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**Associations between Sensory Issues,  
Mealtime Behaviours, and Food and Nutrient Intakes  
in Children with Autism Spectrum Disorder**

A thesis presented in partial fulfilment of the  
requirements for the degree of

Master of Science

in

Human Nutrition and Dietetics

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## Abstract

**Background:** Sensory issues are defined as dysfunction within the integration of the seven senses within the brain. Dysfunction can lead to issues within higher-level integrative functions such as social participation and planning and praxis, and lead to atypical responses to one's environment. Sensory issues are highly prevalent in children with Autism Spectrum Disorder (ASD) and have been associated with difficult mealtime behaviours. It is not known if sensory issues are associated with food or nutrient intake in ASD children living in New Zealand (NZ). Nutritional deficits during development could have compounding effects on cognition and behaviour in ASD.

**Methods:** Analysis of baseline data from an ongoing randomised-controlled trial was undertaken. Using a cross-sectional observational study design we investigated associations of sensory issue severity with frequency of difficult mealtime behaviour and food and nutrient intakes of children aged 2.5–8 years with ASD in NZ. The Sensory Processing Measure (SPM), Behavioural Paediatric Feeding Assessment Scale, Dietary Intake for Child's Eating (DICE), and four-day food diaries were used to measure sensory issues, difficult mealtime behaviours, food intake, and nutrient intake, respectively.

**Results:** Of 113 participants, 90.2% of children had sensory issues, and 41.5% of children had clinical difficult mealtime behaviours. An increase in sensory issue severity corresponded to an increase in frequency of difficult mealtime behaviours ( $r=.265$ ,  $p=.007$ ). Social participation issue severity was inversely associated with the total DICE score ( $r=-.305$ ,  $p=.003$ ). More than 50% of the children did not meet Ministry of Health recommendations for servings of fruit, vegetables, breads and cereals, milk and milk products, or nutrient intakes for calcium. Neither sensory issue severity nor frequency of difficult mealtime behaviours appeared to be associated with food and nutrient intakes.

**Conclusion:** Sensory issues are highly prevalent in ASD children and sensory issue severity is positively associated with frequency of difficult mealtime behaviours. Intervention is required in a number of children with ASD to ensure food and nutrient intake recommendations are met.

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## List of Abbreviations

AI	Average Intake
AMDR	Acceptable Macronutrient Distribution Range
APA	American Psychological Association
ASD	Autism Spectrum Disorder
BAMBI	Brief Autism Mealtime Behavior Inventory
BMI	Body Mass Index
BPFAS	Behavioural Paediatric Feeding Assessment Scale
CEBI	Child's Eating Behaviour Inventory
CFS	Child Frequency Score
CRP	C-Reactive Protein
DICE	Dietary Index for a Child's Eating
DHB	District Health Board
DNZ	Dietitians New Zealand
DSM-5	Diagnostic and Statistical Manual of Mental Disorders, Fifth Edition
EAR	Estimated Average Requirement
EBQ	Eating Behaviour Questionnaire
FFQ	Food Frequency Questionnaire
Hb	Haemoglobin
ID	Intellectual Disabilities
IOM	Institute of Medicine
MoH	Ministry of Health
NHMRC	National Health and Medical Research Council
NRV's	Nutrient Reference Values for Australia and New Zealand
NZ	New Zealand
PFS	Parent Frequency Score
RDI	Recommended Dietary Intake
RRB	Repetitive and Restrictive Behaviours
SBMD	Sensory-based Motor Disorder
SDD	Sensory Discrimination Disorder
SF	Serum Ferritin

SIPT	Sensory Integration and Praxis Tests
SIT	Sensory Integration Theory
SMD	Sensory Modulation Disorder
SP	Sensory Profile
SPD	Sensory Processing Disorder
SPM	Sensory Processing Measure
SPSS	Statistical Package for the Social Sciences
SSP	Short Sensory Profile
SSRC	Sense and Self-Regulation Checklist
TFS	Total Frequency Score
US	United States
VIDOMA	Vitamin D and Omega-3 in Autism
WHO	World Health Organisation

# Chapter 1

## 1.0 Introduction

Autism Spectrum Disorder (ASD) is a life-long neurodevelopmental condition affecting how individuals interact with others and their environment. Diagnostic criteria include repetitive and restrictive behaviours (RRB), social and communication deficits, and sensory issues (American Psychological Association 2016).

### 1.1 Sensory Issues

There are seven defined sensory systems: hearing, vision, touch (tactile), taste, smell, body balance and motion (vestibular), and body awareness (proprioception) (Ayres 2005; Nadon 2011). These sensory systems are used in a process called sensory integration (Ayres 1972). The brain receives and processes information resulting from environmental stimulus of the senses via the nervous system. The organisation of these sensations within the brain allow for the effective use of the body within the given environment (Ayres 1972).

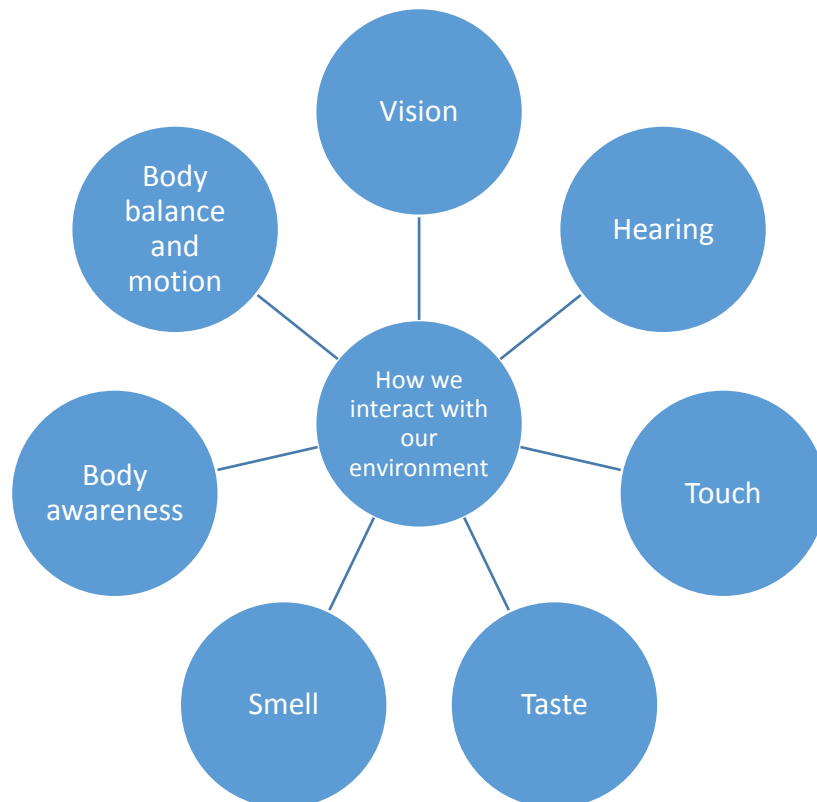


Figure 1. *The senses affecting how we interact with the environment.*

Typical sensory integration enables social participation and the ability to plan and conceive new ideas (planning and praxis). These are expressions of how we interact with our environment and are called higher-level integrative functions. Sensory systems and higher-level integrative functions should be measured conjointly due to their collective involvement in sensory integration (Parham 2007). Some individuals have typical, or 'good' integration of certain senses, while others do not. Children can have 'vulnerabilities' in specific senses, such as under- and over-responsiveness, sensory-seeking behaviour, and perceptual problems (Parham 2007). These vulnerabilities indicate atypical sensory integration.

Sensory Processing Disorder (SPD) is the term used to define the presentation of sensory integrative dysfunction in individuals (Miller 2008), otherwise called "sensory issues". Sensory issues lead to higher-level integrative function issues, and alter the way an individual responds to their environment (Ayres 1972). Until recently, children with sensory issues were overlooked as the disorder does not present as a physical illness, leading to diagnosis difficulties for medical professionals. Now there is a growing understanding of the impacts that sensory issues have on individuals, including children with ASD.

Prevalence of sensory issues in ASD children range from 44-90% (Baranek 2002; Leekam 2007). Sensory processing in ASD is more varied than in typically-developing children, and can range from typical to highly dysfunctional (Watling 2001). ASD individuals are more likely to have multiple sensory issues than a single issue alone, and those with ASD have significantly more sensory issues across multiple sensory systems than controls (Leekam 2007). Sensory issues can make daily life challenging, and can affect many activities that are simple for others, such as mealtimes.

## 1.2 Difficult Mealtime Behaviours

Common difficult mealtime behaviours include aversions to texture (Cermak 2010; Marshall 2014; Whiteley 2000), refusal to try new foods (Bandini 2010; Marshall 2014; Nadon 2011), excessive fussiness or food selectivity (Bandini 2010), limited food variety (Marshall 2014), problems with object manipulation and control (Riquelme 2016; Staples 2010) and self-feeding skills (Martins 2008), and aversions to eating foods when presented in a certain way, such as foods touching on a plate (Schreck 2006). Whilst the terminology may differ, "difficult mealtime behaviours", "feeding difficulties" and "feeding issues" in the literature describe problems similar or the same to those mentioned above.

Whilst not currently included in diagnostic criteria for ASD (APA 2015), up to 95% of children with ASD have been reported to present with difficult mealtime behaviours (De Meyer 1979). Not only do children with ASD display a greater range of such behaviours compared to typically-developing children, they tend to have greater severity of these behaviours (Castro 2016; Lockner 2008). Evidence suggests difficult mealtime behaviours are associated with sensory issues (Cermak 2010; Lockner 2008; Nadon 2011). For example, a child who has body balance and motion issues may struggle to sit upright in a chair, affecting their ability to focus on eating their food. Therefore, sensory issue-associated difficult mealtime behaviours may be a significant factor leading to atypical or restricted food and nutrient intakes.

### 1.3 Food and Nutrient Intakes in ASD

Compromised nutrition, especially during early childhood, can result in growth and developmental delays, permanent damage to body systems, invasive medical procedure interventions, and impede socialisation and learning (Sharp 2013). Promoting adequate nutrition in children with ASD is important to optimise health and development, and reduce the impact that ASD has on New Zealand (NZ) children and their families.

Difficult mealtime behaviours have been linked to an increased risk for nutritional inadequacies (Cermak 2010; Lukens 2008; Paterson 2011). Despite these findings, research has not identified any distinctive pattern within ASD food or nutrient intakes. While food intakes in some cases appear to be more limited or selective, it is uncertain if these food restrictions are severe enough to impact growth and development. While vitamin and mineral deficiencies have been identified, the same or different nutrients have been found in excess among other populations of ASD children (Adams 2004; Barnhill 2015; Bicer 2013; Castro 2016; Levy 2007; Ranjan 2015; Sharp 2013).

### 1.4 Study Purpose

Associations between sensory processing, mealtime behaviours, and food and nutrient intakes in children with ASD have not been fully explored. The purpose of this study was to investigate the links between sensory issues, mealtime behaviours, and food and nutrient intakes in a group of children aged 2.5 to 8 years of age with ASD. This group of children were part of a larger ongoing randomised-control trial, the Vitamin D and Omega-3 in Autism (VIDOMA) study. Baseline data involved the assessment of sensory processing dysfunction using the Sensory Processing Measure (SPM) (Parham 2007) and difficult mealtime behaviours using the Behavioural Paediatric Feeding Assessment Scale (BPFAS) (Crist 2001). These tools are commonly used in clinical practice. Food and nutrient intakes were measured using four-day food diaries and the unpublished Dietary Index for a Child's

Eating (DICE) tool developed by researchers at Massey University. Biochemical markers for vitamin B12, folate, haemoglobin, and serum ferritin were also taken to provide additional evidence concerning the extent of dietary sufficiency of these nutrients.

Children with ASD in NZ are regularly monitored by medical health professionals to ensure the best possible outcomes for both physical and psychological development. However, from a nutritional perspective faltering growth is the standard symptom leading to dietetic referral (World Health Organisation 2016). However, ASD children with sensory issues who are experiencing minor nutritional inadequacies may not necessarily experience faltering growth and nutrition can be sub-optimal even if the child appears to be getting sufficient food. If associations are found between the SPM, BPFAS, and/or food and nutrient intakes, these tools may then be useful for the nutritional screening of children with ASD in NZ.

### 1.5 Study Aim, Objectives, and Hypotheses

#### *Aim:*

To investigate associations between sensory issues, difficult mealtime behaviours, and food and nutrient intakes in children aged 2.5-8 years with ASD.

#### *Objectives:*

- To measure sensory processing issues in children aged 2.5-8 with ASD using the Sensory Processing Measure (SPM).
- To measure difficult mealtime behaviours using the Behavioural Paediatrics Feeding Assessment Scale (BPFAS).
- To measure food intake, nutrient intakes, and biochemical markers using the Dietary Index for Child's Eating (DICE) tools, four-day food diaries, and blood sample analysis, respectively.
- To investigate relationships between sensory issues, difficult mealtime behaviours, and food and nutrient intakes.

#### *Hypotheses*

- 1) Increases in sensory issue severity will be related to increases in frequency of difficult mealtime behaviours.
- 2) Increases in sensory issue severity will be related to decreases in food and nutrient intakes.
- 3) Increases in frequency of difficult mealtime behaviours will be related to decreases in food and nutrient intakes.

## 1.6 Thesis Structure

This thesis comprises four chapters. Chapter 1 introduces the scope and justification of this research, including aim, objectives, hypothesis, thesis structure, and researchers' contributions. Chapter 2 presents the literature review, providing a summary and analysis of research relevant to this study, and identification of previous literature limitations. Chapter 3 presents the research manuscript. It provides a summary of the study, a brief background of ASD, and current studies involving difficult mealtime behaviours and food and nutrient intakes in ASD children. The justification for the study and the tools and methods used for data collection are described. A succinct summary of the most important findings is given, their relevance for current ASD research, and considerations for future research based on study findings and limitations. Chapter 4 concludes the study, providing a summary of study highlights and learnings.



## 1.7 Researchers Contributions

Table 1. *Researchers contributions.*

Nicole Taylor	Aided recruitment and data entry, conducted research, statistical analysis, interpreted results and subsequent recommendations, authored thesis.
Dr Pamela von Hurst	Primary supervisor. Devised the concept for the proposed study, provided guidance of thesis writing, data analysis, revised and approved thesis, and is Principle Investigator for VIDOMA trial.
Dr Cath Conlon	Co-supervisor, provided guidance of data analysis, revised and approved thesis.
Kathryn Beck	Assisted with appropriate amendments to Dietary Index for a Child's Eating tool.
Hajar Mazahery	Project Leader of VIDOMA trial. Participant recruitment, data collection, and aided understanding of tools. Provided writing guidance.
Owen Mugridge	Participant recruitment and contact, data collection.

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# Chapter Two

## 2.0 Literature Review

### 2.1 What is Autism?

ASD is a life-long neurodevelopmental disorder that affects how individuals relate to their environment. It is measured on a spectrum as a number of different signs and symptoms indicate ASD, and vary in their severity. Symptoms can be recognised in children as young as 18 months of age, noticed by lack of eye contact, little or no engagement with playmates, and no apparent recognition of name (Johnson 2007). Alongside social and communication deficits, RRB are considered a categorical characteristic of ASD, shown through continuous behaviours such as noise-making or flapping of the hands (APA 2016). Another common and recently recognised symptom of ASD are sensory issues (Schoen 2014), which is a focal point of a lot of current research.

#### *Diagnosis and Severity*

ASD diagnosis is undertaken by a medical professional using the Diagnostic and Statistical Manual of Mental Disorders, 5<sup>th</sup> edition (DSM-V) (APA 2015). The main criteria for diagnosis include:

- 1) “Persistent deficits in social communication and social interaction across multiple contexts”.
- 2) “Restricted, repetitive patterns of behaviour, interests, or activities”. Note that at least two specified behaviours must be present. Hyper- and hyporeactivity to sensory input is one of these specified behaviours.

Additionally, symptoms must be observed within the early development period and must cause significant functional impairments. As diagnostic criteria focuses heavily on social interaction observation, concerns may not develop until children enter the early childhood education environment or school system and are exposed to new environment and other children (Ministries of Health and Education 2016). For this reason, guidelines for accurate diagnosis of ASD differ between ages from 1-3 years and 4-8 years.

An ASD diagnosis is only given where no better explanation is provided for the presentation of specified symptoms e.g Global Developmental Delay. Symptoms of ASD are not exclusive, and it is important that health care professionals have a good understanding of other conditions that share ASD symptoms for accurate diagnosis (MoHE, 2016). As well as

identification of symptoms, a severity level is provided for both social communication impairments and RRB. Severity is categorised as either Level 1, 2, or 3, where level 3 is the most severe.

It is important that diagnosis occurs as early as possible to reduce challenging behaviours and improve treatment outcomes. Despite this, access to assessments leading to diagnosis is inconsistent and inequitable in NZ, and the applicability of diagnosis and assessment tools have yet to be established in NZ population (MoHE 2016).

### *Prevalence in NZ*

Currently, an estimated 65,000 people living in NZ have ASD (Autism New Zealand 2016). The prevalence of ASD is increasing (Neggers 2014; Ranjan 2015), although accurate diagnosis can be difficult. Changes in the definition for a positive diagnosis, genetic, environmental, immunological influences, or a combination of factors could be contributing to rising numbers (Autism Research Institute 2012). Autism is estimated to be 4.2 times more common in males than females, with no clear understanding of why this occurs (Fombonne 2009).

## 2. 2 Sensory Issues

Every person experiences the world in a slightly different way. For most people, our senses allow us to interpret and respond to environmental stimuli in a typical manner. For others, issues within the integration of sensory information lead to interpretation differences, and therefore an atypical response to the environment. This is known as the Sensory Integration Theory (SIT) developed by Dr Anna Jean Ayres in 1970's (Ayres 1972). Based on this theory, the term Sensory Processing Disorder (SPD) was coined. It covers individuals with over-responsiveness, under-responsiveness, sensory seeking, poor sensory discrimination, and atypical responses to sensory stimuli (Miller 2008). There are three classifications of SPD:

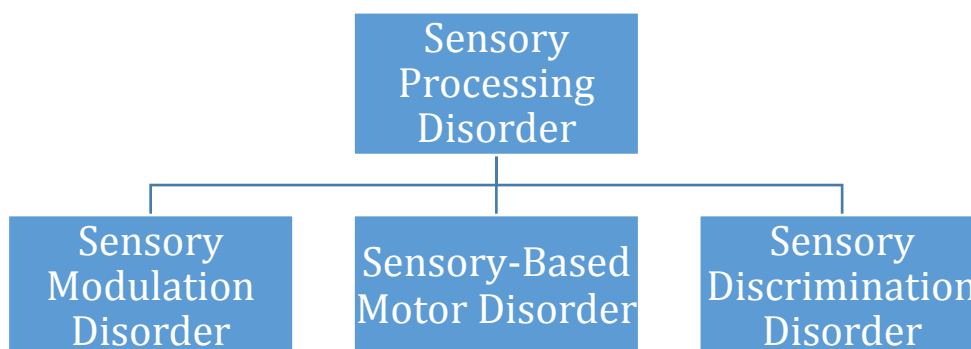


Figure 2. *Classifications of sensory processing disorder.*

### *Sensory Modulation Disorder (SMD)*

SMD refers to issues occurring within the central nervous system process which provides information regarding the intensity, duration, frequency, complexity and novelty of sensory stimuli (James 2011). SMD covers three subtypes: over-responsivity, under-responsivity, and sensory seeking behaviour. Individuals with SMD may exhibit self-involved behaviours, stubbornness, anxiety, or actively seek specific sensations (James 2011).

### *Sensory-based Motor Disorder (SBMD)*

SBMD is where an individual presents with atypical motor responses, including postural control difficulties or poor coordination as a result of issues within sensory processing (Miller 2007). Subtypes include dyspraxia and postural disorder.

### *Sensory Discrimination Disorder (SDD)*

SDD involves atypical sensory information processing, where symptoms are dependent on the subtype and how poorly the information is processed (Miller 2007). Subtypes include visual, auditory, tactile, taste, smell, position/ movement, and interoception. These terms can also be referred to by different names, despite being interchangeable. For example, tactile is also common referred to as touch, and interoception as body awareness.

SPD can affect one senses or multiple senses, and symptoms vary between individuals depending on their classification and subtype. While our understanding of the neural processes resulting in SPD are becoming clearer, the initial cause of SPD is unknown. There is some evidence to suggest that certain sensory issues such as tactile and auditory can be genetically influenced (Goldsmith 2006). Additionally, it has been discovered that children with SPD may have a different white matter microstructure within the brain (Owen 2013). This difference is distinguishable between children with SPD, typically-developing children, and children with ASD, suggesting that while sensory issues are present in ASD, ASD does not determine whether or not a child will have atypical sensory processing.

## 2. 3 Sensory Issues in ASD

Sensory issues are a recent addition to ASD diagnostic criteria within the DSM-V. Sensory issues are defined as “hyper- or hyporeactivity to sensory input or unusual interests in sensory aspects of the environment” (APA 2015). While not every child with ASD has SPD, the number of children with ASD experiencing sensory issues has been reported from 44-88% (Baranek 2002), and as high as 90% (Leekam 2007). Descriptions of sensory issues and their various symptoms are described below (Table 2).

Table 2. Sensory stimuli and their possible effects on children and young people with ASD.

Sensory system	Description	Some behaviours that might be observed
Vestibular	Movement of body in space	<ul style="list-style-type: none"> <li>• Motion sickness</li> <li>• Fear of heights</li> <li>• Avoidance of balancing activities or participation in sports</li> <li>• Seeking fast-moving activities</li> <li>• Engaging in frequent spinning, bouncing or running</li> <li>• Seeming oblivious to the risks of heights or moving equipment</li> </ul>
Tactile	Provides information about factors such as touch, pressure, texture, hard/soft, sharp, dull, heat/cold, pain	<ul style="list-style-type: none"> <li>• Avoidance of touch contact</li> <li>• Disliking and avoiding messy play</li> <li>• Disliking having hair brushed or washed</li> <li>• Appearing irritated by certain clothing and food textures</li> <li>• Appearing irritated by others' proximity</li> <li>• Appearing fidgety or active</li> <li>• Using hands to explore</li> </ul>
Proprioceptive	Provides information about where a certain body part is and how it is moving	<ul style="list-style-type: none"> <li>• Enjoying rough-and-tumble play</li> <li>• Relaxing when given firm touch or massage</li> <li>• Exerting too much or not enough pressure while handling objects</li> </ul>
Visual	Provides information from the eye about objects and people	<ul style="list-style-type: none"> <li>• Discomfort in strong sunlight</li> <li>• Sensitivity to television/computer screens or changes in lighting</li> <li>• Enjoying flickering objects (eg, computer, flicking pages, flickering hands)</li> <li>• Focusing on shadows, reflections or spinning objects, lines, patterns</li> </ul>
Auditory	Provides information about sounds in the environment	<ul style="list-style-type: none"> <li>• Becoming upset at loud or unexpected noises</li> <li>• Humming or singing to screen out unwanted noise</li> <li>• Unusual responses to voices</li> <li>• Dislike of large indoor spaces</li> <li>• Fleeing the area and refusing to go back</li> <li>• Behaviour such as flapping or rocking</li> </ul>
Olfactory (smell) or gustatory (taste)	Provides information about different types of tastes or smells	<ul style="list-style-type: none"> <li>• Dislike of strong smells or tastes</li> <li>• Craving strong smells or tastes</li> <li>• Eating non-edible items (sometimes referred to as 'pica')</li> <li>• Eating a restricted range of foods</li> </ul>

Table reproduced from *The New Zealand Autism Spectrum Disorder Guidelines (2<sup>nd</sup> ed.)* (MoHE 2016).

## 2. 4 Tools Used To Measure Sensory Issues in ASD

There are a vast majority of tools available which can be used to measure sensory issues in children. A slightly smaller pool of tools have been validated in children with ASD. A full description of these tools have been completed in Table 3.



Table 3. Tools used to measure sensory processing in ASD children.

Title & Author	Description	Standardisation, Reliability, Validity	Advantages/ Disadvantages
<p>The Sensory Profile (SP) (Dunn 1999)</p>	<p>For ages 3-10 years, developed in the USA. 125-item parent/caregiver questionnaire using a 5-point Likert Scale. It measures sensory processing within the following systems:</p> <ul style="list-style-type: none"> <li>• Auditory</li> <li>• Visual</li> <li>• Vestibular</li> <li>• Touch</li> <li>• Multisensory</li> <li>• Oral Sensory</li> </ul> <p>It also measures modulation, behaviour and emotional responses. Children are classified into one of: sensation seeking, sensation avoiding, sensory sensitivity, and low registration.</p>	<p>The SP was standardised on 1,200 children including those with intellectual disabilities, attention deficit hyperactivity disorder and ASD. Cronbach's alpha for internal consistency for the sections ranged from .47 to .91 (Dunn 1999). In addition, good validity was reported in a comparative sample involving 26 parents of ASD children and 26 parents of typically-developing children in Australia (Brown 2008).</p>	<p>A well-known, widely used tool. It has been used in a sample of medically diagnosed ASD children in Taiwan (Chuang 2012) and Canada (Jasmin 2009), alongside multiple studies in the US as described by McConachie (2015).</p>

<p>The Short Sensory Profile (SSP) (Dunn 1999)</p>	<p>For ages 3-10 years, developed in the USA. The SSP is a shortened version of the Sensory Profile. Is a 38-items parent/caregiver questionnaire consisting of 7 sections covering:</p> <ul style="list-style-type: none"> <li>• Sensitivities for tactile, taste/smell, movement, visual/auditory, under-responsiveness/seeks sensation, auditory filtering and low energy/weak.</li> </ul>	<p>The SSP is a standardised questionnaire, with a Cronbach's alpha for internal reliability (.70 to .90) for test total and sections. Construct validity has also been established for the different sections ranging from .25 to .76 (McIntosh 1999b), and Watling (2001) described good validation in a sample of ASD children.</p>	<p>The SSP is specifically designed for research. It eliminates items of the SP which overlap with the diagnostic features of ASD e.g social-communication items (Tomchek 2007). However, it does have a more limited range of assessment than other tools.</p>
<p>Sensory Integration and Praxis Tests (Ayres 1989)</p>	<p>For ages 4-9 years, developed in the USA. This tool is undertaken on a battery-run electronic device and consists of 17 tests designed to assess:</p> <ul style="list-style-type: none"> <li>• Visual performance</li> <li>• Tactile performance</li> <li>• Movement perception</li> <li>• Motor performance.</li> </ul> <p>The tests are completed by the clinician or trained administrator with the child, taking up to 2 hours for the full test.</p>	<p>The normative sample consisted of 1,997 children aged 4-8 years old. The individual tests have a high inter-rate reliability of .90. Content validity and construct validity were established.</p>	<p>Developed by Dr Anna Jean Ayres based on SI (Ayres 1972). Does not require parent/caregiver reporting. Extensive training is required to administer the test. Inappropriate for children with significant behavioural or communication issues, which may lead to difficulty following test instructions (Ayres 1989).</p>

<p>The Sensory Processing Measure (SPM) (Parham 2007)</p>	<p>For ages 5-12 years, developed in the USA. It was based on the SIT (Ayres 2005). The Home form (75-items) and the Main Classroom Form (62 items) consist of a 5-point Likert-scale parent/caregiver/teacher questionnaire. It measures dysfunction in the seven sensory systems and higher-level integrative functions:</p> <ul style="list-style-type: none"> <li>• Vision</li> <li>• Hearing</li> <li>• Touch</li> <li>• Body awareness</li> <li>• Body balance and motion</li> <li>• Taste and smell (subscale)</li> <li>• Social participation</li> <li>• Planning and praxis</li> </ul> <p>T-scores are provided for each scale and determine which sensory category the child fits into: typical, some problems, or serious dysfunction.</p>	<p>The SPM was standardised in a demographically representative sample of 1,051 typically-developing children. The Home Form scales have good internal consistency from .77 to .95 and a test-retest reliability from .94 to .98 (median .97) (Parham 2007). The Main Classroom Form scale have an internal consistency from .75 to .95 and a test-retest reliability from .95-.98. The tool has been standardised and validated in a sample of NZ children (Brown 2010).</p>	<p>Different versions of the SPM are available (3-5 and &gt;5 years old) to allow for different developmental stages. The different forms (home. vs classroom) allow for the test to be undertaken in a specific environment, as literature suggests different settings provide unique challenges resulting in different sensory responses (Fernandez-Andres 2015).</p>
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<p>The Sense and Self-Regulation Checklist (SSRC) (Silva 2012)</p>	<p>For children under 6 years of age, developed in the USA. The tool comprises a 3-5 point Likert Scale parent/caregiver questionnaire to measure sensory and self-regulatory difficulties identified as comorbidities specific to ASD children. It consists of 6 sensory subdomains:</p> <ul style="list-style-type: none"> <li>• Touch-pain</li> <li>• Auditory</li> <li>• Visual</li> <li>• Taste-smell</li> <li>• Hyper-reactive to non-injurious stimuli</li> <li>• Hypo-reactive to injurious stimuli</li> </ul> <p>Specific body areas are tested providing individual items for each subdomain. Self-regulation is also tested, (sleep regulation, emotional regulation, self-soothing, orientation/ attention) in response to social stimuli.</p>	<p>Tool items were developed through conducting interviews with more than 100 parents of children with ASD. The SSRC was validated in 264 children less than 6 years of age with typical development (n=138), ASD (n=99) or other developmental delays (n=28) (Silva, 2012). Overall scale scores provided good internal consistency, with a Cronbach's alpha of .87 for children with ASD. Test-retest reliability was calculated in a sample of 38 children with ASD, with a coefficient of .67 for the overall score.</p>	<p>In addition, the SSRC had adequate psychometric testing validation and is able to discriminate sensory processing and self-regulation between ASD children and children from other groups. However, it does not fully assess all the sensory domains and is limited to children under the age of 6 years.</p>
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Sensory issues are not solely responsible for social, communicative, and behavioural problems observed in ASD, but contribute to a wider pool of factors theorised to influence these symptoms (Baranek 2006). Additionally, sensory issues impact many other aspects of life and can have a significant influence on basic daily activities, such as mealtimes.

## 2.5 Difficult Mealtime Behaviours

Eating and feeding are two critical activities of daily living, and are defined as “the ability to keep and manipulate food or fluid in the mouth and swallow it” and “the process of setting up, arranging, and bringing food or fluid from the plate or cup to the mouth”, respectively (American Occupational Therapy Association 2008). Issues with eating or mealtime behaviours can be disruptive not only for the child who struggles with these tasks, but the family as well. As eating is vital to our health and wellbeing, a parent or caregiver who believes that their child is not eating well or is struggling at mealtimes may find this activity stressful.

### *What are Difficult Mealtime Behaviours?*

Difficult mealtime behaviours have been described in a number of different ways and a clear definition is not always present within studies. Difficult mealtime behaviours encompasses all issues related to eating issues and behaviours at mealtimes, including aversions to texture (Cermak 2010; Marshall 2014; Whiteley 2000), refusal to try new foods (Bandini 2010; Marshall 2014; Nadon 2011b), excessive fussiness or food selectivity (Bandini 2010), limited food variety (Marshall 2014), problems with object manipulation and control (Riquelme 2016; Staples 2010) problems with self-feeding skills (Martins 2008), and aversions to eating foods when presented in a certain way, such as foods touching on a plate (Schreck 2006).

### *Causes of Difficult Mealtime Behaviours*

Difficult mealtime behaviours may be a result of a single issue, or a combination of different issues. These may include motor disorders which affecting feeding, learning differences, communication difficulties, behaviour difficulties, or SPD (Marshall 2014). SPD has been directly associated with difficult mealtime behaviours within the literature (Cermak 2010; Lockner 2008; Nadon 2011b). Additionally, environment factors, and medical issues such as respiratory or gastrointestinal symptoms can result in mealtime behaviour issues (Stevenson 1991). Children with ASD have significantly more gastrointestinal symptoms than typically- developing children, where onset of symptoms is associated with the initiation of difficult mealtime behaviours (Mason-Brothers 1993). Therefore ASD children who experience such medical issues may be at greater risk of developing difficult mealtime behaviours (Lukens 2008).

### *Prevalence of Difficult Mealtime Behaviours*

It is commonly known that many young children are “fussy” when it comes to their food. About 25% of typically-developing children experience feeding issues and up to 80% in children with developmental delays (Schmitt 2008). In ASD, difficult mealtime behaviours appears to be highly prevalent, where up to 90% may present with behaviours that would dietary intake (Sharp 2013a). Difficult mealtime behaviours in ASD children do not appear to improve with age (Provost 2003), hence the need for intervention as early as possible.

### *Comparison of Mealtime Behaviours in Typical-Developers and Children with ASD*

Provost (2010) led an investigation covering early feeding, mealtime environments, food preferences and restrictions, and parental perceptions of children with ASD compared to typically-developing children using the unpublished Mealtime Survey developed by the authors. Controls were age-, gender- and ethnicity- matched, with the overall study consisting of 48 children aged 3-6 years old. Children with ASD showed significantly more difficult mealtime behaviours, including resistance to trying new foods, limited food repertoires, picky eating, gagging, and resistance to eating at new locations. Differences in eating and mealtime issues appear to begin around 1 year of age, and increase in severity after age 2, reinforcing the need for early intervention to reduce the impacts of these issues.

Similar findings were observed by Castro (2016). Difficult mealtime behaviours of 49 boys aged 4-16 years with ASD were investigated using the BPFAS. It was found ASD children had higher overall frequency scores (92.9 vs 69.06) compared to age- and socioeconomic status matched controls. Higher frequency of difficult mealtime behaviours were also associated with overweight/ obesity. Study limitations such as parental bias with the use of food diaries and lack of consideration of drug administration and impacts on behaviour were noted.

Lockner (2008) conducted a study on 20 children aged 3-5 years old with ASD and 20 gender-, age- and ethnicity-matched controls. Significant differences in eating behaviours were reported between parents of children with ASD and those of typically-developing children. They reported children with ASD were far more likely to have favourite food textures (68.0% vs 5.0%), exhibit picky eating behaviours (79.0% vs 16.0%), refuse new foods (95.0% vs 47.0%) and also less likely to have a variety of foods (16.0% vs 58.0%).

Comparisons of difficult mealtime behaviours between ASD children and their typically-developing siblings have also been undertaken. Nadon (2011b) used a modified version of the Eating Profile (Lussier 2002) to compare 96 children (48 families) where half the children were typically-developing and half had ASD. Children were aged 3-12 years. The

sibling with the closest age to the ASD child was chosen for comparison. On average, children with ASD had 13.3 eating problems according to the Eating Profile, whereas their siblings had only 5.0. Again, children with ASD appeared to have greater issues as infants compared to the sibling. Direct comparison of children within the same family means that children are more likely to have been exposed to a similar social and learning environment, which reduces these as limitations within the study.

## 2. 6 Tools Used to Measure Difficult Mealtime Behaviour

A number of different tools have been used to measure difficult mealtime behaviours in ASD children. Those which have been validated in ASD are presented in Table 4.

It is important to note that while typically-developing children may also present with difficult mealtime behaviours, parents show greater concern for children with ASD, even if overall behaviour frequency is similar (Provost 2010, Harvey 2015). This should be addressed as a potential limitation within studies. Tools used to measure difficult mealtime behaviours are usually parent- or caregiver- based observation questionnaires, and are open to bias. On the other hand, while professional objectivity is important, parents and caregivers are also very familiar with their child's behaviours, and observations tend to reflect a broader range of behaviours, whereas a researcher or professional's observation hours may be limited. Therefore, input from both parties would be likely to produce more accurate results.

Table 4. Tools used to measure mealtime behaviours in children with ASD.

Title & Author	Description	Standardisation, Reliability, Validity	Advantages/ Disadvantages
<p>Brief Autism Mealtime and Behavior Inventory (BAMBI) (Lukens 2002)</p>	<p>Designed for ages 3-10 years, and developed in the US. This parent/caregiver questionnaire comprises a 5-point Likert Scale to report the frequency of behaviour, as well as a yes or no question to determine if the behaviour is perceived as a problem for the parents. The original BAMBI (Lukens 2002) consisted of 20-items to evaluate mealtime behaviour issues in ASD children. The tool collected information on 2 factors: food variety and food refusal. It was later reduced to 18-items (Lukens 2005), then to 15 items (DeMand 2015), and finally to 10-items and renamed the Brief Assessment of Mealtime Behaviour in Children (Hendy 2013). The updated 10-item tool can be used in special needs including ASD, and measures:</p> <ul style="list-style-type: none"> <li>• Limited Variety</li> <li>• Food Refusal</li> <li>• Disruptive Behaviour</li> </ul>	<p>The BAMBI was standardised on 68 children with ASD and 40 typically-developing children, with an original internal consistency was .61 for the full scale (Lukens 2002). The 18-item BAMBI scored .87 for test-retest reliability undertaken over a mean time of 7 months and Good validity was also established (Lukens 2005). A study within 308 parents of Turkish children with ASD instigated the removal of 4 more items to create an updated valid and reliable measure (the 15-item BAMBI) (Meral 2014).</p>	<p>The BAMBI is specifically designed to measure feeding issues in ASD children. The 15-item tool distinguishes between clinical and non-clinical feeding problems, and can be used as a screening tool (Meral 2014). While the 15-item tool correlates highly with BPFAS (Lukens 2008) and is similar in design, it contains fewer items than the BPFAS so has a limited ability for individual behaviour analysis. Validation of any BAMBI tool has yet to be undertaken in a NZ sample.</p>



<p>Mealtime Survey (Unpublished) (Provost 2003)</p>	<p>This tool is designed for children aged under 6 years old, and was developed in the US. It consists of a 49-item parent/caregiver survey measuring:</p> <ul style="list-style-type: none"> <li>• Early feeding history</li> <li>• Mealtime Environment</li> <li>• Child likes and dislikes</li> <li>• Parental views</li> </ul>	<p>The tool was piloted on 4 families, 2 with ASD children, 2 with typically-developing children. It was face and content validated in ASD children by a panel of ASD experts, although no further reliability or validation tests have been undertaken (Provost 2003).</p>	<p>Designed specifically for the assessment of mealtime behaviours in ASD children. It covers a wide number of behaviours. However this tool has very limited reliability and validity results. Normative sample consists of only 2 families.</p>
<p>Eating Profile (Lussier 2002)</p>	<p>The Eating Profile was developed in France. An age range specification could not be found. It consists of a parent/caregiver reported 145-items questionnaire covering 11 domains measuring:</p> <ul style="list-style-type: none"> <li>• Child and family diet history and behaviours</li> <li>• Parental perception of intake</li> <li>• Child's health</li> <li>• Food behaviours</li> <li>• Non-mealtime behaviours</li> </ul> <p>The questionnaire contains both 3 to 5 Likert-scale questions and a number of yes/no questions.</p>	<p>The original Eating Profile has good face validity within an ASD population as reported by the developers, which was established by 5 experienced occupational therapists and a consultant with ASD (high functioning). It had good to high test-retest reliability although kappa scores were below 0.4 for 4 domains (Lussier 2002).</p>	<p>The tool was designed specifically to address behaviour, food intake, and parental strategies of children with ASD. However, the psychometric analysis of the Eating Profile is limited (Nadon 2011).</p>

<p>Children's Eating Behaviour Inventory (CEBI) (Archer 1991)</p>	<p>This tool was developed in the US and is designed for the assessment of children aged 2-12 years. This parent/caregiver questionnaire measures the frequency and severity of mealtime problems, as well as the level of caregiver stress associated with these problems who have children with developmental disorders. Originally 71-items, the updated version consists of 40 items and covers:</p> <ul style="list-style-type: none"> <li>• Food preferences</li> <li>• Motor skills</li> <li>• Mealtime behaviours</li> <li>• Caregiver emotions and responses to behaviours</li> </ul> <p>The CEBI is in a 5-point Likert-Scale format, with reverse scoring depending on the phrasing of the question with the total sum provides a total eating problem score.</p>	<p>Preedy (2011) describes how this standardised tool presented a Cronbach's alpha ranging from .58 to .76 across four subgroups of children. The test-retest reliability was undertaken over 4-6 weeks and produced a coefficient of .87 for the total problem score. The tool also has good construct validity, and is able to distinguish between children referred for clinical feeding problems and those that are not (Archer 1991).</p>	<p>The CEBI was not designed specifically for an ASD population. It has been used for the behavioural assessment of with ASD children and has a similar concept to the BPFAS, although has a limited number of studies investigating the validity of the tool compared to the BPFAS (Preedy 2011).</p>
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<p>Behavioural Paediatric and Feeding Assessment Scale (BPFAS) (Crist 2001)</p>	<p>This tool was developed for children aged 9 months to 8 years in the US. It consists of a 35-item parent/caregiver reported 5-point Likert Scale questionnaire. It provides a number of measures cover behaviours and emotional responses, including:</p> <ul style="list-style-type: none"> <li>• Total Frequency Score</li> <li>• Total Problem Score</li> <li>• Both Child-related and parent-related Behavioural Score</li> <li>• Both child-related and parent-related Problem score.</li> </ul>	<p>Validation has been undertaken in a sample of children with cystic fibrosis, with a Cronbach's alpha of .88 for the full scale, and a test-retest reliability over 2 years ranging from .82 to .85 (Crist 1994). Further validation has been undertaken taken within a sample containing children with clinical feeding issues and non-clinical feeding issues. Internal consistency was .76 for the full scale showing adequate reliability, and adequate validity was also shown when used to compare children with clinical feeding issues to children without clinical issues (Crist 2001).</p>	<p>This tool measures a wide variety of different behaviours and has a high number of outcome measures. The tool has previously been used within ASD children, identifying significant differences between eating difficulties in children with and without ASD (Martins 2008). The tool reportedly has adequate results on psychometric tests, and can be confidently used for research and clinical practice (Preedy 2011).</p>
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## 2.7 Potential Impacts of Sensory Issues on Mealtime Behaviours

Sensory issues and behavioural symptoms have previously been described (Table 2). Mealtime behaviour specific symptoms relating to sensory issues are occasionally described in the literature, though tend to focus on senses which are more commonly associated with food, such as touch, taste, and smell. There has been very limited evidence provided on the effects of other senses on mealtime behaviours. Associations which have been mentioned are discussed below, as well as logical hypotheses as to how certain senses could relate to mealtime behaviours, which need to be explored with more specific investigations.

### *Auditory*

The inability to accurately process and interpret auditory information is common in ASD (O' Connor 2012). Greater sensitivity to loudness is observed in ASD compared to controls (Khalfa 2004), responded to by clapping the hands over the ears (Attwood 1998; Marco 2011) or screaming, indicating high levels of stress (Attwood 1998). Mealtimes can be quite noisy, the sound of food being prepared or chewed, or utensils being used has the potential to cause distress (Nadon 2011b). A distressed child is less likely to want to eat, and may impact upon food intake, especially as individuals learn to avoid noises which cause them distress (Marco 2011). Limited literature was found on links between food and nutrient intake and auditory issues and further investigation is required.

### *Visual*

Reviews of the literature by O' Connor (2012) and Marco (2001) describe multiple studies investigating ASD difficulties in processing visual information. Atypical responses to visual stimuli suggest that certain colours, shapes, or other visual aspects may become more or less appealing, affecting food intake. It was found that particular food brands or packaging impacted whether or not the child ate the food (Cornish 1998; Whiteley 2000), and food appearance affected intake (Hubbard 2014; Williams 2000). Nadon (2011b) suggested that in typically-developing children, the appearance of food may encourage curiosity and exploration, whereas individuals with visual issues may avoid foods, decreasing food repertoire and restricting nutrient intake.

### *Touch*

Hypersensitivities to touch in ASD are common (Cesaroni 1991; Marco 2011; Rogers 2005; Tavassoli 2015) and are linked to dietary intake and food behaviours as they result in food aversions, making certain food textures intolerable to some individuals (Cermak 2010). Tomcheck (2007) measured touch sensory processing using the SSP in a group of 287 children aged 3-6 years old with ASD. It was found that more than half (56.2%) were picky

eaters, especially regarding texture, compared to 9.7% of the age-matched controls. Alternatively, touch hypo-sensitivities may result in the child stuffing his or her mouth with too much food (Cermak 2010). Smith (2005) described how children with touch hypersensitivity also demonstrated greater sensitivities towards smell, temperature, and textures, compared to typical-developers, reinforcing previous evidence that children with ASD tend present with multiple sensory issues.

#### *Taste and Smell*

Large discrepancies were seen between ASD individuals and controls when investigating taste and smell. Tomcheck (2007) again found that more than half (52.7%) of ASD children would eat only certain tastes, compared to 7.4% of controls. Additionally, 45.9% of children avoided tastes and smells typically found in a child's diet compared to 17.8% of controls. Nadon (2011b) observed a high percentage of ASD participants (48.4%) with definite differences in taste/smell sensitivity according to the SPP. Schreck (2006) reported greater sensitivity was observed towards bitter compounds than other children, causing avoidance of these foods. Sweet foods were heavily preferred by all children. Altered intakes of bitter and sweet foods suggest heightened sensory responses may impact food choices. Overall, taste and smell sensory issues can result in picky eating or distress at mealtimes, reducing the food repertoire and increasing likelihood of nutritional insufficiencies (Bandini 2010).

#### *Body Awareness*

Proprioception refers to the awareness of limb positioning and strength (Fuentes 2011). Previous literature has been inconclusive on the extent of proprioception processing in ASD, and studies investigating proprioception in ASD children is even more limited. Fuentes (2011) found no significant differences in proprioception were found between 12 ASD individuals aged 12-16 years and aged- and IQ-matched controls. Contrastingly, reports of hypo-sensitivities to proprioception in ASD are also common, and upper limb proprioception was found to be poorer in ASD (n=27) than in controls (n=30) (Riquelme 2016). No studies could be found investigating the specific effects of proprioceptive issues on mealtime behaviours in ASD children.

#### *Body Balance and Motion*

The vestibular system is responsible for balance and movement, and involves use of the inner ear, eyes, and associated neural-systems (Vestibular Disorders Association 2016; Ritvo 2013). The vestibular functionality of 89 children aged 4-11 years with ASD was measured using the SPM and SIPT tests. It was found that vestibular bilateral functioning was reduced in ASD children affecting postural control (Roley 2015). Minshew (2004) investigated 79 ASD individuals aged 5 -52 years compared to 61 typically-developing

controls. It was found that overall postural development was delayed in the ASD individuals and never fully developed even once after entering adulthood, meaning the effects of vestibular issues continue throughout the lifespan. Postural stability was also found to be more highly disrupted in ASD compared to typical developers as in previous research.

Sensory information from proprioceptive and vestibular systems are integrated to provide overall sense of balance and strength of movement, also integrating visual systems (Cheldavi 2014; Fuentes 2011). Individuals with ASD present with deficits in postural stability (Fuentes 2011; Minshew 2004) and motor skills (Fuentes 2011; Mache 2016), theorised to have resulted in part to due proprioceptive, vestibular, and visual deficits (Molloy 2003). Reports of motor skill dysfunction include gait, manual dexterity, object control, and locomotor skills (Riquelme 2016; Staples 2010). Closing the eyes has a significant effect on postural control compared to controls, suggesting ASD individuals rely more highly on visual input than proprioception and vestibular systems (Molloy 2003; Stins 2015). While no studies could be found identifying specific vestibular or proprioceptive issues with mealtime behaviours, hypothetically, issues within these senses may have implications for nutrition. A child with poor motor skills or postural stability may struggle with manipulating a knife and fork, or sitting upright to eat a meal, resulting in difficult mealtime behaviours which in turn may affect food and nutrient intake.

#### *Planning and Ideas (Praxis)*

The ability to plan and conceptualise new ideas is part of developmental processes that occur with social interaction and observation. Praxis is the ability to integrate these concepts to complete motor actions, vital to the process of learning new skills (May-Benson 2007). Planning and praxis integrative function can be impeded by sensory issues (Parham 2007) and ASD children were consistently ranked as problematic (Bodison 2015). Fernandez-Andres (2015) found ASD children performed better at home than at school, likely due to being able to follow routines. Difficulty with basic learned mealtime concepts such as using utensils to transfer the food to the mouth as opposed to using the hands can make mealtimes difficult (Rogers 2010). There is limited investigation into the effect of planning and idea processing dysfunction on food and nutrient intake.

#### *Social Participation*

Poor performance in social participation was found in both home and classroom environments in ASD children and is closely linked to planning and idea processes (Fernandez-Andres 2015). The teachers reported greater dysfunction than the parents, being able to observe the children amongst their peers. Children with both ASD and intellectual disabilities (ID) were found to have smaller friend groups and a poorer

relationship with existing friends than children with ID only or TD (Taheri 2016). Children with both ASD and ID also participated much less frequently than other participants in activities. As children learn from observing and responding to their peers, poor performance in this area may affect eating behaviour. While typically-developing children want to engage in the same activities as their peers, such as eating at the same time or trying one another's food, children with ASD are less likely to engage in similar behaviours. Nadon (2011b) found that children with ASD may also have difficulty with social interaction at meal time. As social interaction forms the basis of many eating occasions, dysfunction may affect food and nutrient intake.

## 2. 8 Studies investigating Sensory Issues and Difficult Mealtime Behaviours

A number of studies have investigated associations between sensory issues and difficult mealtime behaviours. Parents of 100 ASD children aged from 22 months to 10 years reported sensory-related aspects affect mealtime behaviours, such as food texture, appearance, smell, taste, and temperature (Hubbard 2014; Williams 2000). However, there are inconsistencies within the literature. Schreck (2004) found that difficult mealtime behaviours were unrelated to ASD characteristics, including sensory issues, and were much more affected by parental food selection. However, these results were produced by comparing severity of ASD diagnosis using the Gilliam Autism Rating Scale (Gilliam 1995) with food intakes. This was a broad measure and researchers did not consider sensory issues independently of other ASD characteristics.

Methodology used in a number of studies appeared to have resulted in missed opportunities for more in-depth investigation of the effects of sensory issues. For example, Johnson (2014) found associations between food selectivity and sensory issues based on a total sensory score combining all systems. Individual influence of each system (olfactory, gustatory, vestibular, auditory and visual) was not noted. Studies also focused on over-sensitivities (Cermak 2010), and with additional biases towards touch and smell (Johnson 2014, limiting our understanding of the full impact of sensory issues on difficult mealtime behaviours.

Paterson (2011) published the only study which appeared to have undertaken a systematic investigation. Participants involved 20 parents of 20 children with ASD. The SSP (Dunn 1999) and the Eating Behaviour Questionnaire (EBQ) (developed by the author) were used to measure sensory issues and difficult mealtime behaviours, respectively. While 20% of items indicated that an increase in sensory issues was significantly associated with an increase in difficult mealtime behaviours, the EBQ was not validated in ASD children. The study also had a small sample size, and the mean age of children was 10.8 years, which is



considerably higher than other studies. Additionally, there was no investigation of potential association of either variable with food and nutrient intakes.

There appears to be an established link between sensory issues and difficult mealtime behaviours within the majority of the literature. However, the consequences of difficult mealtime behaviours on food and nutrient intakes have yet to be more clearly defined.

## 2. 9 The Importance of Nutrition

During infancy and childhood, meeting nutritional requirements for adequate growth and development is important. Nutrition plays a vital role in gene regulation, development, and maintenance of healthy brain structures and function (Dauncey 2013). In typically-developing children, poor nutrition can have quite serious consequences. In children with ASD the impacts of nutrient deficits on neuro-functioning is less understood, although it is thought that an adequate diet may reduce ASD severity, alleviate psychological, gastrointestinal, and metabolic issues (Kawicka 2013).

## 2. 10 Food and Nutrient Intakes in ASD

Despite nutritional inadequacies in ASD children appearing to be common (Mari-Bauset 2014) comparisons of food intake data within studies of ASD children show no discernible pattern. While vegetable intakes across children ASD populations tend to be below recommendations (Cornish 1998; Herndon 2009; Johnson 2008), intakes of other food groups such as breads and cereals, milk and milk products, and meat and meat alternatives show limited consistency across multiple studies (Attlee 2015; Cornish 1998; Herndon 2009; Levy 2007; Mari-Bauset 2014; Stewart 2015).

Fruit, vegetable, carbohydrate, and salt, sugar and fat intakes in ASD do not appear to differ significantly when compared to intakes of typically-developing children (Herndon 2009; Johnson 2008; Sharp 2013b). On the other hand, dairy consumption was lower on average in ASD children compared to controls even after controlling for age, sex, and parental dietary restrictions (Herndon 2009).

While nutrient intakes in ASD vary widely, deficiencies are frequently observed in studies. These include folate (Bicer 2013; Castro 2016; Ranjan 2015), vitamin B12 (Al-Farsi 2013; Ranjan 2015; Sharp 2013b) pantothenic acid, biotin, vitamin C (Adams 2004), vitamin D



(Cannell 2008; Ranjan 2015; Sharp 2013b; Stewart 2015), vitamin E (Mari-Bauset 2014; Ranjan 2015), iron (Castro 2016; Latif 2002; Mari-Bauset 2014) and zinc (Bicer 2013). Protein intakes in ASD children vary considerably, being both low (Sharp 2013b) and in excess of the recommended dietary allowance (Levy 2007). Barnhill (2015) found that among 120 autistic children, only 2 had insufficient energy from protein, and many bordered on excessive. On the other hand, Mari-Bauset (2014) found ASD children were 3.28 times more likely to have inadequate intakes compared to controls. Calcium intakes were low in ASD across multiple studies (Bicer 2013; Castro 2016; Sharp 2013b; Stewart 2015), lower compared to controls (Herndon 2009; Mari-Bauset 2014), yet also found in excess of requirements (Cornish 1998).

It appears that typical-developers also frequently have nutritional deficiencies. Herndon (2009) found that both their ASD participants (n=46) and their control group (n=31) did not meet national recommendations for fibre, calcium, iron, vitamin E, and vitamin D. Additionally, the ASD children consumed significantly more vitamin E than the control group overall, suggesting that in some cases nutrient deficiency severity is greater in typically-developing children.

The effects of nutritional inadequacies in ASD are currently being investigated. It is theorised that nutrient inadequacies may worsen ASD severity (Kawicka 2013). Nutritional supplementation therapy has been used effectively to treat a number of mental disorders, including ASD (Lakhan 2008). Improvements in ASD symptoms severity upon supplementation provide evidence that current diets are insufficient to provide nutrition for optimal neuro-functioning. It is also unknown the extent to which ASD can impact nutrient utilisation within the body. For example, Stewart (2015) noted vitamin D status remained inadequate despite supplementation. It is not known if ASD causes increased requirements of any nutrients compared to typically-developing children.

As a recent addition as distinct criterion for diagnosis, sensory issues may be exacerbated by nutritional inadequacies contributing to increased ASD symptom severity. There is a need for further research into nutritional impacts on cognitive function.

## 2.11 Tools used to Measure Food and Nutrient Intakes

Food diaries are commonly used to analyse food and nutrient intake and are usually completed by study participants, clients, or patients. Participants are asked to record their food and fluid intake over a set number of days. Food and drink portions can be weighed,

measured, or estimated. Food diaries allow researchers or clinicians to gather information about the average intake of individuals and their eating habits. Macronutrient and micronutrient data can also be collected from food diaries. However, food dairies present a number of limitations. They can be time consuming, fictitious in cases where the participant may have forgotten what they ate or embarrassed by their intake, provide inaccurate estimations of intake, or poorly represent typical intakes as they are measured over a limited period of time. A seven-day weighed food record is the gold standard, but is unrealistic for many participants. Alternatively, a shorter food diary should consist of both week-end and week-days, as food patterns and intakes change with work or school commitments. Food dairies should be used in combination with another measure of food and nutrient intake to provide an accurate representation of a typical diet.

Twenty-four hour recalls are another method used to measure food and nutrient intakes. This technique involves requesting the participant to recall all foods eaten the previous day. This tool requires less time and commitment compared to other methods, however it presents all the same limitations as food diaries, as well as representing only one day of intake. In addition, food can only be estimated by the participant, which lacks objectivity and can lead to inaccurate data.

Food Frequency Questionnaires (FFQ) are also commonly used to measure food intakes. This consists of a series of questions usually presented with multiple-choice questions. It may cover the food groups, fluid intake, and other food, nutrients, or behaviours of interest. A dietary index is a larger measure, also laid out in a questionnaire form with a more holistic approach to dietary assessment. They are designed to compare food intakes to national food intake recommendations. There are currently no tools published which assess food intakes against the national MoH Food and Nutrition Guidelines for Healthy Children and Young People (MoH 2012) recommendations in NZ. While there are tools available overseas, these would be inappropriate for the assessment of a NZ diet. The development of a tool designed within NZ would be required for dietary assessment with reference to the national recommendations.

## 2.12 Biochemical Assessment of Nutrient Status in ASD Children

Biochemical assessment of nutrient status indicates the physiological use of nutrients entering the body. Biochemical assessment is used as a strong diagnostic tool for a number of clinical health issues, and is also used to measure the effectiveness of treatment as it directly reflects use of nutrients, medications, or other substances within the body.

Concerning nutrition, while in some cases biomarkers can accurately reflect nutrient intake, different biological processes may affect the absorption or metabolism of certain nutrients, resulting in a reduced or increased use of that nutrient. Use of biochemical assessment is important to reinforce data collected on food and nutrient intakes, and to provide extra evidence in reference to dietary sufficiency. It could also indicate a physiological issue. For example, a person may be consuming their recommended amount of iron each day, yet present with a suboptimal iron status. This may indicate that the body's utilisation of this nutrient is being affected, and further investigation into the cause of this can be undertaken.

While biochemical assessment is an accurate and reliable measure of nutrient status, it is expensive and can cause distress, as a blood sample is required by the participant. For this reason, biochemical markers have been used sparingly in research with autistic children, and even less so where food intake data is also collected.

As an example of the use of food intake data in conjunction with biochemical markers, Sun (2013) investigated the diets and nutritional status of 53 children aged 4-6 years with ASD, and compared them to the diets of 53 age-matched typical developers in China. A three day food diary was used to measure food intake and fasted blood samples were taken to provide biochemical assessment of Hb, zinc, calcium, iron, vitamin A, folate, and vitamin B12. Nutrient intake was also analysed from the collected food diaries using nutritional assessment software by a qualified dietitian. Both results illustrated a number of nutritional inadequacy concerns across calcium, vitamin A, and zinc. Overall, biochemical results supported nutrient intake gathered from the food diaries, suggesting reasonable accuracy and reliability.

Due to the large number of studies not inclusive of biochemical assessment with conflicting results, the use of biochemical markers in conjunction with food intake analysis should be used in future research to improve evidence quality, or otherwise indicate strong physiological influences which need to be addressed.

## 2. 13 Mealtime Behaviours and their Effects on Food and Nutrient Intakes in ASD

There is a considerable amount of evidence to support that difficult mealtime behaviours compromise nutritional intake (Cermak 2010; Lukens 2008; Paterson 2011). Feeding difficulties may affect nutrition from a very young age. Emond (2010) compared 79 ASD infants with 12,901 typically-developing children as part of the Avon Longitudinal Study of Parents and Children. Feeding issues were found to be more prevalent from infancy in ASD,

resulting in a diet with decreased food variety intakes from the age of 15 months despite uncompromised growth and energy intakes.

Schmitt (2008) analysed the nutrient intakes of 20 ASD children aged 7-10 years of age using a 3-day food record. While feeding difficulties were significantly greater in ASD compared to a control group and demonstrating more limited food variety, there were no significant differences in nutritional quality of the diet compared to controls. On the other hand, Kral (2013) found that limited food variety indicates that a child will still have a reduced micronutrient intake and diet quality.

#### *Food Selectivity and Nutritional Impacts*

The term 'food selectivity' is considered a difficult mealtime behaviour, yet has not been consistently defined. Due to its frequent use in research and recognition as a significant issue for ASD children, a more specific investigation of it has been undertaken. 'Food selectivity' includes or exclusively refer to any of the following: "picky eating, frequent food refusals, limited repertoires of foods, excessive intake of a few foods, and selective intake of certain food categories" (Cermak 2010). Food selectivity may result from type, texture, or appearance of the food (Sharp 2013b) and is associated with nutritional deficits (Bandini 2010). Dietary assessment of 22 ASD children showed food selectivity significantly increased risk for at least one serious nutrient deficiency compared to age-matched controls (Zimmer 2012). Analysis of nutrient adequacy was undertaken using a 174 item FFQ and intakes were compared to the averages of typically-developing controls and the US Estimated Average Requirement (EAR) and Acceptable Macronutrient Distribution Range (AMDR). Specific risks of inadequacy were increased for calcium, zinc, vitamin D and vitamin B12. Additionally, Hubbard (2014) found that food refusal significantly restricted vegetable intakes based on colour in both ASD children aged 3-11 years and in the control group.

#### *Difficult Mealtime Behaviours Affecting Growth and Development*

Failure to thrive and a declining growth rate are the standard indicators for inadequate nutrition (WHO 2006). There is cause for concern that children who have nutritional deficiencies may be overlooked if they do not present with faltering growth or failure to thrive. Despite the high prevalence of nutritional deficiencies in ASD children, growth appears in some cases to be unaffected. Sharp (2013b) conducted a review and meta-analysis of 17 studies investigating feeding behaviours and diet quality in ASD, in which all studies contained a comparison group. Despite more frequent nutritional inadequacies identified in ASD, no evidence was found to suggest this translates in to growth issues due to a lack of significant differences in anthropometry (height, weight, BMI) between ASD and

controls. However, it has been established that anthropometry is a poor indicator of dietary quality (Hyman 2012). Additionally, Keen (2008) found ASD-related physical and psychological deficits were linked to severe feeding difficulties in the first year of life. Early onset of inadequate nutrition could have both physical and cognitive health implications for childhood, adolescence, and adult life, especially if deficits are left untreated.

#### 2.14 What is Missing from the Research?

While evidence strongly suggests sensory issues predict difficult mealtime behaviours, there is limited and inconclusive evidence linking both factors to food and nutrient intake inadequacies. Of studies that investigated sensory issues associations with nutrient intakes, the focus was on over-sensitivities (Cermak 2010; Suarez 2012), and lacked investigation into other expressions of sensory issues. No studies were found systematically investigating individual influences of each sensory system on mealtime behaviours or food and nutrient intakes, and frequently only total scores from sensory processing measures were reported. Limited research was found highlighting distinctions between sensory issues and higher-level integrative function issues on mealtime behaviours.

Biomarkers were infrequently used as evidence to determine nutritional status. While more expensive and invasive than other methods, biomarkers give greater detail than food and nutrient intake alone as they allow researchers to understand how the nutrients are being used by the body. Whilst many researchers describe how nutritional deficits are common in their participants, this evidence is based on comparisons of intake to national recommendations. However, without a clear understanding of how the nutrients are absorbed and metabolised, it is difficult to determine if food and nutrient intake is actually insufficient to meet individual requirements. Studies should aim to include some aspects of biomarker analysis to compare with their nutritional data and improve accurate determination of nutritional status.

Future studies should aim to improve upon limitations identified in the current literature to provide exemplary evidence to contribute to the field of research. A systematic distinction between sensory processing and integrated higher-level functions issues, difficult mealtime behaviours, and associations with food and nutrient intakes is needed. A standardised test undertaken with the supervision of a qualified psychologist to evaluate sensory processing and reduce parental bias is recommended. A combination of a dietary index, food diaries, and biomarker evidence should be used to accurately determine and evaluate food and nutrient intakes. Should associations between sensory issues, mealtime behaviours, and food and nutrient intakes be found in a group of NZ children with ASD, the

tools used can be further employed to aid identification and assessment of such issues which may lead to compromised nutrition.

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# Chapter 3

## 3.0 Associations between Sensory Issues, Mealtime Behaviours, and Food and Nutrient Intakes in Children with Autism Spectrum Disorder

*A manuscript prepared for submission to the Journal of Autism Research.*

### 3.1 Introduction

Autism Spectrum Disorder (ASD) is a life-long neurodevelopmental condition affecting 1 in every 100 New Zealander's (New Zealand Guidelines Group 2010). Diagnostic characteristics can include social and communication deficits, repetitive and restrictive behaviours (RRB), and sensory issues (American Psychological Association, 2015). Individuals with ASD vary greatly in the expression and severity of their symptoms, and require a medical diagnosis using the Diagnostic and Statistical Manual of Mental Disorders (5<sup>th</sup> Edition) (DSM-5).

Up to 90% of children may present with sensory issues (Baranek 2002; Leekam 2007). Sensory issues stem from alterations in processing and integration of incoming nervous information received by the sensory systems: vision, hearing, texture, taste, smell, body awareness, and body balance and motion (Fernandez-Andres 2015). Integration of these sensory systems within the brain enable social participation, and the ability to plan and conceive new ideas (planning and praxis) otherwise known as higher-level integrative functions. This process is known as sensory integration (Ayres 1972). Atypical neuro-processing of incoming sensory information (sensory issues) can lead to altered responses to our environment. For simplicity throughout this paper, "sensory issues" will include all sensory systems and integrative functions collectively, unless otherwise stated.

Typical daily activities such as mealtimes can be impacted by sensory issues (Cermak 2010; Nadon 2011; Williams 2000). Difficult mealtime behaviours are commonly observed in ASD, and occur more frequently than in typical-developers (Schreck 2004). Difficult mealtime behaviours include aversions to texture (Cermak 2010), refusal to try new foods (Bandini 2010; Nadon 2011), excessive fussiness and food selectivity (Bandini 2010), or problems with object manipulation and control (Riquelme 2016; Staples 2010).

Difficult mealtime behaviours have in turn been suggested to compromise food or nutrient intakes (Kral 2013) although evidence is inconsistent (Cermak 2010; Johnson 2014;

Lockner 2008; Sharp 2013a). Optimal nutrition is vital for development and maintenance of a healthy brain (Dauncey 2013). Nutritional inadequacies compromise growth and development, resulting in social and learning deficits in children (Sharp 2013b) and could worsen ASD symptoms (Kawicka 2013). There is currently no clear pattern between ASD and food or nutrient intake (Adams 2004; Barnhill 2015; Bicer 2013; Castro 2016; Levy 2007; Ranjan 2015; Sharp 2013b).

Studies which have investigated the relationships between sensory issues, mealtime behaviours and food and nutrient intakes have shown limited findings. Possible explanations for such findings include:

1) Investigations were overly selective or limited, such as linking specific sensory oversensitivities to dietary inadequacies (Cermak 2010). As sensory issues result from a poor integrative process it is important to consider the potential impacts of poor integration upon all of the senses. This may help improve our holistic understanding of the associations between sensory issues on difficult mealtime behaviours and food and nutrient intakes.

2) Investigations were not specific enough, where sensory issues were reported based on a collaborated total score despite tools used being able to provide a more specific analysis (Johnson 2014). While it is understood that sensory issues are related to difficult mealtime behaviours and may impact food and nutrients, it may be possible that certain senses are more highly associated with difficult mealtime behaviours and food and nutrient intakes than others. Individual investigation of all the senses also allows for researchers to distinguish between the senses and the higher-level integrative functions, and their potential associations with difficult mealtime behaviours and food and nutrient intakes.

3) Despite finding associations between sensory issues and difficult eating behaviours, there was no translation of these factors collectively into consequences for food and nutrient intakes (Nadon 2011; Paterson 2011; Smith 2016). This is important to gain a greater understanding of the full significance that sensory issues and difficult mealtime behaviours have for children with ASD. A systematic analysis of associations between sensory issues, difficult mealtime behaviours, and food and nutrient intakes needs to be undertaken in order to determine if there is any relationship between them.

A tool used to measure sensory processing is commonly part of the diagnostic process with ASD, but (anecdotally) we believe that in New Zealand (NZ) these children only receive dietetic assessment if they are demonstrating faltering growth. However, they may be at risk of specific nutrient deficiencies due to both sensory issues and difficult eating behaviours. To our knowledge, there have been no studies investigating the relationships

between sensory issues, mealtime behaviours, or food and nutrient intakes in NZ children with ASD. The purpose of this study was to determine if the presence or severity of sensory issues could be used as a proxy for difficult eating behaviours, or to indicate the need for referral for dietetic assessment in children with ASD.

#### *Aim and Hypothesis*

The aim of this study was to explore the relationships between sensory issues, difficult mealtime behaviours, and food and nutrient intakes in a group of children with ASD.

It was hypothesised with an increase in sensory issue severity, frequency of difficult mealtime behaviours would increase, and dietary quality would decrease.

### 3.2 Methods

Analysis of baseline data from the ongoing Vitamin D and Omega 3 in Autism (VIDOMA) randomised-controlled trial (Australian New Zealand Clinical Trial Registry, ACTRN12615000144516) was undertaken using a cross-sectional observational design. VIDOMA study protocol has previously been described (Mazahery 2016). In brief, recruited children were aged 2.5-8 years old with a medical diagnosis of ASD according to the DSM-5, and onset of symptoms post 1.5 years of age to ensure symptoms resulted from ASD, not neural damage at birth. Children with Global Developmental Delay were excluded. Parents were required to be proficient in the English language due to nature of tools used. Recruitment was via media releases, support organisations, and Waitemata and Auckland District Health Boards (DHB's).

#### *Baseline Data Collection*

Parents/ caregivers and their child/children attended Massey University Campus for a morning or afternoon session to complete baseline the SPM, BPFAS and DICE tools. All tools were completed under the supervision of a VIDOMA researcher to aid with proper completion and understanding of research requirements. Food diaries were mailed to parents/ caregivers prior to their visit in order to complete them at home and bring them in on the day. They were encouraged to bring in food packaging with nutritional labels to provide accurate nutritional data.

To reduce the stress for both the parent and child the tools were completed as efficiently as possible. Toys were provided for the children and communication with the parents was very important to ensure that each individual child was treated as how they were accustomed. Additionally, a visit was made by the parents and child to either North Shore or Waitakere



Hospital for a baseline blood sample. Written informed consent was gained from the parents or primary caregivers of each child at Massey University. Ethical approval was granted by the Health and Disability Ethics Committee. Ethics ref: 14/NTA/113.

#### *Nutrient Biomarker Data Collection and Analysis*

Non-fasting blood samples were taken under the supervision of paediatric hospital staff. Biomarkers were assayed from a venous blood sample. Biomarkers required for this study included serum ferritin (SF), haemoglobin (Hb), folate, and vitamin B12. Blood samples were analysed at North Shore Hospital Laboratory using the following methods: Ferritin, serum: Siemens Dimension Vista® System. FERR Flex® reagent cartridge, Cat. No. K3085, Serum: Siemens Dimension Vista® System. B12 Flex® reagent cartridge, Cat. No. K6442, and Serum: Siemens Dimension Vista® System. FOL Flex® reagent cartridge, Cat. No. K6444.

Biochemical status for Vitamin B12 and folate were determined using reference values from Waitakere and North Shore Laboratories (Table 12). To estimate iron status the World Health Organisation (WHO) cut-off values for serum ferritin (WHO 2011b) and haemoglobin (WHO 2011a) were used (Table 12). These markers were not used independently to determine status as they can be affected by inflammation (Dietians New Zealand 2013; Mahan 2012). Inflammation markers were not included in the biomarker analysis. Additionally, as determining iron status is ambiguous, cut offs for iron depletion and anaemia only were provided by the WHO. Other sources may contain a greater number of classifications, such as iron depletion, iron deficiency, and iron deficiency anaemia (DNZ 2013), though are not as widely recognised.

#### Tools

##### *The Sensory Processing Measure (SPM)*

The SPM Home Form (Parham 2007) was used to measure sensory issues in the home environment. The SPM is a standardised 75-item frequency questionnaire covering scales for vision, hearing, touch, body awareness, balance and motion, social participation, and planning and ideas. Taste and smell were measured together and comprise a smaller scale of fewer items. For each scale item, parents were asked to rate the frequency of the described behaviour as “never”, “occasionally”, “frequently”, or “always” in a Likert-scale format. A score from 1-4 was allocated to each answer, a higher score indicating a greater issue. A total raw score was calculated for each scale alongside a corresponding T-score using the SPM Profile Sheet (see Appendix A). Raw scores were used to investigate associations within our data. T-scores were used for sensory severity categorisation: a T-score of 40-59 indicated typical sensory functioning, 60-69 indicated some problems, and

70-80 indicated definite dysfunction for each scale. Corresponding T-scores were not provided for taste and smell on the Profile Sheet. Additionally, a total sensory issue score was calculated from the sum of raw scores of the sensory systems only (excluded social participation and planning and ideas). Sensory issues were evaluated with the appropriate age-related SPM variation (ages 3 to 5, or >5), adapted for different developmental stages. Evaluation was completed by a trained child psychologist through a face-to-face interview with the parents or caregivers. The environment distinction is important, as in the home environment touch is the least affected sense, whereas in the classroom it is one of the most affected (Fernandez-Andres 2015). The tool has been standardised and validated in a sample of NZ children (Brown 2010).

#### *The Behavioural Paediatrics Feeding Assessment Scale (BPFAS)*

The BPFAS is a reliable measure of mealtime behaviours (Cronbach's  $\alpha > .80$ ) for ages 8 months to 9 years (Crist 2001), has been used in studies with ASD children (Martins 2008), and has since been validated in ASD children (Allen 2015). Parents or caregivers completed the tool online at Massey University under the supervision of a researcher. It comprised of a 35 item 5-point Likert scale questionnaire (Appendix B). The first 25 items asked parents to rate how frequently the stated child behaviour occurred from "never" to "always". This provided a Child Frequency Score (CFS). A score from 1-5 was allocated to each answer. A higher score indicated increased frequency of the difficult mealtime behaviour. The additional 10 Likert-Scale items provided scores concerning how frequently the parent felt that their child's behaviour was a problem and strategies they used to deal with the behaviour. This produced a Parent Frequency Score (PFS). The CFS and the PFS were summed to provide the Total Frequency Score (TFS), an overall measure of difficult mealtime behaviours. A participant can score out of a maximum of 175. The TFS was used to investigate associations within our data. A TFS >81 was found to be significantly higher than the mean, therefore determined by the authors to be a clinical feeding issue and warrant nutritional intervention (Crist 2001). A total sum for each CFS item determined which behaviours occurred the most frequently in the children (positively phrased questions were reverse scored).

#### *The Dietary Intake for Child's Eating (DICE)*

The DICE is an online observation-based questionnaire and was used to assess participant diet quality. Parents or caregivers completed the form with the supervision of a VIDOMA researcher. The DICE is based on food intake recommendations laid out in the NZ Ministry of Health (MoH) Food and Nutrition Guidelines for Healthy Children and Young People (MoH 2012) (Appendix C). Data obtained included the number of serves consumed for each

of fruits, vegetables, breads and cereals, milk and milk products, meat and meat alternatives, and colour variety for fruits and vegetables. Fluid intake and quality, meal and snack frequency, and frequency of low fat, salt, and sugar foods are also measured. A score was provided for each component, and the sum of the component scores provides a total DICE score out of 100. DICE has shown to be a valid and reliable tool for the assessment of typically-developing children's adherence to MoH Food and Nutrition Guidelines for Healthy Children and Young People (MoH 2012) (unpublished data from our laboratory) and validation in children with ASD is currently underway.

### *Food Diaries*

Nutrient intakes were measured using a four-day estimated food diary, inclusive of three week-days and one week-end day. This was used to estimate average daily nutrient intakes for each participant. Diaries were checked at Massey University by researchers to ensure they were completed appropriately. Researchers requested extra detail over the phone if necessary. Poorly completed diaries were excluded from the study, such as where days were missing or food intake seemed unrealistic. Completed food diaries were entered into the nutritional analysis programme Foodworks8 (Xyris Software 2016). Macronutrient energy proportions were compared to the Institute of Medicine (IOM) Acceptable Macronutrient Distribution Ranges (AMDR's) (Institute of Medicine 2005) as there was no available data in NZ for this comparison. Protein was the sole macronutrient for which a Recommended Dietary Intake (RDI) was provided by the Nutrient Reference Values (NRV's) for Australia and New Zealand (National Health and Medical Research Council 2006) and so was chosen to compare participant intakes to NZ recommendations, as the Estimated Average Requirements (EAR) was unavailable for protein. For micronutrients, the following are reported: iron (mg), calcium (mg), vitamin C (mg), folate (ug), omega-3 (mg), and sodium (mg). Fibre (g) was also included. Micronutrient intakes were compared to the EAR based on age and gender laid out in the NRV's (NHMRC 2006). EAR was chosen as it indicates that 50.0% of the typical population will have their nutritional needs met by this recommendation. While the Recommended Dietary Intake (RDI) is commonly used as a reference value in NZ, use of the RDI may lead to overestimation of dietary inadequacy, as it indicates the nutritional values at which 97.0-98.0% of the population would likely meet nutritional requirements. In cases where EAR and RDI were unavailable for comparison, the Adequate Intake (AI) was used. Analysed nutrients were selected based a number of criteria, such as if the nutrient plays an important role in neurodevelopment (e.g iron, folate), indicates intake of a particular food group (e.g calcium – dairy products), and an appropriate reference value is provided for comparison. Children were analysed by their

age range if it was specified by the reference value. Age ranges were either 2-3 years old or 4-8 years old.

### *Anthropometry*

Participant heights and weights were obtained at Massey University using a portable stadiometer and standard weighing scales. One measurement for each was taken to reduce participant stress. Data was used to calculate Body Mass Index (BMI) percentiles, using the equation  $BMI = \text{weight}(\text{kg}) / \text{height}^2(\text{m})$ . BMI was then compared to sex and age appropriate percentiles using NZ MoH Growth Charts (MoH 2010).

### *Statistical Procedures*

Statistical analysis was performed using SPSS for Windows version 23 (SPSS Inc 2015). Normality of distribution was evaluated using the Shapiro-Wilk and Kolmogorov-Smirnov tests of normality. Non-parametric testing was used for all result associations corresponding to non-normal distributions.

Descriptive statistics were used to characterise the study population and scores from the SPM, BPFAS-TFS and DICE using mean  $\pm$ SD, median (25<sup>th</sup>, 75<sup>th</sup> percentile) or frequency and percentage summary statistics. Nutrient intakes and biomarkers were reported alongside reference ranges and the number and percentage summary statistics of participants who were within these reference ranges. Significance was set at  $p < 0.05$ .

Spearman's rho was used to investigate relationships between sensory issue severity (SPM) and frequency of difficult mealtime behaviours (BPFAS-TFS), and the total DICE score.

Kruskal-Wallis tests were used to investigate relationships between SPM scores and select BPFAS-TFS items where an association was justified based on the literature. For example, "Eats only ground, strained food" was investigated with the SPM scale for touch. Similarly, investigations of differences between select SPM scales and individual DICE scores were undertaken using Kruskal-Wallis tests. For example, associations between the number of colours eaten for fruits and SPM vision scores were investigated.

Spearman's rho was used to compare the BPFAS-TFS to the total DICE score to investigate associations between frequency of difficult mealtime behaviours and adherence to MoH Food and Nutrition Guidelines for Healthy Children and Young People (MoH 2012). Chi-square tests were used to investigate potential differences across individual DICE scores with individual BPFAS-TFS items where justified by the literature. For example, "Has problems chewing food" was investigated with meat and meat alternative intakes.

Spearman's rho was used to compare BPFAS-TFS scores with macronutrient distributions and macronutrient and micronutrient intakes. Kruskal-Wallis tests were used to investigate associations between the BPFAS-TFS and biochemical markers.

### 3.3 Results

#### *Participant Characteristics*

Children (N=113) were predominantly recruited from across the Auckland area. Although every attempt was made to collect all measurements from all children there was some missing data, especially in the food diaries (n=56) which many parents found too burdensome to complete. The characteristics of the children included in the study are shown in Table 5.

Table 5. *Participant characteristics.*

Characteristic	Description	n(%)
Age	Mean of 5.25±1.39 years	
Sex	Male	93(82.3)
	Female	20(17.7)
ASD Severity <sup>^</sup>	Mild	40(35.4)
	Moderate	51(45.1)
	Severe	22(19.5)
Weight Status*	Underweight (BMI Centile <5)	2(1.8)
	Healthy weight (BMI Centile 5 to <85)	64(56.6)
	Overweight (BMI Centile 85 to <95)	15(13.3)
	Obese (BMI Centile ≥95)	26(23.0)
	Missing	6(5.3)
Ethnicity	NZ European	54(47.8)
	Māori	16(14.2)
	Pacific Islands	11(9.7)
	Philippines	6(5.3)
	Chinese	4(3.5)
	Indian	3(2.7)
	Mixed race	15(13.3)
Missing	4(3.5)	

<sup>^</sup>ASD severity based on medical diagnosis and confirmed by Social Responsiveness Scale, Second Edition (Constantino and Gruber 2012), as per VIDOMA protocol (Mazahery 2016).

\* Weight status based on NZ MoH Growth Charts (MoH 2010) percentile ranges.

### *Sensory Processing Measure*

Overall, 90% of participants had sensory issues, where 49.6% percent of participants were defined as having definite dysfunction, 39.8% had some problems, and 10.6% had typical sensory processing (Table 6).

Table 6. *Categorisation<sup>^</sup> of sensory issue severity.*

Sensory Processing Measure Scale	Typical Function n(%)	Some Problems n(%)	Definite Dysfunction n(%)
Body Motion	39(34.5)	36(31.9)	38(33.6)
Body Awareness	21(18.6)	42(37.2)	50(44.2)
Hearing	21(18.6)	38(33.6)	54(47.8)
Touch	11(9.7)	45(39.8)	57(50.4)
Vision	11(9.7)	45(39.8)	57(50.4)
Planning and Ideas	11(9.7)	49(43.4)	53(46.9)
Social Participation	11(9.7)	45(39.8)	57(50.4)
Total severity	12(10.6)	45(39.8)	56(49.6)

<sup>^</sup>Categorisation of sensory issue severity based on SPM T-score corresponding to raw score for each scale. Typical sensory function 40T-59T, some problems 60T-69T, definite dysfunction 70T-80T. T score not available for taste and smell.

*Behavioural Paediatrics Feeding Assessment Scale*

The BPFAS-TFS ranged from 44-121 with a mean of 81.43±18.4. Out of 106 participants, 44(41.5%) scored >81 indicating clinical feeding issues (Table 7).

Table 7. *Most frequently occurring difficult mealtime behaviours.*

TFS Item	Total Score <sup>^</sup>
Enjoys eating*.	420
Eats starches	419
Eats fruits*	399
Comes readily to mealtimes*	388
Eats meat and/or fish*	367
Gets up from table during meal	353
Drinks milk	344
Tries to negotiate what he/she will and what he/she will not eat	313
Eats vegetables*	306
Takes longer than 20 minutes to finish a meal	298
Eats junky snack foods will not eat at mealtime	261
Spits out food	258
Refuses to eat meals but requests food immediately after the meal	254
Will try new foods*	242
Tantrums at mealtimes	241
Has poor appetite	231
Would rather drink than eat	228
Whines or cries at feeding time	222
Delays eating by talking	203
Has problems chewing food	184
Lets food sit in his/her mouth and does not swallow it	181
Chokes or gags at mealtimes	176
Eats only ground, strained, or soft food	160
Vomits just before, at, or just after mealtime	114
Has required supplemental tube feeds to maintain proper nutrition status	107

<sup>^</sup> Sum of scores from each CFS items

\*Item is reverse scored.

### *SPM Associations with BPFAS-TFS*

Overall, sensory issues were positively associated with frequency of difficult mealtime behaviours ( $p=.007$ ). Individual SPM scales with significant associations included body awareness ( $p=.002$ ), touch ( $p=.004$ ), planning and ideas ( $p=.004$ ), and social participation ( $p=.002$ )(see Table 8).

Table 8. *Sensory issue severity associations with frequency of mealtime behaviours.*

Sensory Processing Measure Scale	TFS ^ <i>r</i>	TFS <i>p value</i>
Body Motion	.189	.055
Body Awareness	.296	.002
Hearing	.172	.081
Touch	.283	.004
Vision	.155	.116
Taste and Smell	.163	.138
Planning and Ideas	.277	.004
Social Participation	.307	.002
Total severity	.265	.007

^Spearman's Rho correlations.

### *Individual SPM Scale Associations with BPFAS-TFS Items*

Two associations were found between specific sensory issues and difficult mealtime behaviours. Touch sensory issues were greater for children who always “lets food sit in his/her mouth and does not swallow it” than those who never did ( $\chi^2(1)=7.502, p=.006$ ). In addition, children with greater social participation issues more frequently get up from the table during meal compared to those who never do ( $\chi^2(1)=5.795, p=.016$ ). No other statistical differences were found between the TFS items and individual SPM scales investigated.

### *SPM Associations with DICE*

Of 106 completed DICE, median total score was 65.6/100, ranging from 22-100. One child scored 100%. Only 13.2% of children met recommendations for vegetable serves (Table 9). Both vegetable and fruit colour variety were limited, with 8.1% of children having no fruit and 7.2% of children having no vegetables at all (Table 10).

No significant associations were found between sensory issue severity (total) and DICE. There was a significant inverse correlation between social participation and total DICE scores ( $r=-.305, p=.003$ ). We also investigated correlations between touch, vision, and taste and smell, with total DICE scores but none were statistically significant. There were also no significant differences between children who were and were not meeting recommendations



for number of food group serves when comparing individual SPM scales and individual DICE scores where justified.

Table 9. *Participants meeting food serving recommendations.*

DICE Components	Recommended serves/day*	Met Recommendations n(%)
Fruits	2 or more	35(33.0)
Vegetables	2 or more	14(13.2)
Breads & Cereals	4 or more	38(35.8)
Milk & milk products	2 or more	37(34.9)
Meat & Meat Alternatives	1 or more	53(50.0)

\* NZ MoH Food and Nutrition Guidelines for Healthy Children and Young People (MoH 2012).

Table 10. *Colours of fruits and vegetables eaten using DICE.*

Measure	Colour	Fruit n(%)	Vegetable n(%)
Colours eaten	Red	86(81.1)	84(79.2)
	Yellow/orange	76(71.1)	83(78.3)
	Green	69(65.1)	77(72.6)
	Blue/purple	69(51.1)	16(15.1)
	White	90(84.9)	79(74.5)
Number of total colours eaten	0	8(7.5)	8(7.5)
	1	6(5.7)	12(11.3)
	2	10(9.4)	21(19.8)
	3	12(11.3)	18(17.0)
	4	19(17.9)	30(28.3)
	5+	51(48.1)	17(16.0)

#### *BPFAS Associations with DICE*

The BPFAS-TFS was significantly inversely correlated with the total DICE score ( $r=-.308$ ,  $p=.003$ ). No justifiable significant associations were found between BPFAS-TFS items and individual DICE categories.

*Food Diary Findings - Macronutrients*

A total of 56 food diaries were completed. Fourteen children were aged 2-3 years old and forty-two were aged 4-8 years old. Almost half (48.2%) of participants were not within the AMDR for fat (Table 11). Nine participants (16.1%) were not meeting their AMDR for carbohydrate. While 6 participants were within the AMDR for protein, average intakes of protein were higher than the NZ RDI (NHMRC 2006) for both age ranges (14g/d for ages 2-3, 20g/d for ages 5-8) No significant associations were found between AMDR's nor macronutrient intakes with the BPFAS-TFS.

Table 11. *Participants meeting acceptable macronutrient distribution ranges.*

Nutrient	Ages (years)	AMDR* (% of energy)	Participant mean* % Energy	Range	Average* Intake(g)	Below AMDR n(%)	Above AMDR n(%)
CHO	2-8	45-65	51.5±7.0	35.6-72.6	186 (155,278)	9(16.1)	2(3.6)
Protein	2-3	5-20	14.1±2.6	9.2-20.7	54.2±14.1	1(7.1)	2(14.3)
	4-8	10-30	14.2±2.6	8.5-20.7	55.1±13.64	3(7.1)	0(0.0)
Fat	2-3	30-40	32.0±6.7	18.9-46.1	55.1 (46, 74)	5(35.7)	2(14.3)
	4-8	25-35	31.9±6.9	18.5-46.7	55 (44, 86)	8(19.0)	12(29.0)

^Mean±(SD), Median (25<sup>th</sup>, 75<sup>th</sup>).

\*IOM (2005).

*Food Diary Findings - Micronutrients*

The EAR was frequently not met for calcium (23.2%), and vitamin C (11.0%), as well as the AI for fibre (23.2%)(Table 9). More than twice the recommendations were consumed for iron (8.9%), and in addition to a large percentage of children consuming insufficient calcium, many were also consuming it in excess (17.9%). Regarding sodium intakes, 85.7% of participants age 2-3 years consumed over the 1000mg Upper Limit (UL), and 88.1% of participants age 4-8 years were over the 1400mg limit. No significant associations were found between micronutrient intakes and the BPFAS-TFS.

Table 12. *Participants meeting micronutrient intake recommendations.*

<b>Nutrient</b>	<b>Ages (years)</b>	<b>RDI*</b>	<b>EAR*</b>	<b>AI*</b>	<b>^Median</b>	<b>Below recommendations N(%)*</b>
Iron(mg)	2-3	9			9.6 (6.3,20)	
	4-8	10	4		10 (6.6,20.1)	1(<1.0)
Calcium(mg)	2-3	500	360		642 (448,1345)	2(14.3)
	4-8	700	520		639 (417,1344)	11(26.2)
Fibre(g)	2-3			14	17.5 (11.3,32.8)	4(28.6)
	4-8			18	18 (11.5,33)	9(21.2)
Vitamin C(mg)	All	35	25		47 (25,172)	11(19.6)
Folate(ug)	2-3	150	120		266.5 (181, 440)	1(7.1)
	4-8	200	160		281 (167,671.5)	3(7.1)
Omega-3(mg)	2-3			40	507.5(272,1236)	1(7.1)
	4-8			55	468 (252,2501)	2(4.8)

^Mean represented as mean±(SD), median represented as median (25<sup>th</sup>, 75<sup>th</sup>).

\*Based on Nutrient Reference Values for Australia and New Zealand (Council 2006). EAR used where possible. If EAR unavailable, based on RDI then AI respectively

*BPFAS Associations with Biochemical Markers*

Nutritional biomarkers were available for all 113 children. Iron levels were sufficient for 84 children (77.0%). Within this study population very few of the children had overt nutrient deficiencies although 24 children (22.0%) did have poor iron stores and one was anaemic (Table 13). There were no significant differences across the TFS for any biochemical status.

Table 13. *Participant biochemical status for iron, serum folate, and serum vitamin B12.*

Nutrient	Biomarker	Age in years	Reference Value <sup>+</sup>	Status	Participant n(%)	Median <sup>^</sup> Status
^Iron (Fe)	Serum Ferritin	2-4	≤12ug/L	Iron depletion	7(6.6)	(SF) 23 (13,55)
		5-8	≤15ug/L		17(16.0)	
	Serum Ferritin	1-4	≤12ug/L	Iron deficiency anaemia	1(>1.0)	(Hb) 130(119,140)
			Haemoglobin			
	Serum Ferritin	5-8	≤15ug/L			
Haemoglobin			≤115g/L			
*Vitamin B12	Serum vitamin B12	2-8	90-140/L			
			<90pmol/L	Deficiency	1(>1.0)	
*Folate	Serum folate (folic acid)	2-8	<7nmol/L	Deficiency	0(0.0)	43 (38, 49)

<sup>^</sup>Median (25<sup>th</sup>, 75<sup>th</sup>)

<sup>+</sup>Reference values from (WHO 2011a, 2011b) as reference values unavailable from North Shore Hospital Laboratory.

<sup>\*</sup>Reference values from North Shore Hospital Laboratory

### 3. 4 Discussion

To determine associations between sensory issues, difficult mealtime behaviours, and food and nutrient intakes, a cross-sectional observational study was performed in 113 children aged 2.5-8 years with ASD.

#### *Identification and Quantification of Sensory Issues*

Sensory issues were highly prevalent in this population. This has been reported previously, with high proportions of children (65.0-95.0%) demonstrating sensory issues meeting DSM-5 criteria (Tavassoli 2016; Tomchek 2007). We found the greatest issues within touch, vision, and hearing sensory systems. Social participation issues were also highly prevalent, demonstrating sensory issues impacts on higher-level integrative functions. In support of our findings, previous research shows that hearing and touch issues were the most commonly reported sensory issues across a range of tools (Fernandez-Andres 2015; Kientz 1997; Tomchek 2007), followed by visual issues (Tomchek 2007). Kientz (1997) likewise found high levels of dysfunction within social participation.

#### *Identification and Quantification of Difficult Mealtime Behaviours*

Difficult mealtime behaviours were highly prevalent in our participants. Previous literature reports up to 90% of children with ASD may present with feeding difficulties (Sharp 2013a). Compared with the average TFS score of  $81.43 \pm 18.4$  in the current study, Castro (2016) found a mean TFS of  $92.2 \pm 8.72$  in 49 boys aged 4-16 years with ASD. Lukens (2008) found a mean of  $83.30 \pm 16.51$  in 68 children with ASD aged 3-11 years. While these averages are similar, note that both studies used the BPFAS tool outside of the age limit of 8 years as well as having children of a broader age range. These averages may shift with the removal of data from children over the age of 8. Other researchers who used alternative tools also found high frequencies of difficult mealtime behaviours in ASD children (Ahearn 2001), higher frequencies in ASD compared to controls (Provost 2010; Zobel-Lachususa 2015), and greater parental-perceptions of difficult mealtime behaviours in ASD compared to typical-developers (Lockner 2008). Only study was found which reported investigations of individual items on the BPFAS within an ASD population (Allen 2015). Among 374 children with ASD from ages 3-5 years, it was found that the highest average frequency score was for “will try new foods” (reverse scored), followed by “gets up from table during meal”. Our results did not support these findings. Allen (2015) also found the lowest frequency score for items: “Has required supplemental tube feeds to maintain proper nutritional status”, followed by “vomits just before, at, or just after mealtime”. These lower score findings were supported by our study results. These issues indicate serious clinical issues, where a child has or may require medical intervention to maintain adequate food and nutrient intake.

Children presenting with these issues should be carefully monitored as they are at increased risk of growth and development deficits. Overall, greater participant numbers are more likely to provide accurate representation of a typical population. Continued use of the BPFAS tool is suggested for future research to gain a clearer understanding of mealtime behaviour patterns in ASD children in NZ.

#### *Sensory Issues Associations with Difficult Mealtime Behaviours*

Overall sensory issue severity was positively associated with frequency of difficult mealtime behaviours, supporting our hypothesis. The sensory issues with the strongest associations with difficult mealtime behaviours were body awareness and touch. In contrast to our findings, previous research has had a strong focus on taste, smell, touch and vision associations with mealtime behaviour (Cermak 2010). While our data supports touch having a significant impact on mealtime behaviours, vision and taste and smell did not appear to be significantly associated. However, due to the understanding that sensory issues have a collaborative effect on how we respond to our environment, it could be that while some sensory systems have no individual effects, collective issues within sensory processing may result in difficult mealtime behaviours. This is supported by our results, as the overall sensory issue severity score (which measures sensory systems excluding higher-level integrative function scores) is significantly associated with difficult mealtime behaviours, despite only two individual sensory scales being significantly associated.

Literature supports the current study findings where sensory issues are highly associated with difficult mealtime behaviours in ASD children (Johnson 2014; Paterson 2011; Zobel-Lachiusa 2015). However, it is important to note that the methodology differed significantly to our study. For example, Johnson (2014) and Zobel-Lachiusa (2015) both used the Brief Autism Mealtime Behavioural Inventory (BAMBI) as the behavioural measure. This tool correlates highly with the BPFAS (Lukens 2008). However, the Short Sensory Profile (SSP) (Dunn 1999) used in all 3 studies was used to measure sensory issues. To the best of our knowledge the SSP has not been compared to the SPM within an ASD population, and different clinical cut-offs are presented for classification of severity (Hansen 2013). Additionally, Paterson (2011) used the Eating Behaviour Questionnaire (developed by the author) was used to measure difficult mealtime behaviours, which is not validated in ASD.

Our study found higher-level integrative functions were also significantly associated with difficult mealtime behaviours. Social participation is important, as it is understood that food intake relies heavily on social observations and the behaviours of others (Birch 2007; Cruwys 2015; Salvy 2008). A compromised ability to typically read and respond to social

cues may lead to negative behaviours becoming the norm at mealtimes. For example, our results showed that children were more likely to get up and leave the dinner table in the middle of a meal if they had more severe social participation issues. While investigations between planning and ideas showed no significant associations with difficult behaviours such as “will try new food”, the literature provides evidence that this higher-level integrative function defines how we learn new skills (Ayres 2005). Issues within planning and ideas therefore may limit a child’s ability to learn how to use a knife and fork, or how to peel an orange, demonstrating how planning and idea issues can be associated with difficult mealtime behaviours as indicated by our results.

With a more specific approach to our data we found increased issues with touch were present in children who more frequently let food sit in their mouths. Issues with touch and food behaviours were also observed by Nadon (2011) where children with touch sensitivity were more likely to drool or have unusual food preferences with respect to food aspects such as texture.

#### *Identification and Quantification of Food Intakes*

More than half of our participants were not meeting recommendations for vegetables, fruits, milk and milk products, and breads and cereals. In comparison, Herndon (2009) found that in a group of 46 children aged 1-8 years with ASD, average fruit serves met the recommendations, while average intakes for grains and vegetables were below recommendations. A study focusing on food group intakes was undertaken by Cornish (1998). Diets of 17 children with ASD aged 3-9 years were analysed used parent-reported 3-day dietary recall combined with a food frequency questionnaire. It was found that 25.0% of children were not having at least 2 serves of fruits and vegetables each day. One child consumed all of their 5 fruit and vegetables serves in red apples only. This an example of the limited variety of foods consumed by this population, and also supported by our data where limited colours of fruits and vegetables were consumed. No meat products were eaten by 35.0% of participants. While 3 children ate no dairy at all, 6 children were meeting over half their required energy intake through dairy products alone. Despite no NZ data being available for comparison, and food intakes vary greatly in children with ASD, it appears that these children frequently do not meet food intake recommendations across a number of food groups.

### *Sensory Issues and/or Difficult Mealtime Behaviour Associations with Food Intakes*

Our results suggest a decreased ability to participate socially may be a significant factor not only related to our eating behaviours but also to the quality of our diet. Children may have a decreased food intake and quality of those foods if they are not able to adhere to social eating expectations and therefore do not exhibit acceptable mealtime behaviours such as staying at the dinner table for the duration of the meal, or eating all the food on their plate. ASD children may also have a reduced intake of healthier foods or number of food serves as parents may struggle to reason with them compared to a typically-developing child. It is important to remember that social participation issues result from sensory system processing issues, despite no significant associations being found between our sensory system scales and difficult mealtime behaviours.

In contrast to our results, other researchers have found direct associations between difficult mealtime behaviours and food intake. Johnson (2014) reported that an increased frequency of difficult mealtime behaviours in 256 children with ASD resulted in a lower adherence to federal dietary guidelines in the United States. Increases in difficult mealtime behaviours measured using the BAMBI were found to be significantly associated ( $p=0.0001$ ) with decreased adherence to federal guidelines. In addition, a review of the literature has shown that multiple other studies have also found strong associations between mealtime behaviours and food intakes, despite differing methodology (Cermak 2010).

There are many other factors which play a role in determining food intakes in children such as parent food choices (Schreck 2006), culture, socio-economic status, or food availability (MoH 2012). As our results were non-significant, it would be important to consider these factors as confounding influences within future research to investigate the possibility that these factors are masking patterns in our data.

### *Identification and Quantification of Nutrient Intakes*

#### *Macronutrients*

In our study, children with ASD appeared to consume very high amounts of protein. This was also observed by Levy (2007), who found of 62 ASD children aged 3-8 years, the average protein intake was 211% above the recommended dietary allowance. Likewise, Herndon (2009) found protein intakes were much higher than recommendations in ASD children. Despite excessive intakes in grams/day, protein was still within the AMDR for the majority of our participants. This suggests that while energy from protein proportions meet



recommendations, children are consuming an excessive amount of energy. This idea is supported by the high incidence of overweight and obesity in our participants.

Carbohydrate intakes were on the lower end of the AMDR, although most children were consuming energy from carbohydrates within the recommended range. This pattern has appeared before in previous literature (Herndon 2009; Levy 2007), however a study of 40 ASD children aged 6-9 years also showed that 75% of children were not within the AMDR for carbohydrates, and frequently had low intakes of carbohydrates (g/day). While intakes of carbohydrates vary in this population, it seems that carbohydrate intake tends to trend towards insufficient intakes when compared to national food intake guidelines.

Fat intakes appear to vary the most across the literature. Almost half of our participants were not within the AMDR for fat (more exceeding it than not meeting it). In comparison, Herndon (2009) and Levy (2007) both found that the majority of children were within the AMDR for fat. Mari-Bauset (2014) found average fat intake in grams per day was 31.16g, which was much lower than our average of 55g.

Overall it seems that while the majority of our participants are within the AMDR for macronutrients, many children appear to be exceeding daily fat and protein recommendations, while not getting sufficient energy from carbohydrates.

### *Micronutrients*

Insufficient intakes of micronutrients were common in our participants, and nutrients were also consumed in excess. This has also been observed within other samples of ASD children, although with little pattern among which nutrients were consumed in excess or deficit (Adams 2004; Barnhill 2015; Bicer 2013; Castro 2016; Levy 2007; Ranjan 2015; Sharp 2013). While a number of our participants were not meeting calcium recommendations, five children were also consuming calcium in excess of the EAR. Investigation into foods causing high calcium intakes showed these children had excessive intakes of milk and milk products. One child was consuming a litre of cow's milk a day. Two participants were drinking a large proportion of their requirements through toddler milks, also corresponding to their high iron intakes (28g and 21g/day). While these high milk and milk product intakes contributed to high protein and fat intakes for these children, overall fat and protein intake other children with typical milk and milk product consumption were still above recommendations, suggesting that other foods are contributing to atypically macronutrient proportioned diets. However, it is important to note that a cow's milk limit of 500ml per day is recommended in children to reduce the likelihood of the displacement of other foods

(MoH, 2012). Displacements of foods could restrict food variety and intake and compromise nutrition. In comparison, Williams (2003) reported average calcium intakes of 1092mg, which were also in excess of requirements. On the other hand, calcium intakes have also been found in deficit (Bicer 2013; Sharp 2013b; Stewart 2015). While our study provided no associations with calcium intake across other variables, it would certainly be an interesting area in which to conduct further study.

Both excessive and inadequate iron intakes were also noted in our participants. Excessive intakes resulted from regular intakes of iron-fortified bread and cereals products, appearing unrelated to sensory dysfunction or difficult mealtime behaviours. The single case of low iron intake appeared to result from limited consumption of meat products. In future studies, fortification of foods should be considered a confounding factor as added nutrients are not found in the original product, and can give the impression that a child is consuming a variety of food and nutrients when in fact their food intake may be quite restricted. While food fortification can improve the nutritional status of individuals, from a dietetic perspective it is recognised that foods in their most natural state should be provided first, and fortification and supplementation only where nutritional recommendations cannot be met by food intake alone.

### *Biomarkers*

Our food diary data was not well supported by our biochemical data. Iron depletion was considerably more common than would be assumed based on food diary measures of intake. However, iron absorption is influenced by a number of different dietary factors, including vitamin C, tea or coffee consumption, presence of other minerals such as calcium, and whether iron is from a haem- or non-haem source (Geissler 2011). In previous literature, Reynolds (2012) reported that iron status is mainly based on serum ferritin and reported as frequently low in ASD populations in Wales, Canada and Turkey. On the other hand, much lower incidences of poor iron status have also been reported, similar to our study. Within a sample of 222 ASD children aged 2-11 years Reynolds (2012) compared both food diaries and biochemical markers. They found 8% of children had SF levels below 12ug/L, while less than 2% had iron intakes below the EAR. Iron markers did not appear to reflect sufficient intakes in both groups, despite nutrient intake analysis indicating otherwise. As with our study, it was reported that low SF prevalence may be an underestimate as a measure of CRP was not included, which can falsely elevate SF levels. Estimating iron status is difficult (Zimmermann 2008), and it is important to note that reference value cut offs vary significantly across sources for all biomarkers, and so prevalence of insufficiency is only an indicator of status.

Despite food diaries indicating that 4 children had low intakes of folate, no children were found to be deficient based on biochemical results in our study. For vitamin B12 status, one child was deficient and only 1 other borderline. Comparative studies have used biochemical markers in their methods. Overall, our results were not supported by other literature. A study undertaken in 40 Omani children recently diagnosed with ASD found that levels of serum folate and serum vitamin B12 were well below recommendations (Al-Farsi 2013). Another study in 55 ASD children aged 5-16 years found that for vitamin B12, 4.0% of children were below the reference ranges used (327-938ng/L) and 18.0% were above (Adams 2011). In addition, 20.0% of children fell below the reference ranges for folate and 7.0% of children were above.

The disparity between our food diary data and our biochemical results may be due to alterations in absorption or metabolism based on body requirements, measurement errors, or due to certain inaccuracies observed with the use of food diaries. It is also important to remember that nutrient intakes are very strongly influenced by external factors (e.g country, culture, poverty rates, etc) and so intake recommendations and diets vary accordingly. Therefore, while comparisons between countries may be useful for future research, within our study their significance is limited.

#### *Prevalence of Nutritional Inadequacy in Comparison to Typically-Developing Children*

Currently, there is no data within NZ which is appropriate for comparison to our results concerning typically-developing children due to data missing for the age ranges 2-5 years old. Future research should aim to quantify food and nutrient intake in such a population.

#### *Were Difficult Mealtime Behaviours, Nutrient Intakes and/or Biochemical Markers Associated?*

We found no relationships between difficult mealtime behaviours and nutrient intake or biochemical markers. However, Johnson (2014) found increases in problematic feeding behaviours were predictive of decreasing nutritional adequacy. On the other hand, Schmitt (2008) found that despite eating difficulties being more frequent in ASD compared to controls, no significant nutritional differences were identified between the groups. Other results were inconclusive (Cermak 2010). While nutrition inadequacies are frequent in ASD, demonstrated in our study and others (Al-Farsi 2013; Attlee 2015; Sharp 2013b), confounding factors may be impeding significant findings. For example, specialty diets and supplementation (Cornish 2002), medication side-effects on nutrient absorption and metabolism (Williams 2003), innate metabolic differences (Vancassel 2001; Yui 2016) or

other factors could be obscuring identifiable relationships between nutritional inadequacies and eating behaviours.

#### *BMI Percentiles*

Overweight and obesity was highly prevalent in our participants, with proportions similar to other studies in ASD (Egan 2013). Comparatively, of the NZ population aged 2-14 years, 22% are overweight and 11% are obese (MoH 2016). Compounding effects of weight-associated health risks (WHO 2016) in conjunction with ASD into adulthood could have serious health implications.

#### *Strengths and Limitations*

The participant group consisted of a similar male:female ratio noted in other research (Fombonne 2009). Children were of a wide range of ages, ethnic backgrounds, and ASD severities, providing participant diversity. A wide range of tools were used to measure nutrition as single indicators provide limited data. A systematic and specific approach was taken to analysing sensory issues to allow for a greater understanding of individual and collaborative effects of sensory issues on difficult mealtime behaviours and food and nutrient intakes.

A number of limitations were identified. Our primary limitation was that the DICE had not been validated in an ASD population, and that it may be beneficial for score weighting of specific items to differ from that of typically-developing children. For example, children with ASD demonstrate idiosyncratic behaviours observed during mealtimes such as eating only a select range of foods (Schreck 2004). Our results showed that fruit and vegetable colour variety is limited in our participants, yet did not contribute significantly to the overall score. Additionally, variety based on colour alone appears to be an insufficient measure, as food variety can include other factors such as food texture, temperature, or even the presentation of food on a plate. The inclusion of a more diverse variety score should be considered, and perhaps a greater score weighting, especially as food variety is a key component of meeting the NZ MoH Food and Nutrition Guidelines for Healthy Children and Young People (MoH 2012).

The scoring of the DICE does not allow for the measurement of food intake adequacy compared to the recommendations for children aged 5-8 years. Originally, this tool was designed for a younger age group, and therefore cut-off ranges for recommended serves are for ages 2-4 years only. In addition, instead of providing a maximum serve option to parents, it would be more helpful to provide an average daily serve intake for each food group. This would allow for the measurement of adequacy across all age ranges, but also the

measurement of over-consumption within food groups. This could be important for finding further associations between mealtime behaviours and food intake, as the excessive consumption of only very specific foods is a negative mealtime behaviour. It is important to identify limited food repertoires as they can lead to other nutritional inadequacies in the long term (Cermak 2010).

Another limitation is that there is no consideration of macronutrient intake. Macronutrients contribute energy to the diet and may indicate aetiology of under- or overweight, both of which have associated health risks. We found an obese child can score highly on the DICE tool (e.g BMI category=4, DICE score=95) indicating good adherence to the MoH Food and Nutrition Guidelines for Healthy Children and Young People (MoH 2012), as can a child who is severely underweight (e.g BMI category=1, DICE score=91.5). This suggests that in this participant group, either BMI is not a good predictor of food and nutrient intake, which is supported by other literature (Hyman 2012) or tools used require greater specificity to an ASD population. It is a concern that overweight/obese children may be overlooked when it comes to undernutrition. This concern is similarly expressed by Sharp et al (2013), who noted that failure to thrive and faltering growth are the standard indicators for inadequate nutrition (WHO 2006). Our results provide insight into the difficulties that medical professionals face when determining undernutrition, and the importance of nutrition screening for all ASD individuals.

Concerning the SPM, taste and smell were measured as a subscale limited to five questions, and a T-score was not provided. This hinders the ability to measure issues in comparison to controls and thoroughly analyse its effects. This is especially concerning not only because taste and smell play a fundamental role in what we eat (Bartoshuk 1991) but because taste and smell were commonly reported in the literature to affect eating patterns in ASD (Williams 2000). A more thorough measure would be desirable. Additionally, the SPM provides detail on under- and over-sensitivities as well as sensory seeking behaviour, yet this requires individual assessment of each of the 75 items for each participant. Analysing the data to this depth in our study was illogical due to time constraints. Opportunities for further exploration may have been missed. A thorough investigation into under- and over-sensitivities and sensory seeking behaviour may prove beneficial in future research.

CRP was not measured alongside iron studies in these participants. As serum ferritin can be affected by inflammation, CRP would have indicated falsely increased serum ferritin levels. Not measuring CRP may have limited our ability to accurately measure low iron status in these children. Using serum ferritin in combination with haemoglobin (only low in the

presence of iron deficiency) rather than as a single indicator has helped to negate some of the effects of not having measured CRP.

A poor response rate for food diaries (n=56) limited the potential to investigate associations between food and nutrient intakes to other variables. Additionally, certain foods were not found in any of the available Foodworks 8 (Xyris Software 2016) databases during data entry. In this case, it was replaced with a food of a similar nutrition profile, or the online nutritional panel entered. However, micronutrient information was not always available online. As this study had a strong focus on micronutrients, choosing an alternative food from the Foodworks 8 database was the most accurate way to represent replaced food. Despite this, results may contain imprecisions. Furthermore, food diaries may not be completed by parents or caregivers with the required accuracy. Completing a four-day food diary requires a considerable amount of time, effort, and observation. Understandably, providing a detailed and accurate diary may not take precedence for parents who are busy with work, childcare, and other commitments.

Finally, data collection was undertaken without a strong focus on the identification of confounding factors influencing mealtime behaviour and food and nutrient intake. Potential factors may include metabolic disorders, impacts of parent food choices on diet, and medication side-effects. Food fortification may also have significant contributions to nutrient intake (Hyman 2012). Due to the lack of association seen between sensory issues and difficult mealtime behaviours with food and nutrient intakes, these confounding factors may be masking patterns in the data. More detailed investigation into confounding factors and their effects is important to accurately determine associations between sensory issues, difficult feeding behaviours, and food and nutrient intakes.

### 3.5 Conclusion

We found significant relationships between sensory issues and difficult mealtime behaviours. We found evidence to suggest an association between difficult mealtime behaviours and food intakes. Social participation issues appear to be related to reduced adherence to food intake guidelines, with explanatory evidence provided in the literature. Alterations to the SPM and DICE tools to increase measurement scope of the taste and smell subscale and ASD dietary characteristics may show more significant findings. Validation of DICE in an ASD population is recommended. This study has highlighted the multiple issues confronted when investigating ASD. Potential confounding factors make it difficult to identify patterns within food and nutrient intakes. Considering the additional implications of the high rates of overweight/obesity, many of these children are in need of intervention, and screening for malnutrition should be extended to children who are overweight as well

as underweight. Results support the use of the SPM to be used as a proxy to identify NZ children with ASD who are at risk of difficult mealtime behaviours. Greater numbers of food diaries are recommended to improve nutritional analysis and improve analytical comparisons to other variables. Finally, further research should pay particular attention to the intricacies of confounding factors and their effects for improved identification of food patterns and excessive or inadequate nutrient intakes in relation to sensory issues and difficult mealtime behaviours.



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## Chapter 4

### 4.0 Conclusions and Recommendations

This study aimed to investigate associations between sensory issues, difficult mealtime behaviours, and food and nutrient intakes in a group of NZ children with ASD. It was hoped that results from this study would contribute to the growing pool of research concerning the assessment of individual sensory issues, higher level integrative functions and mealtime behaviours in children with ASD. We aimed to quantify food and nutrient intakes in this sample of children, and find associations between dietary quality, sensory issues, and difficult mealtime behaviours. Results would aid the nutritional screening of children with ASD in NZ, and overall help to reduce the frequency of inadequate nutrition in ASD children. The current study used the SPM, BPFAS, DICE, and food diaries to measure sensory issues, difficult mealtime behaviours, and food and nutrient intakes, respectively. Biochemical data was used to supplement nutrient intake data to improve nutritional assessment. Height and weight were used to provide a BMI percentile for each child to indicate over- or undernutrition.

This study provided supporting evidence that sensory issues are highly prevalent in ASD children. The highest levels of sensory dysfunction were found within touch and visual systems, as within other studies. We also learned that social participation issues are highly prevalent, and are linked to food intakes in this sample of children. This study has shown that there is also a relationship between sensory issues and difficult mealtime behaviours, although the impacts of hearing and vision issues were not significant. As our results are contradicted by the literature in this case, research interventions using treatments specific to sensory issues are recommended to further analyse the roles these sensory systems play in difficult mealtime behaviours.

We found further evidence to support that sensory issues are linked to difficult mealtime behaviours, particularly through higher-level integrative functions. Limited evidence was found to suggest that sensory issues are associated with food and nutrient intakes in ASD children. Limitations identified within the SPM and DICE tools should also be addressed in further research to increase scope of these measures. Validation of the DICE tool in ASD has yet to be undertaken.

This study has not eliminated possible sensory issues associations with food and nutrient intakes in NZ children. There is strong evidence in current literature suggesting links between sensory issues and difficult eating behaviours, and difficult eating behaviours and



food and nutrient intakes. A poor response rate for the food diaries was a limitation. The multiple presentations of ASD, associated medical or non-medical treatments, and parental strategies may be masking associations between sensory issues, mealtime behaviours, and food and nutrient intakes. Our research highlighted the importance of thorough investigations and eliminations of all confounding factors for future research. This is with the intention of clarifying the effect of each factor, to identify ASD characteristics which contribute more significantly to mealtime behaviours and food and nutrient intakes.

#### 4.1 Implications for Health Care

The NZ MoH should be aware that ASD children may be at increased risk of nutritional deficiencies. An increased focus on diagnosis of malnutrition in this population may prove beneficial, given that prevention may not be achievable at this stage without a better understanding of causation. BMI appears to be an inappropriate measure of the nutritional competency of the diet to meet MoH recommendations in ASD children, and standards for dietetic referral may need revising with this in mind. Regular nutrition screening should be undertaken for ASD children, with check-ups of key nutrients involved in neuro-development. This would reduce the incidence of delayed or neglected treatment of inadequate nutrition in ASD. However, it is understood that prevention of stress is very important, and a delicate compromise would be required to effectively monitor nutrition without causing physical or emotional distress to the child.

Parents need to be educated and vigilant when it comes to their child's nutrition. Parents have some ability to make alterations to their child's diet, and while it may be difficult with an ASD child, any opportunities to improve nutrition should be taken. Interventions with ASD should also aim at reducing weight where necessary, and parents should encourage physical activity where possible to reduce the health risks associated with excessive weight in children.

#### 4.2 Conclusion

Our research has provided evidence in the support of sensory issues being highly prevalent in ASD children in NZ, and associated with difficult mealtime behaviours. We identified that children with ASD appear to be at increased risk for overweight/obesity, and that children may be at risk of undernutrition regardless of weight status. While our study supports using the SPM as a tool to indicate difficult mealtime behaviours in ASD children, there is still insufficient evidence to use the SPM or BPFAS as nutrition screening tools within this population. Further investigation to find possible associations with food and nutrient intakes is required, and a larger participant sample is highly recommended.

# 5.0 Appendices

## Appendix 1 SPM Profile Sheet



**Home Form  
Profile Sheet**  
L. Diane Parham, Ph.D., OTR/L, FAOTA,  
and Cheryl Ecker, M.A., OTR/L



Name (or ID#): \_\_\_\_\_ Age: \_\_\_\_\_ Grade: \_\_\_\_\_ Gender:  M  F

Date this form completed: \_\_\_\_\_ Reason for assessment: \_\_\_\_\_

%ile	T	SOC	VIS	HEA	TOU	BOO	BAL	PLA	TOT	T	%ile
80		37-40	35-44	29-32	37-44	36-40	35-44	33-36	170-224		80
79		35-36	33-34	27-28	36	34-35	34	31-32	164-169		79
78		34	32	26	34-35	33	33		154-163		78
77			31	25	33	32	31-32	30	142-153		77
76		33	30	24		31	29-30		140-141		76
75		32	28-29	23	32	30	27-28	29	137-139		75
>99	74		27	22	30-31	29	26	28	133-136	74	>99
99	73	31			28-29	28		27	131-132	73	99
72			26	21	27	27	25	26	129-130		72
96	71	30	25	20	26	26	24		122-123	71	96
70		29	24	19		25		25	119-121		70
97	69	28	23	18	25	24	23	24	110-118	69	97
96	68		21-22	17	23-24	23	22		106-109	68	96
67		27	20	16	22	22		23	103-105		67
95	66	26		15	21	21	21	22	99-102	66	95
93	65	25	19		20	20	20	21	94-98	65	93
92	64	24	18	14	19	19	19	20	92-93	64	92
90	63	23	17	13	18	18	18	19	88-91	63	90
88	62	22		12					84-87	62	88
86	61		16		17	17	17	18	81-83	61	86
84	60	21			16	16	17		79-80	60	84
82	59		15	11	16	15	16		77-78	59	82
79	58	20						16	75-76	58	79
76	57		14		15	14	15	15	73-74	57	76
73	56	19		10					71-72	56	73
69	55	18			14	13		14	70	55	69
66	54		13				14		69	54	66
62	53	17						13	67-68	53	62
56	52			9	13	12			66	52	56
54	51	16					13	12	65	51	54
50	50		12						64	50	50
46	49	15								49	46
42	48					11		11	63	48	42
38	47	14			12		12		62	47	38
34	46								61	46	34
31	45	13						10		45	31
27	44								60	44	27
24	43	12		8						43	24
21	42								59	42	21
18	41		11							41	18
16	40	10-11			11	10	11	9	56-58	40	16

%ile	T	SOC	VIS	HEA	TOU	BOO	BAL	PLA	TOT	T	%ile
<b>Raw Score ▶</b>		_____	_____	_____	_____	_____	_____	_____	_____	_____	<b>◀ Raw Score</b>
<b>T-Score ▶</b>		_____	_____	_____	_____	_____	_____	_____	_____	_____	<b>◀ T-Score</b>
<b>Interpretive Range</b>											
Typical (40T-59T) <input type="checkbox"/>											
Some Problems (60T-69T) <input type="checkbox"/>											
Definite Dysfunction (70T-80T) <input type="checkbox"/>											

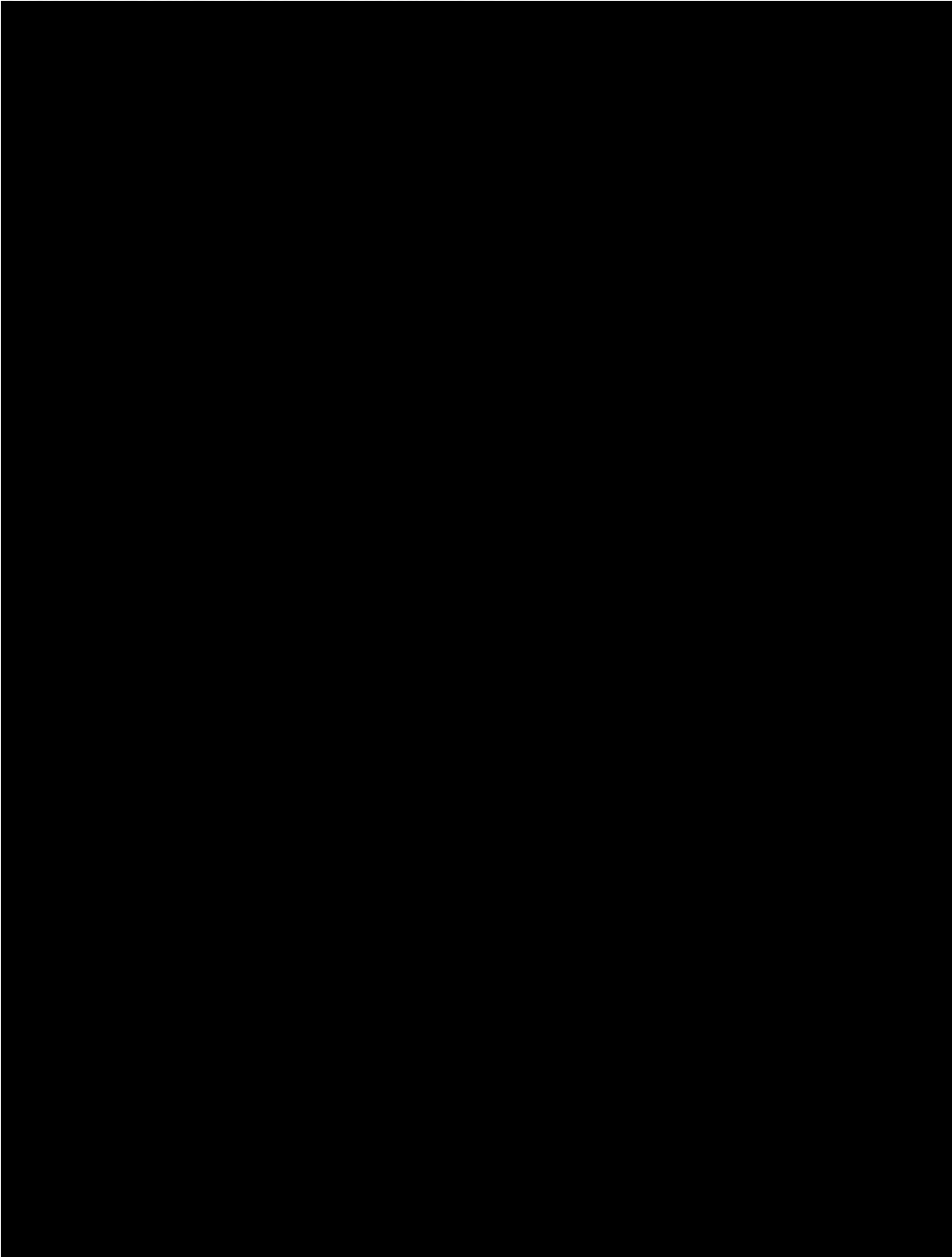
DIF Calculation		DIF Interpretation	
Home Form TOT T-score	_____	<input type="checkbox"/> $DIF \geq 15$ <input type="checkbox"/> $14 \geq DIF \geq 10$ <input type="checkbox"/> $9 \geq DIF \geq -9$ <input type="checkbox"/> $-10 \geq DIF \geq -14$ <input type="checkbox"/> $-15 \geq DIF$	DEFINITE difference: More problems in Home than in Main Classroom
Main Classroom Form TOT T-score	_____		PROBABLE difference: More problems in Home than in Main Classroom
Environment Difference (DIF)	_____		NO difference in amount of problems between Main Classroom and Home
			PROBABLE difference: More problems in Main Classroom than in Home
			DEFINITE difference: More problems in Main Classroom than in Home

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EXAMINER: REMOVE THIS SHEET BEFORE COMPLETING FORM.



Appendix 2  
BPFAS Scoring Sheet



Appendix 3  
DICE Food Group Intake References

Food Group	Age (years)	Recommended Serves/day
Fruit	all	2
Vegetable	2-4	2
	4-8	3
Breads and Cereals	2-4	4
	5-8	5
Meat and meat alternatives	2-4	1
	5-8	2
Milk, milk products and alternatives	2-4	2
	5-8	3

Reference values based on MoH Food and Nutrition Guidelines for Healthy Children and Young People (2012), children intake recommendations. Note that the DICE tool only compares intakes to references for ages 2-4 years based on initial requirements for use.

