has highlighted acoustic salience. Literature has documented the positive influence of food acoustics on behaviour and perception across psychology, gastronomical sciences and marketing (Demattè et al., 2014; Zampini & Spence, 2004, 2005, 2010; Carvalho et al., 2016; Kantono et al. 2016; Trautmann et al., 2017; Spence, 2015, 2016, 2017). During the expert consultations, Pillay (expert speech pathologist and audiologist) explained that he believes that the challenge in measuring the construct “comes from the methodology we use, the science we use.” This method of isolating the acoustic sense was used in this study. However, it is essential to acknowledge this blind spot and rethink the paradigm when studying this construct in the future.

5.5.2. Methodological limitations

As outlined in chapter one, the very choice of the study design being exploratory may be considered a limitation of this study. However, due to the novelty of this study, an exploratory study design was utilised to comprehensively explore the phenomenon of food textural acoustics and its concepts. Exploratory study designs gain insights for research that is still preliminary to

formulate questions, develop hypotheses, or clarify concepts (Hallingberg et al., 2018). The pilot study methodology such as the methods and the protocols and tools developed and tested (i.e. highlighted as study limitations in chapter two) may also be critiqued given the novelty of the area of study. The pilot study attempted to counteract this critique by using standardised protocols that were adapted to assess swallowing. However, adapting these protocols may have caused a possible concern regarding reliability and validity. The scoping review and consultation phase methodology was also revised and adapted to ensure that the methods best suited the study and its objective. It is necessary to note that these papers ensured that these adaptations to the methodology and standardised protocols were overtly presented.

5.5.3. Contextual limitations

A limitation of the pilot study is the small sample size with females only to evaluate the influence of food acoustics on swallow responses. The inclusion of only females may have influenced the results obtained as it did not account for the gender variable, limiting the generalisation of study findings. Nevertheless, given that the field of deglutition sciences has not sufficiently explored this phenomenon, the purpose of the pilot study was not solely focused on the study findings and significance but to assess the feasibility of the construct, methods and tools developed for use in the main study (Thabane et al., 2010; Doody & Doody, 2015). Thus, this concern may be viewed as acceptable. The main study aims to include both females and males to improve generalisation.

5.6. Novelty and significance of the study

The main criterion of a doctoral study is the novelty and significance of the work to contribute to the specific discipline/s. This section will discuss the theoretical, methodological and contextual novelty and significance of the study.

5.6.1. Theoretical significance

This doctoral study has addressed a clear gap noted in the literature across psychology, gastronomical sciences and deglutition sciences regarding the exploration of food acoustics on physiological responses. This study has shown its novelty by being the first study in deglutition sciences to explore the influence of food textural acoustics and its potential link to dysphagia. Hence, this study represents an epistemological shift by encouraging dysphagia practitioners and

researchers to rethink the value of acoustics in the field of dysphagia. The approach used in this study also considered concepts from disparate fields and areas of inquiry (i.e. speech pathology, gastronomical sciences and the multisensory eating frameworks, food oral processing from oral physiology, cognitive neuropsychology, auditory processing in audiology, and food science), and perspectives from a variety of world experts regarding the construct of food textural acoustics. This study aimed to merge numerous fields of speech therapy and audiology, cognitive neuropsychology, gastronomical sciences, food science, and nutrition and dietetics to better understand and apply this construct. This novel study comprehensively explored this construct and proposed subject areas undergirding the construct and methods and considerations when further studying it. Informed thoughts and research influence practice. The study has shown that exploring food textural acoustics may offer a way to reimagine dysphagia practice.

5.6.2. Methodological significance

Data collection and data analysis methods

This study represents a new area of inquiry and is the first of its kind in the field of dysphagia. This study also used disparate and innovative methodologies and perspectives due to the different theoretical and contextual stances adopted. Firstly, this study presents novel self-developed protocols and tools using mixed methods of implementation to evaluate the influence of food textural acoustics on swallow responses. This study incorporated various quantitative and qualitative data collection and analysis methods to promote triangulation and improve the studies' overall trustworthiness. Pilot studies were conducted for the first two papers to improve the study's validity and reliability and establish credibility.

Approach and paradigm

A paradigm is a set of basic beliefs and a principal perspective which informs the ontological, epistemological and methodological assumptions to guide a specific approach to research (Guba & Lincoln, 1994; Labonte and Robertson, 1996). The interrogative framework by Guba and Lincoln (1994) acknowledges three major assumptions; ontological, epistemological and methodological. Ontology refers to the nature of reality. Realities are subjective as they are shaped by social, political, cultural and economic values (Guba & Lincoln, 1994; Parahoo, 2014). Epistemology is one's truth basis and is understood as to how knowledge is created and

communicated (Denzin & Lincoln, 2017). Finally, the methodological assumption represents the research strategies used by researchers to confirm what they believe can be known (Denzin & Lincoln, 2017). This chapter will refer to these three assumptions to discuss the underpinnings of this study.

Traditionally, a positivistic paradigm (“realism”) that uses quantitative studies has undergirded healthcare research and practice (Pillay & Kathard, 2018). However, this study used a different approach by adopting a hermeneutic paradigm to explore food textural acoustics. Hermeneutic or constructivist paradigms facilitate knowledge creation using the interaction between the investigator and respondents and acknowledge multiple realities (Guba & Lincoln, 1994; Pillay & Kathard, 2018). For instance, the expert consultations established perspectives that depicted a plurality of viewpoints from six world experts across the fields of speech therapy and audiology, food science, cognitive neuropsychology, mechanical engineering and gastronomical sciences, and fully acknowledged that subjectivities exist. Furthermore, this type of methodology encompassed critical conversations with world experts to engage their ontological and epistemological viewpoints (i.e. their nature of truth and reality). This produced data that embraced various perspectives.

The expert consultations also employed the notion of memesis (Dawkins, 1977; Wilkins, 1998; Tyler, 2011; Castaño Díaz, 2013). Essentially, this notion of memetics explored the genesis of the construct of food textural acoustics across time and space and explored how it entered and passed on across several fields of study (Brodie, 2009; Castaño Díaz, 2013). Despite the experts’ profession and the disparities presented, all truths and views were accepted and valued. The researcher made no judgments regarding the superiority of one perspective over the other (e.g. chef versus the scientist). Chef Centelles’ opinion regarding food textural acoustics was purely intuitive based on his area of practice as a sommelier and chef.

Conversely, Zampini (expert cognitive neuropsychologist) used more empirical-based ideologies to justify his views on the topic, specifically regarding studying the construct of food textural acoustics. Nevertheless, both these viewpoints and biases are accepted and celebrated. This hermeneutic approach has provided a more holistic understanding of the construct of food textural acoustics and promotes the need to conceptualise alternative methods of researching this construct.

This study also used endoscopic theorising by using principles and theoretical frameworks from other fields such as cognitive psychologies to understand this notion of food textural acoustics. As a result, I acknowledge that despite its significance, this can be contested. There is an acknowledgement that cognitive neurosciences has failed and is failing (Coltheart, 2017). For instance, when considering western cognitive neuroscience, this field explains sensory processing in a particular way that has a strong tradition in dividing the sensory system mainly into five senses (Foley & Bates, 2019). However, apart from extrasensory, there is also the construct of cross-modality or synaesthesia (i.e. the association or interaction between senses) (Alais & Burr, 2004; Prescott, 2015). Cognitive neuropsychology recognises these complexities and cross-modality of eating and argues for sensory pluralism (Fulkerson, 2014). Pluralism is the view that various forms of sensory interactions exist (i.e. cross-modal, multisensory, multimodal) (Fulkerson, 2014). This study has borrowed from this field and considered this notion of pluralism.

Conversely to empirical bottom-up perspectives that upholds a reductionist approach and does not account for multifaceted factors, this study has chosen to use cognitive neuropsychology principles as it perpetuates a top-down perspective. This perspective is holistic and considers higher-order processing and the additional interaction of expectation, culture, linguistics and memory in eating, and the primal enjoyment of texturally hard foods (Spence, 2015; Santeramo et al., 2018; Tey et al., 2019; Dantec et al., 2020; Piqueras-Fiszman, 2020). These interactions have been explored in the study and are particularly necessary to consider to provide a more holistic perspective of eating, especially for individuals with dysphagia.

5.6.2. Contextual significance

The global north perspective has dominated the field of dysphagia. This involves promoting assessment and management measures such as videofluoroscopic swallowing study and fibre-optic endoscopic evaluation of swallowing. However, this makes it challenging for dysphagia practitioners in the global south to adopt these assessment and management measures due to their social and economic challenges. As the THRIVE framework undergirds this study, it aims to address these concerns and inspires to reimagine global dysphagia practices through novel methods such as food textural acoustics. This study proposes re-aligning the lens from the practitioner and resources to the food provided to individuals with dysphagia to account for

global food security and food sovereignty issues. This involves a transformation of dysphagia diets through investing in the sensory aspects of diet textural modifications and conceptualising more sensory responsive foods. These foods should consider the multisensory nature of eating and include textural and associated acoustic properties such as crispy, crunchy and crackly. Through this, context is foregrounded to improve global dysphagia practices.

5.7. Potential implications for research and practice

5.7.1. Research

This foundational study may pose several implications for dysphagia research and practice. Firstly, this study presents valuable information by introducing the construct of food textural acoustics and its potential for dysphagia practice. Second, this study emphasises auditory salience through the preliminary findings to offer a robust epistemological shift by proposing a theoretical basis for studying food textural acoustics. The preliminary findings portray that food acoustics associated with texturally hard foods influence the swallow responses, specifically by reducing the force needed and duration of the first bite, mastication and swallowing. The results further revealed that acoustic properties of texturally hard foods are salient and play a role in texture perception leading to positive hedonic responses. This study also proposes four undergirding subject areas and discusses methods and considerations when further studying the construct. As the construct of food textural acoustics is preliminary research in the field, gaps are still present. As a result, the study concludes by inviting and calling for thoughts and future research from researchers and practitioners to further develop and refine the construct for potential use in dysphagia practice.

5.7.2. Practice

This study has implications for practice environments. Firstly, this study's focus is marginal and far from mainstream thinking regarding diet textural modifications in dysphagia management. Traditionally in deglutition science, dysphagia management, such as the use of diet textural modification, has perpetuated a biomedical perspective. This biomedical perspective predominantly focused on “down modifications” to make food safer for consumption to prevent choking and aspiration risks (i.e. moving from IDDSI Level 6 or 7 to Level 3 or 4) (Cichero et al., 2013; Cichero et al., 2017). This was possibly also to prevent litigation issues arising from

patient fatalities. However, this study hopes to debunk this traditional scientific ontological perspective by proposing an alternative perspective to approach dysphagia. This study proposes investing in the sensory aspects of diet textural modifications, particularly textural and acoustic properties. This may involve adopting an “up-modification” in diet textural modification using IDDSI transitional foods. Up-modifications suggests transitioning an individual with dysphagia from a lower Level 4 (pureed) to a Level 6 (soft and bite-sized) on the IDDSI framework (refer to Pillay (2013) for further explanation). This suggestion will allow the individual with dysphagia to consume texturally hard foods when first placed into the mouth. Upon initial contact during the first bite, these foods will produce acoustic properties of texturally hard food such as crispy, crunchy or crackly sounds. Following the first bite, these foods will transition to become safer to swallow given their prescribed IDDSI level. Studies by Dovey et al. (2013) and Gisel (1991) has shown the benefit of transitional foods in the paediatric population. In addition to the safety and hedonic responses to the textural and acoustic properties in transitional foods, there is anticipation that these foods may pose a similar therapeutic benefit to the adult population with dysphagia.

Mealtimes are a social and cultural phenomenon and a biopsychosocial experience as it involves interpersonal and social connections (i.e. communication and engagement with each other) and food sharing (Fjellström, 2004; Ochs & Shohet, 2006; Wallace et al., 2020; Shune & Namasivayam-MacDonald, 2020). Traditional diet textural modifications may be costly and time-consuming and require the use of food thickeners and additional tools such as electrical blenders (Pownall & Taylor, 2017). As a result, this may eliminate food sharing and food enjoyment and cause caregiver burden due to meal preparations and emotional stress (Nund et al., 2014; Shune & Namasivayam-MacDonald, 2020). By proposing the use of transitional foods, it prioritises the potential therapeutic benefit and promotes food sharing, mealtime enjoyment and overall quality of life. This will support a more biopsychosocial perspective to dysphagia rehabilitation. Finally, as this study is based on the principles of the THRIVE project and positioned within the context of low-to-middle income contexts such as South Africa and Brazil, this study may have significant implications on global dysphagia practice, particularly for these contexts. This includes developing foods that are both economically and ergonomically viable.

5.8. Recommendations for future research

Based on the findings of this study, there are several recommendations. First, this study may inspire researchers and practitioners from the field of dysphagia to think differently by considering textural and its associated acoustics properties and investigating other novel interventions as ways to reimagine dysphagia practice. Second, for a follow up of the pilot study, the researchers should conduct the main study with an alternative research design (such as a quasi-experimental design) and perform amendments to the methods, where necessary, to improve the reliability and validity of the study. For instance, future studies should use trained sensory panels or rheological analysis by including a textural analyser with an attached microphone when selecting and classifying the various food samples. Third, it is challenging to mask the influence of bone conduction due to its robust nature. During the expert consultation, Zampini suggested modulation of masking (e.g. 100%, 50% and 0%). Future studies should explore this method.

Regarding the sample size, the main study should recruit a larger sample size, including males and females of varying ages, to explore the influence of the gender and age variable. The main study will also assist in determining whether the pilot study findings are replicable and generalisable. As this study proposes IDDSI transitional foods, a more comprehensive understanding of its initial dynamic oral processing responses is yet to be explored (Barewal et al., 2020). Hanson (expert mechanical engineer) also suggested alternative ways of incorporating the benefits of acoustic properties for individuals with dysphagia through biofeedback to enhance the food acoustics without affecting the mechanics of the food. These suggestions that promote food acoustic properties should be explored further as potential holistic methods for dysphagia rehabilitation.

5.9. Conclusion

The acoustic properties of food are salient. The influence of food acoustics on behaviour and perception has been well-researched and proven. However, the influence of food textural acoustics on physiological responses in relation to dysphagia is currently a new and uncharted road. This study represents a new incursion in the field of dysphagia, the first step of which is critically exploring the influence of food textural acoustics on typical swallow responses. Based on an intensive scoping review of the literature across the fields and critical conversations with

interprofessionals, this study has provided evidence to demonstrate the sensibility of the construct of food textural acoustics in understanding and potentially intervening in eating for individuals with dysphagia. This study has also taken the next step and developed and tested protocols and tools to evaluate the influence of food acoustics of texturally hard foods on swallow responses. The preliminary findings of the pilot study revealed that food acoustics influence the swallow responses, specifically by reducing the force needed and duration of the first bite, mastication and swallowing. The results further revealed that acoustic properties of texturally hard foods play a role in texture perception, leading to positive hedonic responses. In essence, this study has provided a theoretical basis for the construct of food textural acoustics to be considered in dysphagia management.

This study is significant across both levels; theory and practice. At the theoretical level, it proposes an epistemological shift by encouraging the need to rethink and reimagine the value of acoustics in the field of dysphagia. With regards to the practice environment, this study addresses the challenges faced by both dysphagia practitioners and individuals with dysphagia in low-to-middle contexts across high-to-middle income countries (i.e. globally). This includes, but is not limited to, the small number of practitioners, reduced access to dysphagia services as well as food security and food sovereignty issues such as inadequate availability of affordable, accessible, suitable and culturally appropriate foods. Given the rigorous methods used in this study and the significance of the study findings, this study provides a strong basis for the need to target these issues for individuals with dysphagia by at least investing in the sensory aspects of diet textural modifications. This involves developing foods that consider the multisensory nature of eating, with particular inclusion of food textural acoustics. In addition to these foods being safe for swallowing and economically and ergonomically viable, there is an emphasis on ensuring that these foods also enhance the quality of life of these individuals with dysphagia. This links to the need to review the science we adopt to address the global contextual issues (M. Pillay, personal communication, August 3, 2021).

Traditionally, a triad existed in dysphagia practice; (a) therapist who possessed knowledge regarding the client with dysphagia and worked on providing management to the client, (b) client who was seen as not knowledgeable regarding their swallow mechanism and dysphagia management, and (c) food or dysphagia diet recommended for the client with

dysphagia. This study proposes a much needed shift in this triad by focusing on the duty of the therapist, in this case the dysphagia practitioner, to consider and work with the food for individuals with dysphagia within a low-to-middle income context. This may be challenging as the dysphagia practitioner needs to develop his/her skills, knowledge and expertise around the food and food preparation, and the dynamic interaction of the food in the mouth being prepared for swallowing (M. Pillay, personal communication, August 3, 2021).

As this study represents preliminary research in this area, researchers should critically consider both the strengths and limitations of this study. It is also crucial that researchers and practitioners respond to the call for future research to further widen the scope and impact of this construct of food textural acoustics. Informed thoughts and research influence practice.

It is time to start changing the rhetoric of sound, the “forgotten flavour sense”, to sound the “celebrated flavour sense” (Spence, 2015). This study aspires to promote a more holistic and interprofessional perspective for global dysphagia practice. This involves considering the multisensory nature of eating and global concerns such as food security and food sovereignty to ensure that the food is accessible, affordable and culturally appropriate. In addition, this holistic perspective promotes the development of foods safe for swallowing, maximally enjoyable and therapeutic for individuals with dysphagia from diverse socio-economic and cultural contexts across the globe. Further exploration of this construct of food textural acoustics may be translated into global dysphagia practice for individuals with dysphagia, and especially contextually responsive to those from low-to-middle income contexts.

My challenge to the world: can we revolutionise our thinking and approach to dysphagia practice through an exploration of food textural acoustics? Are you up for it? Let us unite and encourage interprofessional collaboration to improve quality of life for individuals with dysphagia in low-to-middle income contexts globally. Let us consider the use of food textural acoustics as a way to reimagine dysphagia practice!

References (for chapters 1, 2, 3, 4 and 5)

Note. The references of the individual papers are contained in its own list and not double referenced in this main reference list.

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APPENDICES

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Appendix 1.1: Research ethics certificate



Zertifikat Certificat

Certificado Certificate

Promouvoir les plus hauts standards éthiques dans la protection des participants à la recherche biomédicale
Promoting the highest ethical standards in the protection of biomedical research participants



Certificat de formation - Training Certificate

Ce document atteste que - this document certifies that

Tasneem karani

a complété avec succès - has successfully completed

Introduction to Research Ethics

du programme de formation TRREE en évaluation éthique de la recherche
of the TRREE training programme in research ethics evaluation

Release Date: 2019/01/11
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Professeur Dominique Sprumont
Coordinateur TRREE Coordinator





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[REV: 20170910]

Appendix 1.2: Ethics clearance certificate for full approval of the pilot study



22 July 2019

Ms T Fareed Karani (219094365)
School of Health Sciences

Dear Ms Fareed Karani

Protocol: Crispy, crunchy and crackly: An exploration of the food acoustic properties in relation to the swallow mechanism
Degree-MSc
BREC Ref No: BF152/19

FULL APPROVAL LETTER

The Biomedical Research Ethics Committee (BREC) has considered the abovementioned application at a meeting held on 09 April 2019.

I wish to advise you that your responses dated 11 July 2019, 02 July and 21 May 2019 to BREC letter dated 18 April 2019 were noted and approved by a sub-committee of the Biomedical Research Ethics. Please ensure that site permissions are obtained and forwarded to BREC for approval before commencing research at a new site.

This approval is valid for one year from 22 July 2019. To ensure uninterrupted approval of this study beyond the approval expiry date, an application for recertification must be submitted to BREC on the appropriate BREC form 2-3 months before the expiry date.

Any amendments to this study, unless urgently required to ensure safety of participants, must be approved by BREC prior to implementation.

Your acceptance of this approval denotes your compliance with South African National Research Ethics Guidelines (2015), South African National Good Clinical Practice Guidelines (2006) (if applicable) and with UKZN BREC ethics requirements as contained in the UKZN BREC Terms of Reference and Standard Operating Procedures, all available at <http://research.ukzn.ac.za/Research-Ethics/Biomedical-Research-Ethics.aspx>.

BREC is registered with the South African National Health Research Ethics Council (REC-290408-009). BREC has US Office for Human Research Protections (OHRP) Federal-wide Assurance (FWA 678).

Pg. 2/...

Biomedical Research Ethics Committee
Professor V Rambirth (Chair)

Westville Campus, Govan Mbeki Building
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Website: <http://research.ukzn.ac.za/Research-Ethics/Biomedical-Research-Ethics.aspx>



Founding Campuses: Edgewood Howard College Medical School Pietermaritzburg Westville

The following Committee members were present at the meeting that took place on 09 April 2019:

Prof V Rambiritch	Pharmacology (Chair)
Prof D Wassenaar	Psychology (Deputy Chair)
Dr N Abbai	Microbiology and Molecular Biology
Prof R Bhimma	Paediatrics & Child Health
Dr T Hardcastle	Surgery
Dr H Humphries	Research Psychology and Public Health
Dr M Khan	HIV Clinician
Dr Z Khumalo	KZN Health (External) General Medicine
Dr K Naidoo	Family Medicine
Dr S Paruk	Psychiatry
Prof C Rout	Anaesthetics
Prof D Singh	Critical Care
Dr T Sookan	Biokineticist
Prof A Strode	Health Law

This approval will be noted at the next BREC meeting to be held on 13 August 2019.

We wish you well with this study. We would appreciate receiving copies of all publications arising out of this study.

Yours sincerely



PROFESSOR V RAMBIRITCH
Chair: Biomedical Research Ethics Committee

cc: postgrad administrator: khumalot8@ukzn.ac.za Supervisor: PILLAYM1@ukzn.ac.za

Appendix 1.3: Ethics recertification



16 June 2020

Ms T Fareed Karani (219094365)
School of Health Sciences

Dear Ms Fareed Karani

Protocol: Crispy, crunchy and crackly: An exploration of the food acoustic properties in relation to the swallow mechanism
Degree-MSc
BREC Ref No: BF152/19

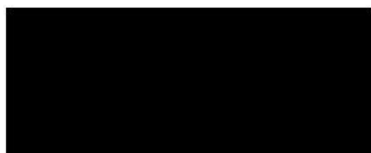
RECERTIFICATION APPLICATION APPROVAL NOTICE

Approved: 22 July 2020
Expiration of Ethical Approval: 21 July 2021

I wish to advise you that your application for Recertification for the above protocol has been noted and approved by the Biomedical Research Ethics Committee (BREC) at a meeting held on 09 June 2020 for another approval period. The start and end dates of this period are indicated above.

If any modifications or adverse events occur in the project before your next scheduled review, you must submit them to BREC for review. Except in emergency situations, no change to the protocol may be implemented until you have received written BREC approval for the change.

Yours sincerely



Ms A Marimuthu
(for) Prof D Wassenaar
Chair: Biomedical Research Ethics Committee

Biomedical Research Ethics Committee
Chair: Professor D R Wassenaar
UKZN Research Ethics Office Westville Campus, Govan Mbeki Building
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Appendix 1.4: Ethics amendment for conducting an expert focus group discussion



17 July 2020

Ms T Fareed Karani (219094365)
School of Health Sciences

Dear Ms Fareed Karani

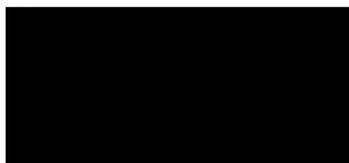
Protocol: Crispy, crunchy and crackly: An exploration of the food acoustic properties in relation to the swallow mechanism

Degree-MSc

BREC Ref No: BF152/19

I wish to advise you that your application for Amendment dated 17 June 2020 (to set up an Expert Reference Group) for the above protocol has been noted and approved by the Biomedical Research Ethics Committee (BREC) at a meeting held on 14 July 2020.

Yours sincerely



Ms A Marimuthu
(for) Prof D Wassenaar
Chair: Biomedical Research Ethics Committee

Biomedical Research Ethics Committee
Chair: Professor D R Wassenaar

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Appendix 2: Participant recruitment poster for the pilot study

PARTICIPANTS NEEDED!



Join me on my scientific venture to determine
how sounds affect how we swallow food

Contribute to the research regarding the management of
individuals with swallowing difficulties

If you are between the ages of 18-25 years old with healthy
hearing and would be interested in participating /would like more
info, contact:

Tasneem Karani: 219094365@stu.ukzn.ac.za

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Appendix 3: Information sheet and consent form for participation in the pilot study

To whom it may concern,

RE: INFORMATION SHEET AND CONSENT TO PARTICIPATE IN THE RESEARCH STUDY

My name is Tasneem Fareed Karani. I am conducting research at the University of KwaZulu-Natal in the fulfilment of a Masters in Speech-Language Therapy. The title of the research study is, “Crispy, crunchy and crackly: An exploration of the food acoustic properties in relation to the swallow mechanism.” You are being invited to consider participating in the research study.

Purpose of the study:

The purpose of the study is to explore how sounds of foods affect swallowing. The study is expected to enrol at least six healthy students from the University of KwaZulu-Natal, aged 18-25 years old, with hearing within normal limits and without any signs of mouth or jaw abnormalities. This screening phase of the study will take place at the University of KwaZulu-Natal Speech Pathology and Audiology Departments and the testing phase at one of the local hospitals. Participants will be provided with refreshments on the research day.

If you agree to be part of this study, your participation will entail:

1. Signing the consent forms
2. Completing a health screening questionnaire, swallow screening questionnaire and undergoing a hearing screening test

Thereafter, the participants who pass the screening will be transported to one of the local hospitals near the university. The participants will be provided with four types of food samples (soft, crispy, crunchy and crackly) to eat in both masked and unmasked conditions, and their swallow response

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will be assessed using observational methods videofluoroscopy and surface electromyography. If you choose to enrol and remain in the study, the total duration of your participation is expected to be approximately 50-60 minutes. You will be blindfolded during the study to eliminate your visual sense to ensure reliable results.

Following the swallow assessments, you will be required to complete two short questionnaires regarding your eating experience. Once completed, you may leave and may be contacted once results are being collated and analysed.

***Kindly wear comfortable non-reflective clothing on the day of the research study**

Voluntary participation:

Participation is completely voluntary; you may refuse to answer questions and have the right to withdraw from the study at any time without any negative consequences or penalties.

Confidentiality:

All identifying information will be removed from the data, and participant numbers/codes will be used to maintain confidentiality. The data will only be available to the researcher and supervisor. Your results will be store as a password-protected file. The data will only be accessible to the researcher and supervisor. The data will be kept for five years and after that will be destroyed.

Possible risks/discomforts associated with the study procedures:

- During the videofluoroscopy, you will be exposed to radiation. To minimise the risk of exposure, you will be required to wear a radiation protection apron.

Implications and/or benefits of the study on the general public and research fields:

- This study could potentially have significant implications on the management of individuals with swallowing difficulties, especially in the South African context, proposing a contextually- relevant and holistic intervention approach.

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- As this study is novel, it may serve as a foundation for further research in exploring this phenomenon of food acoustic properties.
- This study can provide key findings that can be used across fields, such as in dietetics, marketing, gastronomy and food engineering.

This study has been ethically reviewed and approved by the UKZN Biomedical Research Ethics Committee (ref no. BF152/19)

In the event of any problems or concerns/questions, you may contact the researcher at email address; 219094365@stu.ukzn.ac.za or the research supervisor, Prof. Mershen Pillay, email address; PILLAYM1@ukzn.ac.za. In addition, you may contact the UKZN Biomedical Research Ethics Committee, contact details are as follows:

BIOMEDICAL RESEARCH ETHICS ADMINISTRATION:

Research office, Westville Campus

Govan Mbeki Building

Private Bag X 54001

Durban

4000

KwaZulu-Natal, South

Tel:27 31 2604769- Fax: 27 31 260 4609 Email: BREC@ukzn.ac.za

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CONSENT FORM

Participant name: _____

(For Researcher to complete) **Participant number:** _____

Date: _____

I _____ (full name) have received information regarding the study: “Crispy, crunchy and crackly: An exploration of the food acoustic properties in relation to the swallow mechanism” by the researcher, Tasneem Fareed Karani.

I confirm that (please tick box as appropriate):

I understand the purpose and procedures of the study

I have been given an opportunity to answer questions about the study and have had answers to my satisfaction

I declare that my participation in this study is entirely voluntary and that I may withdraw at any time

I acknowledge that the researcher has explained the possible risks associated with the study

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If I have any further questions/concerns or queries related to the study, I understand that I may contact the researcher at 219094365@stu.ukzn.ac.za

If I have any other questions or concerns about my rights as a study participant, or if I am concerned about an aspect of the study or the researcher, then I may contact:

BIOMEDICAL RESEARCH ETHICS ADMINISTRATION:

Research office, Westville Campus

Govan Mbeki Building

Private Bag X 54001

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KwaZulu-Natal, South

Tel: 27 31 2604769- **Fax:** 27 31 260 4609

Email: BREC@ukzn.ac.za

(Print full name)

Signature of participant

Date

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Name of Researcher

Signature of researcher

Date

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Appendix 4: Health screening questionnaire for the pilot study (Adapted from ICF checklist,
WHO, September 2003)

Participant Name: _____ **Gender:** M/F
Date: _____
Title: Mr/Mrs/Ms
Date of birth: _____ **Age:** _____
Postal Address: _____
Contact details: _____
Email address: _____
First language: _____ **Second language:** _____
Degree: _____

Please indicate responses with an “X” where appropriate:

1. Rate your **physical health** over the last month:

Very good () *Good* () *Moderate* () *Bad* () *Very bad* ()

2. Rate your **emotional and mental health** over the last month:

Very good () *Good* () *Moderate* () *Bad* () *Very bad* ()

3. Do you currently have any **disorder(s)** or **disease(s)**?

Yes () *No* ()

If **yes**, please specify: _____

4. Do you have any **difficulty hearing**?

Yes () *No* ()

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If **yes**, please specify (which ear and when it started):

5. Do you **have an aversion to loud sounds**?

Yes () No ()

If **yes**, please specify (what kind of sounds):

6. Do you have any difficulty or pain when **swallowing**?

Yes () No ()

If **yes**, please specify (how often it occurs and when it started):

7. Do you have any **food or texture aversions**?

Yes () No ()

If **yes**, please specify (which foods/textures you do not prefer)?

8. Do you have any significant **family medical history**?

Yes () No ()

If **yes**, please specify: _____

9. Have you had any **surgeries** done on any area above your chest, neck, throat, mouth, ears or nose?

Yes () No ()

If **yes**, please specify: _____

10. Have you been **hospitalised** in the last year?

Yes () No ()

If **yes**, please specify (reason and how long):

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11. Are you currently on any **medication**?

Yes () No ()

If **yes**, please specify: _____

12. Do you **smoke**?

Yes () No ()

13. Do you use any **assistive devices** (glasses, hearing aid, wheelchair, etc.)?

Yes () No ()

If **yes**, please specify:

14. Any other significant information that you would like to mention about your health? (i.e. pregnancy)

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Appendix 5: Hearing screening procedure for the pilot study

The hearing screening procedures will require the following equipment:

1. Otoscope and speculae
2. GSI-39 Auto tymp (Pure Tone and tympanometry screener) with probe tips
3. Infection control items (Gloves, alcohol wipes, hand disinfectant, disinfectant solution)
4. Sound level meter
5. Signs for “testing in progress”

Steps for the hearing screening procedure:

General:

1. Ensure that the environment used for screening is conducive for screening by measuring the noise levels using a sound level meter. Signs should be placed on the door of the screening room
2. Ensure that all screening equipment has been calibrated and daily checks conducted

1. Otoscopy:

1. Ensure the batteries are working well
2. Infection control measures (use of gloves and selection and disinfection of speculae) will be carried out
3. Observe the ear status bilaterally; the status of the ear canal (presence of cerumen or other obstructions), the status of tympanic membrane and visibility of cone of light
4. If the ear canal has no obstructions, which may prevent the visibility of the cone of light, this constitutes a “pass”. If there are partial/complete occlusions of the ear canal which prevents the visualisation of the cone of light, it constitutes a “fail”.

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- The findings will be recorded on the screening form with a tick or cross to indicate a “pass” or “fail” accordingly. The participant is required to “pass” otoscopy bilaterally

2. Tympanometry and Acoustic reflexes (AR):

2.1. Tympanometry:

- Ensure machine is calibrated
- Infection control measures (use of gloves and selection and disinfection of probes)
- Instruct the participant regarding the procedure and what is expected of him/her during testing (i.e. positioning and observing silence)
- Insert the probe into the ear and obtain a hermetic seal
- Present stimulus- Test both right and left ears
- Measure responses- Record ear canal volume, middle ear pressure and static compliance
- Using Stach (2010) norms – record the results and the type of tymp obtained. If the tymp result is anything other than type a, it constitutes a “fail”. Indicate if a “pass” or “fail” is present

2.2. AR testing:

- Test frequencies: 1000Hz in both right and left ears using the 226Hz probe tone
- Present tone
- Record results on the recording form- present/absent. If responses are absent in both ears and the participant “fails” the tympanometry screening, this will constitute a “fail” for the AR testing
- Indicate if the response is a “pass” or “fail”

3. Pure tone audiometry:

- Ensure machine is calibrated

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2. Infection control measures (disinfect headphones after each use)
3. Instruct the participant on the procedure and what is expected of him/her (i.e. observe silence and when he/she hears the tone, respond by raising hand)
4. Place the headphones on the participant. Ensure correct and comfortable placement
5. Test each ear individually. Present stimulus @ 30 dB for 1000Hz, 2000Hz and 4000Hz
6. As this is a screener, the stimulus will be presented @ 30dB for 1000Hz, 2000Hz and 4000Hz, and no threshold searching will be conducted. Record the participant's response, i.e. tick or cross
7. If the participant has a "no response" at one frequency in the same ear and/or two frequencies between the two ears, this will constitute a "fail"

***Overall "pass" or "fail":** If a participant "fails" two or more of the above screenings, this constitutes an overall "fail" and referral for diagnostic assessment.

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Appendix 6: Hearing screening record form for the pilot study

Participant name _____

Participant number: _____

1. Otoscope examination:

	Right	Left
Clear ear canal		
Tympanic membrane intact		
Cone of light visible		

PASS
FAIL

2.1. Tympanometry:

	Ear canal volume	Middle ear pressure	Static compliance	Type
Right ear				
Left ear				

PASS
FAIL

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2.2. Acoustic reflex testing (AR):

	1000Hz
Right ear	
Left ear	

PASS
FAIL

3. Pure-tone audiometric screening:

	1000Hz (@ 30dB)	2000Hz (@ 30dB)	4000Hz (@ 30dB)
Right ear			
Left ear			

PASS
FAIL

PASS
FAIL

Participant able to proceed to main study

Participant unable to proceed to main study, referral for diagnostic assessment

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Appendix 7: Swallowing screening questionnaire EAT-10 for the pilot study

Eating Assessment Tool (EAT-10)

Name of participant: _____

Date: _____

Participant number: _____

Circle the appropriate response	0 = No problem 4 = Severe problem				
1. My swallowing problem has caused me to lose weight.	0	1	2	3	4
2. My swallowing problem interferes with my ability to go out for meals.	0	1	2	3	4
3. Swallowing liquids takes extra effort.	0	1	2	3	4
4. Swallowing solids takes extra effort.	0	1	2	3	4
5. Swallowing pills takes extra effort.	0	1	2	3	4
6. Swallowing is painful.	0	1	2	3	4
7. The pleasure of eating is affected by my swallowing.	0	1	2	3	4
8. When I swallow food sticks in my throat.	0	1	2	3	4
9. I cough when I eat.	0	1	2	3	4
10. Swallowing is stressful.	0	1	2	3	4
For researcher to complete: Total EAT-10:	Pass				
	Fail				

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Appendix 8: Modified Videofluoroscopy Swallowing Study (VFSS) protocol for the pilot study

The following items are required:

1. Videofluoroscopy
2. Infection control measures (use of disinfectant and gloves)
3. Radiation protection apron
4. Barium sulphate made into a paste
5. e'Pap soft and e'Pap soft coated with semolina
6. Texturally hard food samples (Chip, thin toast and e'Pap -based biscuit)
7. Disposable containers and tongue depressors/spoons
8. Blind-folds and distractor scent
9. Stationery
10. KUDUwave for auditory masking, with probe tips

Steps for the VFSS:

1. Participant preparation: donning of radiation aprons and setting up of food sample station. Ensure all food samples required are ready for testing in appropriate disposable containers and on tongue depressors/spoons. The food samples tested should be coated with the barium sulphate made into a paste.
2. Participant to be seated in an upright position safe for swallowing between the machine and table (90 degrees, or as close to 90 degrees as possible).
3. The researchers to ensure appropriate infection control procedures (hand washing and use of gloves)
4. Use the lateral view, no collimation

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5. VFSS and Surface Electromyography (sEMG) will be conducted simultaneously during the dry swallow, e'Pap soft, e'Pap soft coated with semolina and texturally hard food samples (chip, thin toast and e'Pap-based biscuit) in both masked and unmasked conditions
6. Ensure the participant is blindfolded and a distractor scent is applied below the nose. Provide a tap on the shoulder to signal a participant to self-feed using a spoon. The researchers should provide the participant with the food on the tongue depressor/ spoon and thereafter step out of the radiation range and begin recording
7. One e'Pap soft, one e'Pap soft coated with semolina, and three texturally hard food samples will be presented to the participant (masked and unmasked) in a random order
8. Participants will be provided with the following instruction:
 - "Bite and chew naturally on the right side of the mouth, and swallow when you are ready."
9. Record results and save them onto PACS software
10. Analyse:
 - Duration of the oral phase
 - Number of masticatory cycles
 - Duration of the palatal elevation
 - Duration from the entrance of the bolus into the hypopharynx until the opening of the upper oesophageal sphincter (UOS)
 - Hyolaryngeal complex (HLC) excursion at rest, elevation and descent
 - Duration of HLC excursion from at rest to descent and duration of UOS opening and closing

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Appendix 9: Modified Surface Electromyography (sEMG) protocol for the pilot study

The following items are required:

1. Electromyography equipment (VitalStim® Plus programme) with batteries and recording and reference electrodes
2. Infection control measures (use of disinfectant and gloves)
3. Alcohol swabs (use before applying the recording electrodes)
4. e'Pap soft and e'Pap soft coated with semolina
5. Texturally hard food samples (Chip, thin toast and e'Pap-based biscuit)
6. Disposable containers and tongue depressors/spoons
7. Stationery
8. KUDUwave for auditory masking, with probe tips

Steps for sEMG:

1. Participant preparation: donning of radiation aprons and setting up of food sample station. Ensure all food samples required are ready for testing in appropriate disposable containers and on tongue depressors/spoons. The food samples tested should be coated with the barium sulphate made into a paste.
2. Participants to be seated in an upright position safe for swallowing between the machine and table (90 degrees, or as close to 90 degrees as possible).
3. The researchers to ensure appropriate infection control procedures (hand washing and use of gloves)
4. Use the lateral view, no collimation
5. Ensure equipment is switched on and electrodes connected to channel one and channel two

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6. Identify anatomical landmarks of the muscle and palpate the participant
7. Scrub areas using alcohol swabs (helps to reduce impedance between skin and electrodes).
8. Apply the surface electrodes- Arm (reference electrode), oral phase (right masseter) and pharyngeal phase (mylohyoid) and connect to sEMG machine.
9. VFSS and Surface Electromyography (sEMG) will be conducted simultaneously during the dry swallow, e'Pap soft, e'Pap soft coated with semolina and texturally hard food samples (chip, thin toast and e'Pap-based biscuit) in both masked and unmasked conditions
10. Ensure the participant is blindfolded and a distractor scent is applied below the nose. Provide a tap on the shoulder to signal a participant to self-feed using a spoon. The researchers should provide the participant with the food on the tongue depressor/ spoon and, after that, step out of the radiation range and begin recording
11. One e'Pap soft, one e'Pap soft coated with semolina, and three texturally hard food samples will be presented to the participant (masked and unmasked) in a random order
12. Participants will be provided with the following instruction:
 - "Bite and chew naturally on the right side of the mouth, and swallow when you are ready"
11. Record results and save them onto PACS software
12. Analyse:
 - First bite force
 - Mastication force
 - Mylohyoid force

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Appendix 10: Participant perceptual questionnaire 1 for the pilot study

Instructions to the participants:

- This questionnaire is intended to explore your perception of the food samples presented during the study.
- It is divided into two areas: **swallow response** to food acoustic stimuli and **hedonic (pleasure) responses** to the food acoustic stimuli.
- When answering these questions, focus only on your present perception of the food samples (i.e. not on your previous experience of the particular food sample)
- “Could **NOT** hear the BITE SOUND,” refers to when you could **NOT** hear the crispiness/crunchiness/crackliness of the foods due to the ‘shhh’ sound and vibration blocking the bite sound out
- “Could **HEAR** the BITE SOUND,” refers to when you could hear the crispiness/crunchiness/crackliness of the foods when biting into the food samples and/or chewing the food samples
- When answering these questions, think about the texture and sound properties of the different food samples
- When answering these questions, think about the texture and sound properties of the different food samples that were given to you (i.e. when you could **NOT** hear the BITE SOUND in comparison to when you **could HEAR** the bite sound.
- If you have any questions or queries, feel free to direct them to the researcher/research assistant.

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Participant name: _____

Date of assessment: _____

(To be completed by the researcher):

Participant number: _____

1. Swallow response to the food acoustic stimuli

1.1. When I bit INTO the food samples and could **NOT** hear the BITE SOUND, in comparison to when I **could HEAR** the BITE SOUND, I needed to **BITE** with...:

1. the same, i.e. no different

2. Less effort

3. More effort

1.2. When I **CHEWED** on the food samples and could **NOT** hear the BITE SOUND, in comparison to when I **could HEAR** the BITE SOUND, I needed to **CHEW** with...:

1. the same, i.e. no different

2. Less effort

3. More effort

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1.3. When I **CHEWED** on the food samples and could **NOT** hear the BITE SOUND, in comparison to when I **could HEAR** the BITE SOUND, I **CHEWED** for:

1. the same duration, i.e. no different

2. a shorter duration

3. a longer duration

Please explain your overall response to questions 1.1, 1.2 and 1.3. (in 1-2 sentences):

1.4. When I bit into the food samples and could **NOT** hear the BITE SOUND, in comparison to when I **could HEAR** the BITE SOUND, I needed to **SWALLOW** the food sample with:

1. the same effort, i.e. different

2. Less effort

3. More effort

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Please explain your response to question 1.4. (in 1-2 sentences):

2. Hedonic (pleasure) response to the food acoustic stimuli

2.1. When I bit into the food samples and **could HEAR** the BITE SOUND, in comparison to when I could **NOT** hear the BITE SOUND, I...the food sample

1. Liked

2. Disliked

Please explain (in 1-2 sentences):

Thank you for your time and participation in this study!

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Appendix 11: Participant perceptual questionnaire 2 (sensory) for the pilot study

Instructions to the participants:

- This questionnaire is intended to explore your **sensory perception** of four food samples presented
- You will be provided with four food samples to eat, and you will be required to tick the box which best describes these food samples AND/OR provide an alternative description for these four food samples in ENGLISH and/or your FIRST LANGUAGE
- When answering these questions, focus only on your present perception of the food samples (i.e. not on your previous experience of the particular food sample)
- If you have any questions or queries, please direct them to the researcher/research assistant.

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Participant name: _____

Date of assessment: _____

First language: _____

Second language: _____

(To be completed by the researcher):

Participant number: _____

1. Sensory properties of the food:

Kindly tick the box which best describes the following food samples AND/OR provide an alternative description for these food samples in ENGLISH and/or your FIRST LANGUAGE:

1.1. Food sample 1- Commercial crisp:

1. Crispy

2. Crunchy

3. Crackly

4. Other (English): _____

5. Other (First Language): _____

1.2. Food sample -Commercial thin toast

1. Crispy

2. Crunchy

3. Crackly

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4. Other (English): _____

5. Other (First Language): _____

1.3. Food sample 3-E'pap biscuit:

1. Crispy

2. Crunchy

3. Crackly

4. Other (English): _____

5. Other (First Language): _____

1.4. Food sample- E'pap semolina:

1. Crispy

2. Crunchy

3. Crackly

4. Describe: _____

5. Other (English): _____

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6. Other (First Language): _____

2. If you are unable to provide alternative term/s in your other language, please provide reasons (in 1-2 sentences):

Thank you for your time and participation in this study!

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Appendix 12: Pilot study evaluation form for the scoping review (screening protocols and tools)

Date: _____ Pilot study reviewer name: _____

Rate each of the following protocols or tools based on the parameters listed in the table below from 1 to 3 (1 being the most difficult and 3 being the easiest):

	Search Protocols	Screening Protocols	Screening Tools
Time taken			
Ease of understanding of instructions			
Ease of use			
Terms included			
Layout/Format			

Please provide any recommendations to improve the search terms related to the study:

Please provide any recommendations to improve the search protocols, screening protocols and/or screening tools:

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Appendix 13: Scoping review search protocols

The protocols below were used during the initial search by the blind reviewer:

1. **PubMed search protocol**

1. Open internet browser (Preferably Google Chrome).
2. Type in “UKZN Library” OR <https://library.ukzn.ac.za>. LAN Username: 219094365, LAN Password: 75A***** (removed for security reasons)
2. At the bottom of the page, in the blue box under “online resources”, select “Databases”
3. Select “PubMed”
4. Enter login details (LAN username and password)
5. Scroll down, under explore select “MeSH Database”
6. Type in “Sound” and enter
7. Select “Do not include MeSH terms found below this term in the MeSH hierarchy”
8. Select “Add to search builder”
9. Ensure Boolean operator AND is selected on the right of the PubMed search builder
10. Type in “eating” next to MeSH
11. Select “Do not include MeSH terms found below this term in the MeSH hierarchy”
12. Select “Add to search builder”
13. Select “search PubMed”
14. Select filters column on the left side of the page
15. Go to “publication date” in
16. Click on the custom dates.
17. Select the date 01/01/1980 for the first date.
18. Select 30/06/2020 for the second date.

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19. Use the “**Title screening protocol**” to go through the search results

2. Medline search protocol

1. Open internet browser (Preferably Google Chrome).
2. Type in “UKZN Library” OR <https://library.ukzn.ac.za>. LAN Username: 219094365, LAN Password: 75A***** (removed for security reasons)
3. At the bottom of the page, in the blue box under “online resources”, select “Databases”
4. Select “Medline Complete”
5. Enter login details (LAN username and password)
6. Select the option to “deselect all” databases
7. Select MEDLINE with Full Text Complete
8. Press “continue”
9. Click on the advanced search option.
10. In the first field, type in “Sound”
11. In the second field, select “AND” using the dropdown menu.
12. In the second field, type in “Eating”
13. Scroll down to the “search modes and expanders” section and make sure that the option “Boolean/Phrase” is selected
14. Select the option for “apply related words”
15. In the “limit your results” section type in “1980” in the first year block
16. In the “limit your results” section type in “2020” in the second year block
17. Select the “SEARCH” icon
18. Use the “**Title screening protocol**” to go through the search results

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3. **Scopus search protocol**

1. Open internet browser (Preferably Google Chrome).
2. Type in “UKZN Library” OR <https://library.ukzn.ac.za>. LAN Username: 219094365, LAN Password: 75A***** (removed for security reasons)
3. At the bottom of the page, in the blue box under “online resources”, select “Databases”
4. Select “Scopus”
5. Enter login details (LAN username and password)
6. Select “Advanced”
7. Search: sounds AND eating
8. Go to “publication date” in
9. Click on the custom dates.
10. Select the date 01/01/1980 for the first date.
11. Select 30/06/2020 for the second date.
12. Use the “**Title screening protocol**” to go through the search results

4. **EBSCOhost search protocol**

1. Open internet browser (Preferably Google Chrome)
2. Type in “UKZN Library” OR <https://library.ukzn.ac.za>. LAN Username: 219094365, LAN Password: 75A***** (removed for security reasons)
3. At the bottom of the page, in the blue box under “online resources”, select “Databases”
4. Enter login details (LAN username and password)
5. Select “EBSCOhost”
6. Select the first option “EBSOhost Web”
7. Select the option to search all databases

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8. Press “continue”
9. Click on the advanced search option.
10. In the first field, type in “Sound”
11. In the second field, select “AND” using the dropdown menu.
12. In the second field, type in “Eating”
13. Scroll down to the “search modes and expanders” section and make sure that the option “Boolean/Phrase” is selected
14. Select the option for “apply related words”
15. In the “limit your results” section type in “1980” in the first year block
16. In the “limit your results” section type in “2020” in the second year block
17. Select the “SEARCH” icon at the bottom of the page
18. Use the “**Title screening protocol**” to go through the search results

5. **CINAHL search protocol**

1. Open internet browser (Preferably Google Chrome)
2. Type in “UKZN Library” OR <https://library.ukzn.ac.za>. LAN Username: 219094365, LAN Password: 75A***** (removed for security reasons)
3. At the bottom of the page, in the blue box under “online resources”, select “Databases”
4. Enter login details (LAN username and password)
5. Select the option to “deselect all” databases
6. Select CINAHL with Full text
7. Press “continue”
8. Click on the advanced search option.
9. In the first field, type in “Sound”

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10. In the second field, select “AND” using the dropdown menu.
11. In the second field, type in “Eating”
12. Scroll down to the “search modes and expanders” section and make sure that the option “Boolean/Phrase” is selected
13. Select the option for “apply related words”
14. In the “limit your results” section type in “1980” in the first year block
15. In the “limit your results” section type in “2020” in the second year block
16. Select the “SEARCH” icon
17. Use the “**Title screening protocol**” to go through the search results

6. **APA PsycINFO search protocol**

1. Open internet browser (Preferably Google Chrome)
2. Type in “UKZN Library” OR <https://library.ukzn.ac.za>. LAN Username: 219094365, LAN Password: 75A***** (removed for security reasons)
3. At the bottom of the page, in the blue box under “online resources”, select “Databases”
4. Enter login details (LAN username and password)
5. Select “EBSCOhost”
6. Select the first option “EBSOhost Web”
7. Select the option to “deselect all” databases
8. Select APA PsycINFO
9. Press “continue”
10. Click on the advanced search option.
11. In the first field, type in “Sound”
12. In the second field, select “AND” using the dropdown menu.

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13. In the second field, type in “Eating”
14. Scroll down to the “search modes and expanders” section and make sure that the option “find all my search terms” is selected
15. Select the option for “apply related words”
16. In the “limit your results” section type in “1980” in the first year block
17. In the “limit your results” section type in “2020” in the second year block
18. Select the “SEARCH” icon
19. Use the “**Title screening protocol**” to go through the search results

7. Google scholar search protocol

1. Open internet browser (Preferably Google Chrome).
2. Type in “UKZN Library” OR <https://library.ukzn.ac.za>. LAN Username: 219094365, LAN Password: 75A***** (removed for security reasons)
3. At the bottom of the page, in the blue box under “online resources”, select “Databases”
4. Enter login details (LAN username and password)
5. Select “Google Scholar”
6. Click on the menu icon in the upper left corner
7. Select the Advanced search option
8. Type “sound” AND “eating” into the row “with **ALL** the words”
9. Click on the option for “anywhere in the article” in the “where my words occur” row.
10. Go to the “Return articles dated between” row at the bottom of the search page.
11. Type “1980” in the first block, type “2020” in the next block.
12. Click the blue search icon in the upper right corner.
13. Use the “**Title screening protocol**” to go through the search results

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Appendix 14: Scoping review screening protocols for title, abstract and full-text article screening

1. Level 1: Title screening protocol

1. Once duplicates have been removed, select a title to be screened
2. Read through the title
3. Refer to “**Level 1:Title screening tool**” - the eligibility criteria (study characteristics) listed
4. Complete the general information
5. The title must fit the criteria (either 1.1. or 1.2) (“Yes” response) for it to pass the title screening
6. If the article **PASSES** this level, export the reference to the “**Title passed**” group on the **Mendeley** data manager. If the article **FAILS** the screening tool, the article should be excluded from the study.
7. If the article **PASSES**, proceed to “**Abstract screening protocol**”
8. Carry out the above seven steps with all search results

2. Level 2: Abstract screening protocol

This protocol is to be used for level 2: abstract screening after the study has passed title screening (level 1).

1. Select a study abstract to be screened
2. Read through the abstract
3. Refer to “**Level 2:Abstract screening tool**” - the eligibility criteria (study characteristics) listed
4. Complete the general information

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5. The title must fit the criteria (either 1.1. or 1.2) (“Yes” response) for it to pass the abstract screening and for the study to be assessed for eligibility at level 3 (full-text)
6. If the article **PASSES** this level, export the reference to the “Abstract passed” group on the **Mendeley** data manager. If the article **FAILS** the screening tool, the article should be excluded from the study.
7. If the article **PASSES**, proceed to “**Full-text screening protocol**”
8. Carry out the above seven steps with all search results

3. Data coverage protocol (Mapping the distribution)

1. Once the study has passed level 1 and level 2 (title and article screenings), refer to the “**Data coverage**” form
2. Complete the form for each article
3. Once the form is completed for each article
4. The data should be exported to the Data coverage Microsoft Excel spreadsheet to calculate and map the distribution (frequency analysis) of the following:
 - Author/s
 - Year published
 - Journal published
 - Field/s of study
 - Country

4. Level 3: Protocol for full-text eligibility

This protocol is used for level 3: full-text eligibility after the study has passed both title and abstract screenings

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1. Select a full-text to be screened
2. Scan through the full-text
3. Refer to “**Level 3: Full-text eligibility tool**” - the eligibility criteria (study characteristics) listed
4. Complete the general information
5. The full-text should include two of the eligibility criteria to **PASS** the third level of screening.
6. Make any important points in the **NOTES** section
7. If the article **PASSES** this level, export the reference to the “**Full-text passed**” group on the **Mendeley** data manager. If the article **FAILS** this tool, the article should be excluded from the study, and specific reason/s should be noted
8. Carry out the above 7 steps with all search results
9. The articles that have passed this level should be discussed at the meeting between reviewers
10. Articles should be finalised for full-text analysis
11. The “**full-text data extraction form**” should be completed for each article finalised
12. Conduct thematic analysis

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Appendix 15: Scoping review screening tools

1. Level 1: Title screening form**1. General information**

Reviewer no.	A/B
Title of study	
Name of author/s	
Date of publication	
Study no.	

2. Eligibility

According to the title, does the study fit the following inclusion criteria:

Study characteristics	Yes	No
Refers to sound (either environmental sounds/music OR as a result of the breakage of foods) and the process of eating/drinking OR Refers to sound (either environmental sounds/music OR as a result of the breakage of foods) and the perception of eating/drinking		
Result:	Include	Exclude

N.B: The title must fit the above criteria of either 1.1. or 1.2. (“Yes” response) for it to pass the title screening and for the study to be included for screening at level 2 (abstract)

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1. Level 2: Abstract screening form

1. General information

Reviewer no.	A/B
Title of study	
Name of author/s	
Date of publication	
Study no.	

2. Eligibility

According to the abstract, does the study fit the following inclusion criteria:

Study characteristics	Yes	No
Refers to sound (either environmental sounds/music OR as a result of the breakage of foods) and the process of eating/drinking OR Refers to sound (either environmental sounds/music OR as a result of the breakage of foods) and the perception of eating/drinking		
Result:	Include	Exclude

N.B: The abstract must fit the above criteria of either 1.1. or 1.2. (“Yes” response) for it to pass the abstract screening and for the study to be assessed for eligibility at level 3 (full-text)

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2. Data coverage form:

Reviewer:	A/B
Study no.	
Full name/s of author/s	
Year published	
Journal published	
Field/s of study	
Country	

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3. Level 3: Full-text eligibility form

1. General information

Reviewer no.	A/B
Date of review	
Title of study	
Name of author/s	
Date of publication	
Study no.	

2. Eligibility

According to the full text, does the study fit the following inclusion criteria:

Study characteristics	Yes	No	Unsure
Explores the effect/s of sound (either environmental sounds/music OR as a result of the breakage of foods) on the process of eating/drinking OR Explores the effect/s of sound (either environmental sounds/music OR as a result of the breakage of foods) on the perception of eating/drinking			
Reviews the literature OR Fully demonstrates the methodology of studying sounds (either environmental sounds/music OR as a result of the breakage of foods) on eating/ drinking			
Result:	Include	Exclude	

Specific reason/s if article excluded:

N.B: The full-text must fit the above TWO criteria (“Yes” response) for it to pass the full-text eligibility and for the study to be included in the qualitative analysis

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Appendix 16: Information sheet for the online expert focus group discussion

Date

Department of *

University *

Address *

INVITATION TO AN ONLINE FOCUS GROUP INTERVIEW

Dear *Dr/Prof./Mr,

My name is Tasneem Karani. I am a PhD candidate in Speech-Language Therapy at the University of KwaZulu-Natal (South Africa), under the supervision of Prof. Mershen Pillay. I am interested in understanding food acoustic properties and the swallow mechanism. The title of my study is; *“Crispy, crunchy and crackly: An exploration of the food acoustic properties in relation to the swallow mechanism.”* Due to your expertise in (*), I invite you to participate in an online focus group interview.

Previously I conducted a pilot study with eight healthy adult participants to investigate the following objectives:

1. Develop a test battery to evaluate the neurophysiological and perceptual swallow responses (including hedonic (pleasure) responses) to acoustic properties associated with texturally hard foods.
2. To assess the feasibility of the developed test battery based on clinical utility and logistical parameters.

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The pilot study showed the following results:

- The results revealed an increase in the first bite force, mastication force, mylohyoid force, duration of palatal elevation, number of masticatory cycles, and percentage change in the hyolaryngeal complex excursion, in the masked condition (i.e. masked food acoustics).
- These neurophysiological swallow results were similar to those obtained from the perceptual swallow responses, as majority of the participants reported that they perceived their bite force, mastication force and swallow force as requiring more effort, and their mastication duration as longer in the masked condition.
- Furthermore, all participants reported a positive hedonic response to the food acoustics of the texturally hard food.
- The developed test battery has clinical utility and is economically and ergonomically viable with regards to its logistical parameters of time, cost, equipment, and personnel needs.

While I have planned on including you as part of an expert reference group prior to the main study, and due to COVID-19 restrictions, this online focus group interview will be a means of gathering your opinions on this study area and the results of my pilot study in a more rich and extended way.

Should you agree to participate, your participation will entail the following:

Focus group interview over Zoom: An online focus group interview of approximately 60 minutes based on the pilot study results will be set up. **Please note:** If you cannot make any of the proposed dates and/times or do not wish to be part of an online focus group, I will appreciate your contribution through an individual online interview (details to be arranged). The Zoom meeting link and the pilot study results (in a PowerPoint presentation) will be sent to you a week prior to the online focus group. The online focus group will provide an opportunity for you to

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share your thoughts and engage with other experts regarding textural food acoustics and the human swallow mechanism. Then, I hope to analyse this information in order to build a conceptual framework.

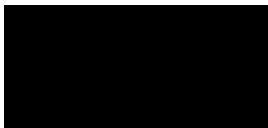
Throughout the interview, the researcher will ensure that the following ethical considerations will be taken into consideration:

1. **Informed consent:** You will be required to provide written consent to be interviewed, audio-video recorded, and for your opinions to be included in the write up of this study.
2. **Benefits:** There are no direct benefits to your participation. However, you will significantly assist in contributing to research that may be valuable to various fields.
3. **Risks:** There are no emotional, physical, financial or personal risks associated with participation. You are allowed to withdraw from the study at any time with no consequences.

Ethical approval has been granted by the University Biomedical Research Ethics Committee (ref no. BF152/19). Should you agree to participate, kindly “comment” on the consent form and sign off using SignRequest (links provided in the email). If you have any other concerns or questions, please do not hesitate to contact me at [REDACTED]. Alternatively, you may contact my research supervisor, Prof. Mershen Pillay at pillaym1@ukzn.ac.za, or the University Biomedical Research Ethics Committee at BREC@ukzn.ac.za.

Thank you in advance for your consideration and I am looking forward to hearing from you.

Kind Regards,



Tasneem Karani

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Appendix 17: Consent form for the online expert focus group interview

Title of study: “Crispy, crunchy and crackly: An exploration of the food acoustic properties in relation to the swallow mechanism”

Participant name: _____

Suitable date and time for the online focus group interview (from proposed options):

I _____ (print full name) have received information regarding the study titled above by the primary researcher, Tasneem Karani.

I confirm that (**indicate with “X”**):

1. I understand what my participation in this study entails

2. I provide full consent to participate in this study

3. I provide full consent to be audio-video recorded during the online interview for the purpose of this study

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Print full name

Signature of participant

Date

Please note: If you are unable to make the online focus group interview, please indicate (YES/NO) if you would prefer an individual online interview (details to be arranged)

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Appendix 18: Protocol for the online expert focus group discussion (FGD)

	<u>Topic</u>	<u>Methodology</u>
<u>Opening/Introduction</u>	Establish connection ²	<ul style="list-style-type: none"> • Greeting • Indicate that the audio and video recording will commence • Introduce oneself and participants, and their area of expertise • Thank participants for their time and for agreeing to participate • Announcement regarding video recording (head-neck shot, lighting – on you, not behind you)
	State the purpose of the online interview/focus group discussion ¹	<ul style="list-style-type: none"> • Explain that it is a duoethnographic interview with the following aims; <ol style="list-style-type: none"> 1. Discussing how the field expert would engage with the construct of food acoustics 2. To co-construct a conceptual framework
	Duration ³	<ul style="list-style-type: none"> • Format: Length of online individual interview/FGD 45 min-60min

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<u>Body</u>	Stimulus-Response	1. Two-three broad questions (refer to questions)
<u>Format: Open dialogue</u>	Interview (SCI):	1.1. Firstly, ask participants for their general thoughts before the presentation OR 1.2. Present pilot study objectives, set up and results and evoke a discussion (aim, methodology, results) 2. Discuss participants' work/publications (unique) and acknowledge their work
<u>Closing/ Conclusion</u>	Summarise and reflection ³	<ul style="list-style-type: none"> Summarise the pertinent points of the FGD Ask participants for any closing statements
	Maintain connection	<ul style="list-style-type: none"> Thank participants again for their time and expertise
	Future actions	<ul style="list-style-type: none"> Send any requested information to participants for follow up

¹Jacob, S. A., & Furgerson, S.P. (2012). "Writing interview protocols and conducting interviews: Tips for students new to the field of qualitative research." *Qualitative Report*, 17, 6.

² Gluck, S. B., & Patai, D. (Eds.). (2016). *Women's words: The feminist practice of oral history*. Routledge.

³ Stansfield, J. (2020). "Giving voice: an oral history of speech and language therapy." *International journal of language & communication disorders* 55(3), 320-331.

Pillay, M. and H.Kathard (2015). "Decolonizing health professionals' education: audiology & speech therapy in South Africa." *African Journal of Rhetoric*, 7(1): 193-227.

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Appendix 19: Online expert focus group discussion (FGD) strategies/troubleshooting

Content	Data categories	Methods
Stimulus-response	Broad generic interview questions	Silence: Promotes silences after responses to encourage participants to add anything further before continuing with the interview.
	Unique information: A summary review of the participant	Non-verbal markers: The researcher should use non-committal cues such as nodding to encourage further discussion from the participants throughout the interview.
	Presentation of pilot study results	<p>Fillers: Use verbal fillers during the participants' responses such as "yes", "that is interesting, can you please comment on this more."</p> <p>Exemplars/ Repetition: Use repetitions to guide the interview</p> <p>Participant-guided: The researcher should allow the participants to respond openly and guide the FGD with specific content areas in mind.</p> <p>Questioning: Target open-ended questions before close-ended questions.¹ Use open-ended questions to allow for discussion.² If the participants do not answer the main broad questions, ask a specific close-ended question. If both do not evoke a response, use stimulus-responses.</p> <p>Timing: Allow the participant sufficient time to think about difficult questions.</p> <p>Clarification: Asking the participant for further explanation or clarification to confirm a concept when the meaning of a point is ambiguous.</p>

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		<p>Follow-up questions: Encourage the participant to dialogue freely with each other. Consider any follow-up questions.</p> <p>Clear responses to participants: The interviewer should have clear responses to wh-questions to provide information about the study and the interviewer's thoughts to the participants.</p> <p>Critical conversations: During the interview, the researcher should foreground concepts of food acoustics and texture and its influence on the swallow mechanism to encourage the participants to reflect on their opinions of the construct.</p>
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² Stokes, J. (2015). Speech and Language Therapy and Professional Identity; challenging received wisdom, J & R Press Ltd.

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Appendix 20: Certificate/s of language and technical editing

C Woudberg

Language Practitioner

██████████ | ██████████

To whom this may concern:

I hereby confirm that I have completed the language and technical editing of this research dissertation of Tasneem F. Karani. My involvement was restricted to language usage, spelling, completeness and consistency, referencing style and general technical formatting. I did no structural re-writing of the content and did not influence the academic content in any way.



Kind regards,

Christelle Woudberg

ND Language Practice






Member of the South African Translators 'Institute

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PROOFREADING CERTIFICATE

This is to certify that I provided proofreading services to Tasneem Faraad Karani to facilitate the completion of her academic work:

CRISPY, CRUNCHY AND CRACKLY: AN EXPLORATION OF FOOD TEXTURAL ACOUSTICS ON THE SWALLOW MECHANISM

Submitted in fulfilment of the requirements for the degree of:
Doctorate in Philosophy - Speech-Language Therapy
School of Health Sciences, College of Health Sciences
University of KwaZulu-Natal, Durban, South Africa

Supervisor: A/Prof Mershen Pillay

The work was completed on 1 April 2021 in Johannesburg by Gaynor Paynter –
Transcriber and Owner Typewrite Transcription and Typing Services CC



Gaynor Paynter (owner)

07/08/2021






Date

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