Understanding and changing children's sensory acceptance for vegetables

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Abstract

Vegetable intake of children is well below recommendations in Australia and in most other western countries. Vegetables are the food category least liked by children. As acceptance is a key driver of intake, strategies are needed to increase children's acceptance of vegetables. The present thesis was directed at understanding and changing children's acceptance for vegetables, focusing on strategies that could be employed by parents in the home environment. The research was conducted with 4-6 year old Australian children.

To gain understanding of vegetable sensory properties, these were compared to sensory properties of other core food groups representative of the diet of Australian children, through the use of trained sensory panel. To increase vegetable acceptance and intake, two types of strategies were investigated. Preparation was investigated as a strategy to create vegetable sensory properties that were more accepted by children. Two experimental taste tests with children and a survey amongst parents together explored a range of vegetables (both across and within vegetable categories) and preparation (including cooking methods such as boiling, steaming, baking, use in mixed dishes, the use of an atypical colour, and cooking time), and sensory evaluation was used to measure the vegetable sensory properties. A behavioural sensory learning intervention strategy was investigated as a strategy to increase children's acceptance of vegetable sensory properties per se, in which repeated exposure to a single and to multiple target vegetables were compared in their effectiveness to increase acceptance and intake.

Compared to other core foods, vegetables were more *bitter* in *taste*, amongst the *hardest* foods, and were low in *sweet, salty* and *sour taste* as well as *fatty mouthfeel.* Unlike the other core food groups, vegetables had no known drivers of liking as well as a known driver of dislike. The preparation studies showed several results generic across the vegetables tested. An atypical colour (e.g. green cauliflower) increased willingness to try vegetables. Despite a more intense flavour profile, boiling and steaming were equally accepted by children. Use in mixed dishes was also well accepted by children. Other effects of preparation method were mostly vegetable specific, and a non-linear combination of flavour and texture properties were driving acceptance. The behavioural intervention study showed that repeated exposure to both single and multiple target vegetables increased acceptance. Exposure to multiple target vegetables increased usual daily vegetable intake from 0.6 to 1.2 serves per day, whereas exposure to a single vegetable did not.

This study showed that vegetable sensory properties predispose to low acceptance based on innate likes and dislikes, and food preferences acquired within the first few months of life. Preparation strategies and sensory learning strategies are both effective to increase vegetable acceptance amongst children in their peak of food neophobia. The results of this research can be used by health professionals to support parents with strategies and advice to increase children's enjoyment and intake of vegetables.

Contents

Chapter 1

Introduction

Children intake of vegetables is well below recommendations in Australia and in most other Western countries [1-4]. Children's food choice is primarily driven by hedonics [5-7], thus changing children's sensory acceptance for vegetables is a viable way to promote their intake. This thesis focused on strategies that can be employed by parents in the home environment of the child. The focus is on 4-6 year old children. This age group has been selected for two reasons: 1) It is very common for parents of children in this age range to encounter refusals by their child of vegetables and other foods, related to a heightened food neophobia of children between the ages of 2 and 6 years [7-9], 2) Children in this upper age range of food neophobia have the cognitive abilities and attention span that will allow them to take part in experimental taste studies that are too complex for younger children within the peak neophobic range [10,11].

This introductory chapter provides the background to the experimental work undertaken as part of the thesis. It starts with a discussion of the health effects of vegetables and the main causes of the low vegetable intake in children. Then it deals with the development of food preferences of children and the current knowledge on vegetable preferences and its relationship with sensory properties. Next, it details two types of strategies that can be used to increase children's sensory acceptance of vegetables, i.e. product modification strategies and behavioural intervention strategies, and how they have been applied to increase children's acceptance of vegetables so far. This chapter concludes with the aim and outline of this thesis.

Vegetable intake in children

Vegetables play an important role in a healthy and varied diet. There is strong evidence that a high intake of fruit and vegetables reduces the risk of cardiovascular heart disease, stroke and hypertension [12-15]. There is also evidence that fruit and vegetable intake reduces the risk of certain cancers [14,16-18], however this is inconclusive [15]. Vegetables can also help to maintain a healthy bodyweight, as their increased consumption reduces energy density of the diet, decreases overall energy intake and promotes satiety [19]. As such, vegetable consumption may help prevent obesity and associated diseases [14,19,20].

Vegetables constitute a diverse range of plant foods that provide a rich source of vitamins, minerals, phytochemicals and fibers [21,22], with large differences between vegetables in nutrient composition and energy density [21,23]. Vegetables as a category are the most micronutrient rich food category [24]. In some countries, including in Australia and the US, starchy vegetables are considered vegetables in dietary guidelines, whereas in other countries and in WHO guidelines, they are not.

Despite the health benefits of vegetables, vegetable intake of adults and children in Australia and most Western countries is well below recommendations. The 2007 Australian Children's National Nutrition and Physical Activity Survey, which collected data from 4,487 children aged between 2 and 16 years, found mean vegetable intake to be 95.0, 109.5, 161.0 and 202.8g per day for 2-3, 4-8, 9-12 and 13-16 year olds respectively [1]. Until recently, recommended vegetable intake for these age groups was 2 serves per day for children up until 7 years of age, and 3 serves for older children, with 1 serve of vegetable representing 75g [25]. In 2013, recommendations have been increased, and current Australian dietary guidelines recommend a daily intake of 2.5 serves for 2-3 year olds, 4.5 serves for 4-8 year olds and 5 serves for older children [26]. Thus, current intakes are well below recommended intake in Australia, and similar patterns are observed in the US [2,3] and Europe [4].

Factors of influence on children's vegetable consumption

Many factors are associated with children's low vegetable consumption, such as low parental intake of vegetables [27-31], limited availability and accessibility of vegetables [5,30-35], lower socio-economic status [30,36], educational level of the mother [27], lack of skills [5,31] and the child's neophobia [27,29]. Children's sensory acceptance of vegetables is recognised as one of the key barriers of vegetable intake [5,28,30,31,34,35,37]. Studies by Blanchette and Brug [31] and by Brug et al [5] identified sensory liking and taste preferences of vegetables as the strongest determinants explaining differences in vegetable intake amongst school aged children (together with availability and accessibility in the first study). In addition, several studies have identified the role of past experience as determining factor of fruit and vegetable intake, for example habit [28], past intake [34], early introduction to vegetables [27] and breastfeeding [27]. As food preferences are highly malleable, as will be discussed in the next section, these factors should not be seen as independent from taste preferences, rather as mediating factors for the acquisition of taste preferences for vegetables. In this view, even availability and accessibility contribute as mediating factors to provide children with the necessary exposure that creates acceptance, thus promoting intake.

Development of food preferences

Human infants are born with very few innate likes and dislikes, and these are largely related to basic tastes. An innate liking for sweet taste has been identified in newborns, as well as an innate rejection of bitter and sour tastes [6,38,39]. Initially newborns respond neutral to salty taste, however an acquired preference for this taste has been identified at 4 months after birth [6].

Innate responses to other sensory modalities seem less prevalent. Köster and Mojet [7] argue that preferences for food odours are learned, with notable exception of odours related to decay. As flavour perception is the result of retro-nasal perception of odours paired with taste perception, this indicates that flavour preferences are largely learned. Preferences for fat are learned through positive post-ingestive feedback and also acquired very early in life [40].

Other than a potentially inborn mechanism to avoid particles in fluids [7] there seems to be little evidence for innate likes and dislikes for textures.

Szczesniak [41] argued that texture preferences of the growing child are largely related to physiological changes in the oral cavity, in particular the dynamic changes related to children's eruption and loss of teeth and molars as well as development of oral musculature. Based on interviews with mothers with four or more children, she found that children up to 12 years old disliked textures that were difficult to manipulate in the mouth, such as slippy and slippery foods, and preferred one-dimensional textures to textural contrast (such as orange juice with fibres). Crispiness became a liked attribute from children from age 6 onwards [41]. The initial negative response to complex textures was confirmed in another study, were infants responded negatively to complex textures whereas toddlers (with an average age of 17 months) showed more positive head and body movements and more eagerness for complex textures [42]. This study also found that exposure to more complex textures shaped texture preference for more complex textures [42]. The importance of early exposure to textures was also reported by Coulthard et al [43], who found that children who received a delayed introduction to lumpy foods during weaning were reported as having more feeding problems at 7 years. Together these findings strongly suggest that most of our food preferences are learned, and childhood is considered to be a critical stage of in the development of food preferences [6,7,44]. Learning shapes preferences through experience [6]. This learning occurs even before infants are born, through exposure to flavours prevalent in the mother's diet via the amniotic fluid [45], and continues during breastfeeding through exposure to flavours in breast milk [45-49]. This direct exposure, or 'mere exposure' [50], continues to be an important learning mechanism once the baby is introduced to weaning foods and throughout childhood, but many other forms of learning can potentially influence the development of food preferences.

There are three important sensory learning mechanisms that play a role in food preference development of the growing child: mere exposure, flavour-flavour learning and flavour-nutrient learning. The mere exposure theory is a sensory learning theory based on the understanding that acceptance of a stimulus increases with repeated exposure to the stimulus itself, through an increased familiarity. The mere exposure theory was developed by Zajonc [51], and applied to a food context by Pliner [50]. Approximately 10 exposures are needed to change liking, but this number depends on the novelty of the stimulus, initial liking when a stimulus is not novel, and individual characteristics [50]. Previous experience with foods also affects number of exposures needed, as the number of exposures needed by children decreases with increased variety in their diet [52].

Flavour-flavour learning (FFL) and flavour-nutrient learning (FNL) are both forms of associative learning or classical conditioning, whereby the valence (hedonic value) of a conditioned stimulus (CS) changes through simultaneous presence of an unconditioned stimulus (US) that either has a positive (liked) or negative (disliked) valence [53,54]. As an example, acceptance for a novel food (vegetable) can increase by consuming it together with a stimulus that children already like. In FFL, this stimulus is another flavour or taste, whereas in FNL, the stimulus is an energy-containing stimulus.

In addition to sensory learning mechanisms, other forms of learning occur, such as modelling and observation of behaviours from others including parents, peers, teachers and others in direct or indirect presence of the child (6,7). In addition, cognitive forms of learning can play a part in eating behaviour. However, children are not sensitive to health messages, which may even negatively affect their acceptance of foods (55). When children are around 2 to 3 years old, they often develop an increased reluctance to try new foods (7,8). This fear of trying new foods, or food neophobia, is thought to be a protective adaptive mechanism to prevent the child from ingesting potentially poisonous foods. Food neophobia is typically viewed as a behavioural character trait (8,56,57) but it has also been proposed that food neophobia is a purely learned behaviour, strongly dependent on the response of parents when dealing with food refusals by the child (7). Either way, it is clear that food neophobia has a dynamic character, as a peak in food neophobia is observed between the ages of 2 and 6 years and it is malleable (7,9).

Most parents seem unaware of the plasticity of food acceptance in childhood. Indeed, the child's dislike of a food is the main reason parents do not offer (58,59), or stop offering a food to their child (60), and mothers attribute their children's dislike of foods mainly to genetic factors (58). This is unfortunate, as parents play an important role in shaping children's food preferences in a number of ways: they provide the food environment and thereby select the foods available for their child to eat, they are implicit role models for their child, and they socially interact with their child around eating behaviours, in particular in dealing with food refusals.

Learning to like a wide range of foods does not only have short term benefits. Food preferences, dietary variety and dietary habits (46,61,62) have been found to track from childhood to adulthood, and therefore developing sensory preferences that support healthy eating patterns in the young child are of utmost importance.

Vegetable preferences in relation to their sensory properties

Studies with children from different countries have shown that vegetables are the food category that is the least liked by children. In an observational study of 2-3 year old French children who self-selected their lunch from a nursery canteen, vegetables were often avoided, and preferentially animal products, starchy foods and their combinations were chosen (63). Similarly, using hedonic ratings of lunch items served as part of 20 school meals which were collected from 4-5 year old Italian children, vegetable dishes were the least preferred of all foods (64). Ratings of vegetable dishes were between 3.0 and 4.5 on a 7 point scale, whereas children rated meat and fish dishes between 6.2 and 6.6. Food frequency questionnaires and subsequent factor analysis further showed that the factor 'Vegetables' had the lowest mean liking score amongst 4-5 year olds [65] from the UK. Another study using food preference questionnaires and 5 point hedonic scales found that liking for vegetables (3.4 ± 0.8) was lower than fatty or sugary foods (4.1 ± 0.6) and fruit (4.2 ± 0.7) amongst British 7-9 year olds [66].

Low acceptance of vegetables has been attributed to a range of sensory properties, most frequently flavour and taste properties. Zeinstra et al (2007) reported a dislike for bitter tasting vegetables amongst 4-12 year olds [67], and the oldest (11-12 year olds) children in this study also disliked sour tasting and bland tasting vegetables. Drewnowski and Gomez-Carneros [68] also attributed dislike and even aversion of certain vegetables to bitter taste, related to the innate dislike for this taste. In addition, the strong flavour of vegetables has been mentioned by several authors as a reason for dislike or low acceptance of vegetables [37,69,70], as well as their lack of sweet taste [65].

The sensory properties identified for low acceptance of vegetables have not been derived through a systematic comparison of sensory properties of vegetables with other foods or food categories in the diet. In fact, such a systematic comparison has not yet been undertaken, as far as we are aware. Research is needed to compare the flavour and texture properties of vegetables with those of other core food groups. This research will help determine would which sensory properties are responsible for low acceptance of vegetables in children.

Strategies to include acceptance and intake of vegetables

Two types of strategies can be employed to increase sensory acceptance of vegetables as mediating factor to increase children's intake of vegetables. The first strategy is to change the product properties to align them to children's preferences. The second strategy is to change the child's sensory preferences for vegetables. Both types of strategies are applicable to parents in the home environment. There are also many other strategies to increase intake of vegetables in children that do not have the increase of sensory acceptance as their primary pathway, such as hiding vegetables and choice offering, and these are not further considered here.

Changing product properties (product-modification strategies)

Changing the product properties of vegetables is one strategy that can be employed to increase children's intake of vegetables. Understanding what the sensory properties are that children like *within* the vegetable category, and how these vegetable sensory properties can be modified for optimal acceptance by children seems a useful strategy, as children's food intake is primarily driven by hedonic appreciation. First, the current knowledge on the role of sensory properties within the vegetable category are discussed. Then, various strategies to modify sensory properties in the home environment are discussed. Strategies not relevant to the home environment are not considered, e.g. the breeding of new cultivars with specific sensory properties. The strategies discussed are colour, preparation method and cooking time, and the addition of flavours.

Role of sensory properties on acceptance within the vegetable category

Within the category of vegetables, sweeter vegetables are more preferred by children than non-sweet vegetables, and vegetables that are bitter are less liked than vegetables that are not bitter [65,69]. Some contradicting findings have been reported for texture preferences for vegetables. A preference for crunchy and dislike for "smooshie" was reported by Baranowski et al [32]. Baxter et al investigated children's perception of vegetables using photographs in two comparable groups of children using the same repertory grid method, and found that children preferred hard and crunchy vegetables in one study [71], and soft and juicy vegetables in the other study [69]. The two studies differed in the type of vegetables used, and these results indicate that it is difficult to examine texture preferences by comparisons across vegetables, since they represent different combinations of flavour and texture properties and do not differ simply in their texture properties. This highlights a need for within-vegetable research which provides some more control over the combination of flavour and texture properties.

In terms of appearance, not much is known yet about children's preferences for vegetables. Focus groups identified colourful vegetables to create positive expectations, whereas ugly, wrinkled and yellow and purple coloured vegetable raised negative sensory expectations [32]. In addition to colour, size was also found to influence acceptance, with Baxter [69] reporting a preference for small, brightly coloured vegetables over large, dark green (leafy) vegetables.

Colour

A study in which children of different age groups categorised fruit and vegetables, found that 4-5 year old children did so on the basis of tangible appearance attributes, whereas older children used more abstract characteristics such as taste [67]. This may indicate that appearance plays a larger role in food choice of these younger children than it does in older children. This is supported by research from Oram et al [72], who presented participants with drinks with incongruent colour/flavour combinations (e.g. a brown drink with orange flavour). Children below the age of 7 identified the drink on the basis of its colour, whereas children aged 10 years or older predominantly used flavour as basis for identification. Colour, as any appearance attribute, creates expectations about in-mouth sensory properties, and expectation theories predict that expectations influence liking (see Schifferstein et al for a review [73]). In familiar disliked foods, the colour of the food itself may trigger negative expectations about the taste, and affect liking negatively through assimilation between expectations and taste experience. Baxter [71] has suggested that colour affects vegetable preferences through previously established colour/flavour associations. As far as we are aware, the role of colour in acceptance for vegetables has not yet been investigated experimentally. Many vegetables are predominantly available in one colour, (e.g. French beans are typically green). However, other coloured cultivars do exist. Their availability is more scarce, and they are typically not available year round, and therefore most children are probably not familiar with these cultivars. Is it unknown what the influence of an unfamiliar colour is on acceptance of vegetables amongst children. This should be studied, as it will help determine to what degree expectations based on prior experience guide children's acceptance for vegetables.

Preparation method and cooking time

Preparation affects colour, flavour and texture of vegetables [(74-78)]. Several studies have suggested that preparation method may influence children's acceptance for vegetables [(28,32,36,37,41,71)]. Using a repertory grid method, Baxter [(71)] found that children preferred raw vegetables to cooked, which was also noted by Szczesniak [(41)], and a distinction between preference for raw and cooked vegetables was also used by Reinaerts et al [(28)] to model differences in vegetable intake in children. Baxter [(71)] further observed that certain preparation methods were in particular associated with dislikes of certain textural properties. Early focus group work by Baranowski et al [(32)] found that children liked vegetables the most when flavourings were added, like raw vegetables served with a dip, or cooked vegetables served with butter or sauce, and similar findings were reported in another study by the same group [(36)]. They further observed that children's preferred method of preparation was the preparation method they were used to eating at home, pointing to the role of familiarity [(32,36)].

However, none of these early studies were based on experimental designs in which children actually tasted vegetables. In fact, not much research has been conducted so far that investigates children's acceptance for vegetable preparation methods. Blossfeld et al [(79)] found that 12 month old infants had a higher intake and reported enjoyment for carrots prepared pureed than chopped. As far as we are aware, only one study by Zeinstra et al [(80)] used older children to experimentally investigate the effect of preparation on actual tasted acceptance for vegetables. They presented children from three different age groups (4-5, 7-8 and 11-12 years old) as well as young adults (18-25 years old) with two vegetables, green beans and carrots, each prepared in six different ways: mashed, steamed, boiled, stir-fried, grilled and deep-fried. The results for both vegetables were the same: participants in all age groups preferred boiled and steamed vegetables over the other preparations. Acceptance for preparation methods was positively related to a uniform appearance and typical vegetable taste, and negatively related to brown colouring and granular texture [(80)].

Research in adults has identified that steaming of vegetables is preferred to boiling [(81)]. Boiled vegetables are less intense in flavour than steamed vegetables, due to leaching out of water-soluble flavour-active compounds such as bitter-tasting glucosinolates and sugars [(74,76,78,82,83)]. In the case of bitter tasting vegetables, such as *Brassica* vegetables, therefore preparation methods that reduce bitter taste may be preferred by children. However, steaming is preferred to boiling from a nutritional perspective, due to the retention of nutrients (flavour-active as well as non-flavour active) such as vitamin C and aforementioned glucosinolates [(75,76,78,82-84)].

Cooking time affects colour, flavour and texture properties of vegetables [(75,85,86)]. Firmness typically decreases with cooking time, however, its potential effect on children's vegetable acceptance has not yet been investigated.

The relative absence of experimental taste studies on children's acceptance for different preparation methods highlights a need for further research. Research comparing similar preparation methods *across* vegetables from different plant categories (and hence different sensory properties) is needed to understand whether preparation methods can be identified that are preferred by children across the entire vegetable category. Research *within* specific vegetable types of similar type is needed for a more detailed investigation of the role that preparation factors, like preparation method and cooking time, have on children's vegetable acceptance.

Addition of flavours

Addition of flavours to vegetables can mask disliked flavours of vegetables. As described previously, children reported liking vegetables better when they were served with a dip or sauce [(32,36)]. Experimental taste testing research on the use of condiments to enhance vegetable acceptance also has been undertaken. Added salt was found to positively affect intake of toddlers, whereas added fat was not [(87)]. A plain and a herb-flavoured reduced fat dip also improved vegetable intake in pre-schoolers [(88)]. Fisher et al [(89)] found a similar result using a salt and fat containing dip, but only in bitter-sensitive children. As salt perceptually suppresses bitterness [(90)], at least in part the perceptual suppression of salt may be responsible for increased liking of bitter tasting vegetables. The use of mixed dishes was suggested as a potentially a viable strategy to increase children's acceptance for vegetables, as it can mask disliked flavour properties whilst retaining liked textural characteristics [(71)]. As far as we are aware, the acceptance of vegetables when part of mixed dishes, compared to acceptance of vegetables served 'on their own', has not yet been investigated in children. Research is needed to determine the acceptance of vegetables in mixed dishes. Similarly, research is needed to determine which preparations parents use to prepare vegetables for their children, including the use of flavourings.

Changing the person (behavioural intervention strategies)

Changing children's sensory preferences for vegetables is a second strategy to increase vegetable intake. This strategy can also be used by parents in the home environment. The three main sensory learning strategies described in the section on food preference development, i.e. flavour-flavour learning, flavour nutrient learning, and repeated exposure, have all been investigated for its potential to increase vegetable intake.

On the surface, FFL and FNL seem to be similar strategies to the strategy of adding flavourings described previously. For example, when salt is added as a positive US, this is similar to a flavouring strategy of adding salt to vegetables. However, there is an important difference. FFL and FNL both view the pairing with the US *as a learning phase*, during which the valence of the US is transferred to the CS. It is then assumed that after the learning phase, the valence of the CS has permanently changed, *also in the absence of the US*. In the case of the previously mentioned example of adding salt to vegetables, FFL assumes that vegetable liking will ultimately increase for the vegetable itself without added salt, whereas the flavour strategy makes no such assumptions, and assumes only that liking changes in the presence of salt.

Mere exposure seems to be at least as or more effective than flavour-flavour learning and flavour-nutrient learning to increase vegetable acceptance and intake in children (91-95). Mere exposure is also the simplest of these strategies to translate to public health recommendations and for parents to implement in their daily activities. Positive effects of mere exposure were found in infants (96-99), children at their peak of food neophobia (92,100-104), and older primary-school aged children (105). The use of a small non-food reward further promotes willingness to taste (100,101,106). In older children, typically smaller increases in intake were observed than in very young children. E.g. an increase from 50 to 90g was seen in infants after a nine-day exposure (96) whereas a similar exposure period led to an increase from 8 to 14g in 4-6 year old children (100).

A limitation in studies with children at their peak of food neophobia is that they have all used repeated exposure to a single vegetable, and measured the increased acceptance and/or intake of that single vegetable. For public health benefits, children should consume a broad range of vegetables, and therefore strategies that promote enjoyment and intake across a range of vegetables are needed.

Variety, built into the mere exposure paradigm, had a beneficial effect in infants on acceptance and intake of vegetables. Gerrish and Mennella (96) measured carrot acceptance and intake of infants before and after repeated exposure to one of three conditions. Carrot intake increased in the group that were exposed to carrot itself (a mere exposure effect) and in the group exposed to a variety of vegetables (not including carrot) but not to a group exposed to potato. Thus, a transfer effect was observed for exposure to a variety of vegetables other than the target, but not for exposure to a single vegetable different to the target. In another study (97), infants were exposed to either green beans (repeated exposure), four vegetables alternatingly offered on consecutive days (between-meal variety), or 2 of 4 vegetables offered on the same day in a rotating schedule on consecutive days (between-meal and within-meal variety). Unlike the other two groups, intake and acceptance in the between-meal and within-meal variety group increased for vegetables not previously offered. Together these two studies indicate that offering variety, especially as within-meal variety, increased intake of vegetables beyond the vegetables the child was exposed to.

Offering variety in exposure in children at their peak of food neophobia has not been investigated yet, so it is not known whether similar beneficial effects can be found in this age group. The dietary experience from these two age groups is very different. The infants studied just started weaning and were all formula fed. Therefore, their dietary exposure since birth was limited to milk formula, and they were novel to the oral exposure to the varied flavour and texture sensations of the vegetables. Children in their peak of food neophobia however, have already been introduced to a wide range of foods, and have had exposure to a wide range of flavour and texture properties. Unlike infants, they are also often not neutral towards vegetables, rather dislike them. Social interaction with the caretaker also differs considerably, as usually mothers and older children have engaged extensively around eating behaviours, e.g. around food refusals. In summary, prior dietary experiences, initial liking, heightened neophobia as well as prior social interactions all come into play when introducing vegetable variety in the age of peak neophobia, and may limit its effectiveness. Thus, research is needed to understand if vegetable variety exposure has benefits over exposure to a single vegetable in children at their peak of food neophobia.

Rationale and thesis outline

This thesis aims to gain insights in the sensory properties of vegetables as related to acceptance, and to understand the effect of vegetable modification and behavioural intervention strategies on sensory acceptance and intake of vegetables amongst children in their peak of food neophobia. The strategies investigated were all relevant for potential application in the home environment of the child.

The research objectives were:

- To compare the key flavour and texture properties of vegetables to those of other core food groups representative of the diet of Australian children
- To investigate the role of an unfamiliar colour on children's expected and actual acceptance of vegetables
- To determine the role of preparation method and cooking time on children's acceptance of vegetables, and as related to sensory properties
- To explore vegetable preparation practices used by parents
- To explore the relationship between acceptance and intake of vegetables across a wide range of vegetable preparations, including mixed dishes
- To investigate the effectiveness of repeated exposure to a multiple versus a single target vegetable to increase acceptance and intake in children

Fig. 1.1 provides a schematic representation of the factors and the characteristics that are investigated in this thesis to enhance understanding and potential to change sensory appreciation of vegetables for higher intake, and provides an insight which factors were investigated in the various chapters of this thesis.

Chapter 2 compares the key flavour and texture properties of vegetables to those of four other core food groups (fruit, dairy, meat/fish and grains). Chapters 3, 4 and 5 investigate different aspects of preparation strategies to change product properties of vegetables. Chapter 3 describes the effect of atypicality of colour and three different preparation methods on children's acceptance of three vegetables from different taxonomic plant categories. The effect of two water based cooking methods (boiling vs steaming) in relation to cooking time on children's acceptance were investigated in a study described in Chapter 4 using two vegetables of the same vegetable category of *Brassica* vegetables. Chapter 5 reports the findings of a survey amongst parents that compares children's acceptance and intake of 5 commonly consumed vegetables using a wide range of preparation methods, including mixed dishes. The last experimental chapter, Chapter 6, reports the result of a study that investigates an intervention strategy that aims to increase acceptance and intake amongst vegetables. Specifically, repeated exposure to multiple target vegetables was compared to repeated exposure to a single target vegetable for its effectiveness to increase vegetable acceptance and consumption amongst children with low vegetable intake.

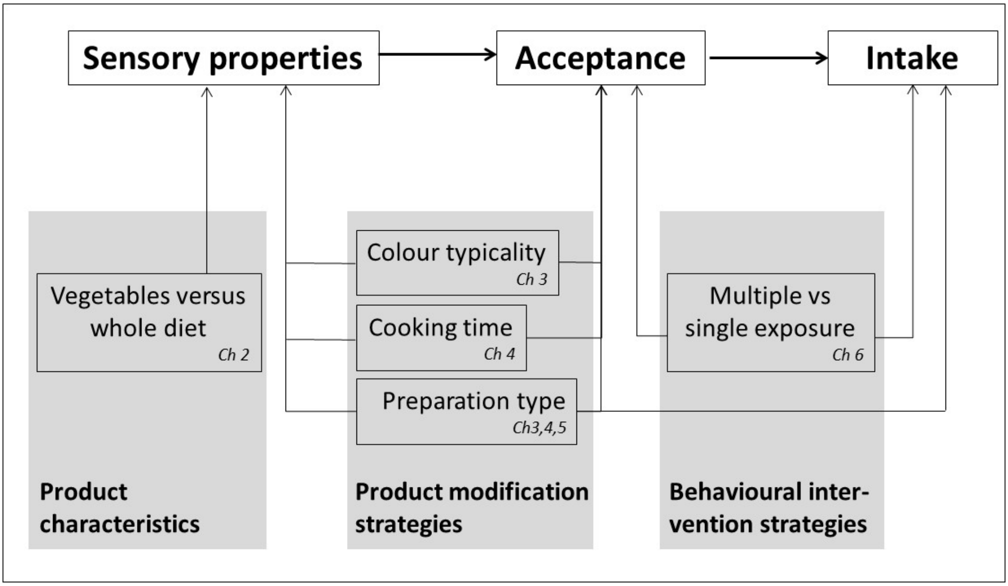

Figure 1.1 Schematic representation of strategies and characteristics investigated in this thesis to understand and increase sensory acceptance and intake of vegetables by children.

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Chapter 2

Vegetables and other core food groups: A comparison of key flavour and texture properties

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Abstract

Vegetables are the food category least liked by children. This research investigated the sensory properties of vegetables vis-a-vis other core foods that comprise children's diets, to determine to what degree low acceptance of vegetables can be attributed to sensory properties. Vegetables (*n* = 34) were compared to fruit (*n* = 26), dairy (*n* = 28), meat/fish (*n* = 28) and grains (*n* = 38); these foods were representative of the diet of Australian children and profiled by a trained sensory panel on 10 key taste and texture attributes as part of a larger study [(1)]. Mean intensities were analysed using ANOVA.

Vegetables were more *bitter* in *taste* than the other food categories and amongst the *hardest*. They were the lowest, or amongst the lowest, in all other flavour properties. Other core food categories had sensory properties known to be drivers of food liking: *sweet* and *sour* for fruit, *sweet, sour, salty* and *fatty* for dairy, *salty, umami* and *fatty* for meat/fish, and *salty* for grains. No food category other than vegetables had a *bitter taste*, a known driver of dislike.

This research shows that vegetables, relative to other food groups, have sensory properties that are known to predispose to low acceptance based on innate likes and dislikes or preferences acquired within the first few months of life. High *hardness* of vegetables implicates a slow eating rate, which is generally beneficial from a public health perspective, but may make it difficult to meet recommended vegetable intake. To increase children's acceptance and intake for vegetables, either vegetable sensory properties can be modified, or children's acceptance for vegetables can be modified through sensory learning strategies.

Keywords: sensory properties of diets; children; vegetables; taste; texture

Introduction

Children's consumption of foods is largely driven by hedonics [(2-4)]. Vegetables are the category of foods least liked by children, and other core food groups such as fruit, dairy, meat and grains are more readily accepted [(5-8)]. As a consequence children in most Western countries do not meet the recommended vegetable intake [(8-11)].

Children's low acceptance of vegetables has been largely ascribed to their bitter taste and lack of sweet taste [(13,14)], as well as a strong flavour [(15-17)]. In addition, energy density in vegetables has been related to vegetable acceptance [(18)], which can be explained by sensory learning through association from positive post-ingestive feedback.

There is ample evidence from nutrition composition databases that vegetables are relatively low in energy density compared to most foods; in fact, this low-energy density combined with their high nutrient density is one of the reasons their intake is promoted [(19,20)]. In contrast, scientific evidence on how the sensory properties of vegetables compare to those of other foods commonly consumed is currently largely lacking. This comparison is important, with consideration that individual foods and food groups are chosen from the selection available to form diet.

Recent research has started to investigate the sensory properties of overall diets, in an attempt to better understand the role that sensory characteristics play in food intake regulation. A French group used an in-home method of sensory analysis to profile foods that comprise the diet of French adults [(21)]. A total of 590 foods were profiled for basic tastes and fatty sensation. Six food classes were identified on the basis of their sensory properties. A large proportion of vegetables pertained to the group of foods with relatively more intense, salty, umami, sour and bitter taste, 19% of vegetables pertained to a class with high saltiness, and 6% of all vegetables pertained to a class characterised by high bitterness.

Ten key flavour and texture properties of the diets of Australian children have recently been characterised and added to a nutritional composition database [(1)]. In this research, a total of 377 foods from all food categories were profiled by a trained sensory panel on five basic tastes, flavour intensity as well as four texture attributes. These profiles were then systematically applied to all foods in a nutritional composition database, and sensory/nutrient relationships were explored. No analyses of specific food categories were reported.

The current study builds onto the research by Lease et al [(1)] by focusing on the sensory data and further analysing it, specifically by comparing the vegetable component vis-a-vis other core food categories. The aim of this research was to compare the flavour and texture properties of vegetables with those of other core food groups representative of the overall diet of Australian children. This research will help to determine which sensory properties are responsible for low acceptance of vegetables in children.

Methods

Samples

This research compared the sensory properties of vegetable items to the sensory properties of other core food groups representative of the diet of Australian children, using data collected as part of a wider study [(1)].

A full description of how the 377 foods that comprise the overall diet were selected is provided in Lease et al [(1)]. In brief, foods were selected on the basis of their frequency of consumption by children, using food intake data from the 2007 Australian National Children's Nutrition and Physical Activity Survey (ANCNPAS). This survey collected food intake data for 1 day from 4487 Australian children aged 2-16 years old using a 24-hr recall method. In general, foods with the highest consumption frequency within a minor food category of the AUSNUT 2007 (Food Standards Australia New Zealand, 2007) food composition database were selected for sensory profiling. The AUSNUT database is a hierarchical system, whereby each food, beverage and supplement in the database is classified into 23 major food groups, and then further categorised in sub-major groups and minor food groups.

"Vegetable products and dishes" is one of the major food groups in the AUSNUT database, The food group consists of 9 sub-major food groups primarily based on taxonomy of vegetables, and 19 minor food groups, primarily based on either vegetable type or preparation/processing method. As part of the 377 food items profiled by the sensory panel [(1)], a total of 47 items pertained to the major food group "Vegetable Products and Dishes". The following exclusions were applied: 1) Potatoes and starchy tubers (e.g. pumpkin, sweet potato). These items (*n* = 10) were excluded as although they are considered vegetables in the Australian context, they are not in most countries and in international guidelines [(22)], 2) Three vegetable items consumed only as an ingredient in a dish due to high level of processing (tomato paste, canned tomato) or intense flavour (garlic). The 34 items included (see Table 2.1) covered a substantial part of intake by Australian children, i.e. 81% (measured as frequency of consumption) and 83% (in terms of volume (in g)) of the consumption of the group of vegetables they represented.

The vegetable category was compared to four other core food categories: fruit, dairy, meat/fish and grains. To select the foods pertaining to each of the categories the following process was used: 1) Foods were considered for which a sensory profile was obtained from the following AUSNUT categories [(23)]: Fruit - "16 Fruit Products and Dishes"; Dairy – "19 Milk products and dishes"; Meat/fish – "15 Fish and Seafood Products and Dishes" and 18 "Meat, poultry, and game products and dishes"; Grains – "12 Cereals and Cereal Products". The fruit category does not include fruit juices, and the category of dairy products does not include dairy spreads [(23)]. 2) Products within these categories that were not core foods but occasional foods according to the Australian Guide for Healthy Eating were excluded [24] (examples of excluded items are processed meats like salami, and ice cream), 3) Dishes within the categories were excluded (examples of excluded items are apple crumble pie and “Beef, stir fry, chow mein (beef & noodles), Chinese restaurant style”). The Fruit category (*n* = 26) consisted of mainly fresh fruit (e.g. apple, banana) and a small number of dried fruit and fruit canned in non-sweetened juice. The Dairy category (*n* = 28) consisted of milks (differing in fat content), goat’s milk, yoghurts (differing in fat content and addition or not of flavourings) and cheeses (hard and soft cheeses, differing in type and fat content). The Meat/fish category (*n* = 28) included meat and fish of different animal origin (e.g. beef, chicken, salmon) and varied in preparation type (e.g. roasting, grilling, frying). The Grains category (*n* = 38), included breads differing in flour type (e.g. white, mixed grain, rye), ingredients added (e.g. dried fruit, fibre) and preparation (untoasted/toasted), other bread variants (e.g. bread rolls, pita bread), unsweetened muffin, pasta, rice, wheat noodles, tortilla, porridge and breakfast cereals differing in ingredients (e.g. corn, wheat bran, rice) and processing type (e.g. extruded).

Table 2.1 Description of 34 vegetable items profiled.

Vegetable products and dishes	Description of item (vegetable and preparation)
Cabbage, Cauliflower And Similar Brassica Vegetables	Broccoli: boiled, stirfried; Cabbage, boiled; Cauliflower; boiled, with white sauce
Carrot And Similar Root Vegetables	Carrot: raw, baked, boiled, stirfried; Beetroot: canned
Leaf And Stalk Vegetables	Celery: raw, stirfried; Lettuce, raw; Spinach, boiled
Peas And Beans	Peas: boiled; Beans: raw, boiled, stirfried
Tomato And Tomato Products	Tomato: raw
Other Fruiting Vegetables	Zucchini: boiled, stirfried; Avocado, raw; Capsicum: green raw, red raw, red stirfried; Cucumber: raw; Eggplant: grilled
Other	Mushroom: boiled, stirfried; Corn, boiled; Onion, stirfried; Coleslaw; Mixed green salad; Mixed boiled vegetables

Sensory evaluation

For a full description of the sensory evaluation methodology, the reader is referred to Lease et al [1]. In brief, a trained sensory panel used a Spectrum® inspired method to collect sensory intensity scores across 10 key sensory attributes. The attributes were the five basic tastes (*sweet, salty, sour, bitter* and *umami*), *overall flavour impact* and four texture attributes; *hardness, moistness, cohesiveness of mass* and *fatty mouthfeel*. Attributes were rated on unstructured 100mm line scales, using Compusense® *five* sensory data acquisition software (version 4.6, 2004; Compusense Inc., Guelph, Ontario, Canada).

Data analysis

Analyses were conducted using SPSS (IBM, SPSS Statistics, v20.0.0, 2011) and Unscrambler (Camo, v.9.1, 2004). A *p* value of 0.05 was used as a criterion for statistical significance.

First, the sensory data from the vegetables were compared to the sensory data of the other core food categories (fruit, dairy, meat/fish, and grains) in the diet of Australian children, by highlighting these categories in a Principal Component Analysis (PCA) biplot representation of the Overall Diet. PCA on the vegetable items was also conducted separately, to gain insights in the key differentiating flavour and texture attributes of vegetables.

The mean flavour and texture intensities of the five food categories were statistically compared using ANOVA, and Bonferroni as post-hoc test. Vegetables were also compared to the overall set of foods that comprise the overall diet ($n = 343$), by calculating distributions for each sensory attribute (minimum, maximum and 25% percentiles). These data were visualized using Box and Whisker plots, and difference in mean intensity ratings tested using t-tests.

Results

Biplot comparison of sensory properties of vegetables and other core food groups

Fig. 2.1 highlights the different core food categories (vegetables, fruit, dairy, meat/fish and grains) in the overall two-dimensional representation of the sensory properties of the foods comprising the overall diet of Australian children. Vegetables occupied a relatively small part of the flavour two-dimensional space (Fig. 2.1a), indicating that they were relatively similar to each other in *flavour intensity* and taste compared with all products profiled. The vegetables were located primarily in the left lower quadrant, which represents foods relatively low in *flavour intensity*. There were several vegetables positioned towards the sweet axis, indicating that they had some degree of *sweetness*. Fruits were positioned more towards the sweet axis, and meat/fish more towards the salty and umami axis. Dairy products were positioned both towards the sweet axis as well as the salty axis. Grains were located partly in the lower left quadrant, indicating low intensities overall, and partly towards the sweet axis.

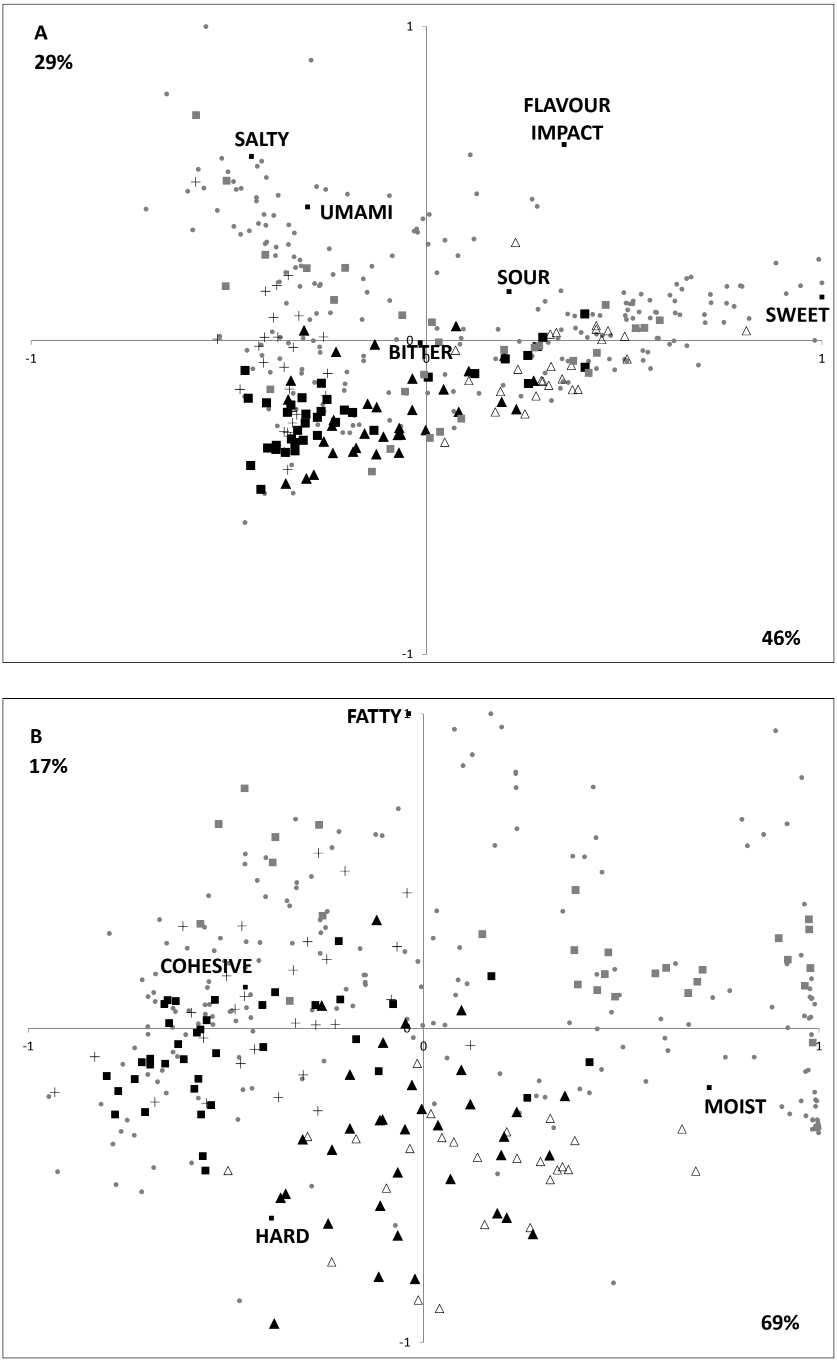

Figure 2.1 Two-dimensional representation derived from Principal Component Analysis describing the sensory properties of foods (n = 377) that together comprise the overall diet of Australia children; ▲ = vegetables; △ = fruit; ■ = dairy; ■ = grains; + = meat/fish; ● = other foods; A) flavour properties, and B) texture properties.

In texture, vegetables as a group were characterised by being both *hard* and *moist* at the same time, as well as low in *fatty mouthfeel* (Fig. 2.1b). Although the vegetables were clustered towards a particular area of the texture sensory space, their representation shows there were still considerable texture differences between them. Fruit largely occupied the same texture space, indicating that vegetable and fruit were similar in their texture properties. Dairy products largely were either *moist* or more *cohesive*, with varying degree of *fatty mouthfeel*. Meat/fish were mostly clustered together around *cohesiveness*, with varying degree of *fatty mouthfeel*, whereas grains were mostly *cohesive* in texture.

Attribute intensity comparison of vegetable sensory properties with those of the overall diet

A comparison of vegetables with the other core food groups on an attribute by attribute level shows that all attributes were highly discriminating between the five categories (Table 2.2). Vegetables were the lowest or amongst the lowest in *salty, sour* and *umami taste,* and in *flavour intensity,* low in *sweet taste* (although higher than meat/fish) but the only category high in *bitter taste*. In texture, vegetables were amongst the lowest in *fatty mouthfeel* and *cohesiveness of mass*, average in *moistness,* and amongst the highest in *hardness*. Fruit was high in *sweet* and *sour taste*, and similar in texture to vegetables. Dairy was characterised by high *sweet taste, salty taste, sour taste, flavour intensity* and *fatty mouthfeel*. Meat and fish was characterised by high *salty* and *umami taste*, and *fatty mouthfeel*. Grains were characterised by high *salty taste* and *cohesiveness of mass*.

Table 2.2 Average sensory intensities for 5 core food categories from consumption data representative of Australian children's diets.

	Vegetables (n = 34)		Fruit (n = 26)		Dairy (n = 28)		Meat/fish (n = 28)		Grains (n = 38)		F value	p value
Sweet taste	18.06	b	37.51	a	26.08	b	7.71	c	18.70	b	19.19	<0.0001
Salty taste	5.86	b	1.17	b	16.32	a	20.09	a	17.22	a	16.80	<0.0001
Sour taste	5.65	b	26.79	a	21.05	a	2.06	b	4.08	b	28.61	<0.0001
Bitter taste	9.66	a	5.21	b	2.32	b	1.57	b	1.93	b	14.92	<0.0001
Umami taste	3.02	b	0.82	b	6.27	ab	12.36	a	2.90	b	8.88	<0.0001
Overall flavour impact	34.69	b	49.74	a	45.96	a	34.96	b	29.40	b	17.37	<0.0001
Hardness	40.56	a	33.67	a	8.48	b	32.69	a	30.00	a	16.68	<0.0001
Moistness	48.14	b	59.08	ab	61.59	a	25.93	c	17.34	c	36.31	<0.0001
Cohesiveness of mass	29.83	b	30.96	b	22.25	b	50.96	a	53.12	a	32.73	<0.0001
Fatty mouthfeel	8.49	cd	1.30	d	35.20	a	25.37	b	12.70	c	61.51	<0.0001

Box and Whisker plots show that the Overall Diet (n = 343) had a larger range of intensity ratings than vegetables (n = 34) for most sensory attributes, which is not surprising given the larger heterogeneity in foods that comprise this group. However, this was not the case for *bitter taste* and *hardness*, of which the 50% range in scores for vegetables was larger than (*bitter*) or similar to (*hard*) the other foods comprising the diet. Vegetables were lower in *sweet, salty, acidic* and *umami taste*, lower in *flavour impact*, and lower in *fatty mouthfeel*, compared to all other foods comprising the diets of Australian children, whereas they were also more *bitter* in *taste* and *harder* (Fig. 2.2). They did not differ in *moistness* and *cohesiveness* ($p > 0.05$).

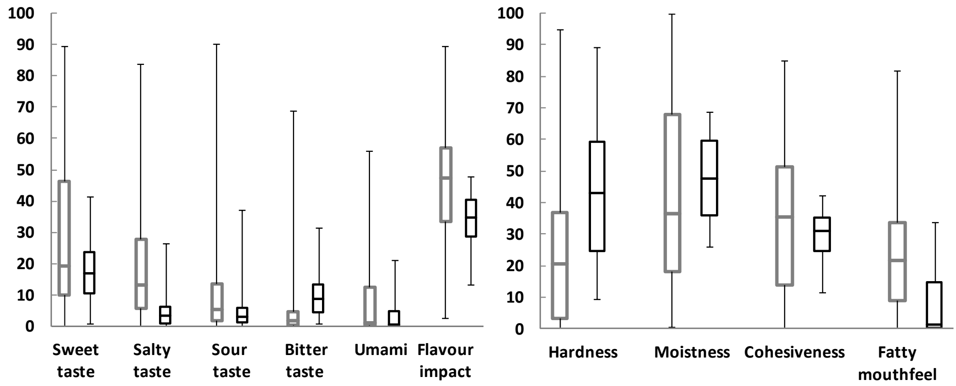

Figure 2.2 Distribution of intensity scores of vegetables (n = 34, black) and other foods items comprising the diets of Australian children (n = 343, grey). Bold horizontal lines represent the medians, boxes the 25% and 75% quartiles, and whiskers the minimum and maximum values.

Two-dimensional representation of vegetable sensory properties

The two-dimensional <u>flavour</u> representation of vegetables (Fig. 2.3a) was determined by *sweet taste, bitter taste* and *flavour intensity*. As the flavour space of the overall diet was determined by *sweet taste, salty taste* and *flavour intensity* (Fig. 2.1a), these results demonstrate that *bitter taste* plays an important role in describing differences between vegetables, whereas this attribute was not highly relevant in describing differences in flavour of children's diets overall. The relatively proximity of the attributes *salty taste* and *umami taste* to the origin indicates that these taste properties were not important in describing the key sensory differences of vegetables commonly consumed by Australian children.

In some cases, vegetables prepared in different ways were clustered together, indicating that they were relatively similar in flavour properties; e.g. carrot was relatively *sweet* in *taste* regardless of whether prepared boiled, baked, stir fried or raw. In other vegetables, preparation had a larger effect of flavour properties, e.g. zucchini, which was more *bitter* when boiled than when stir fried.

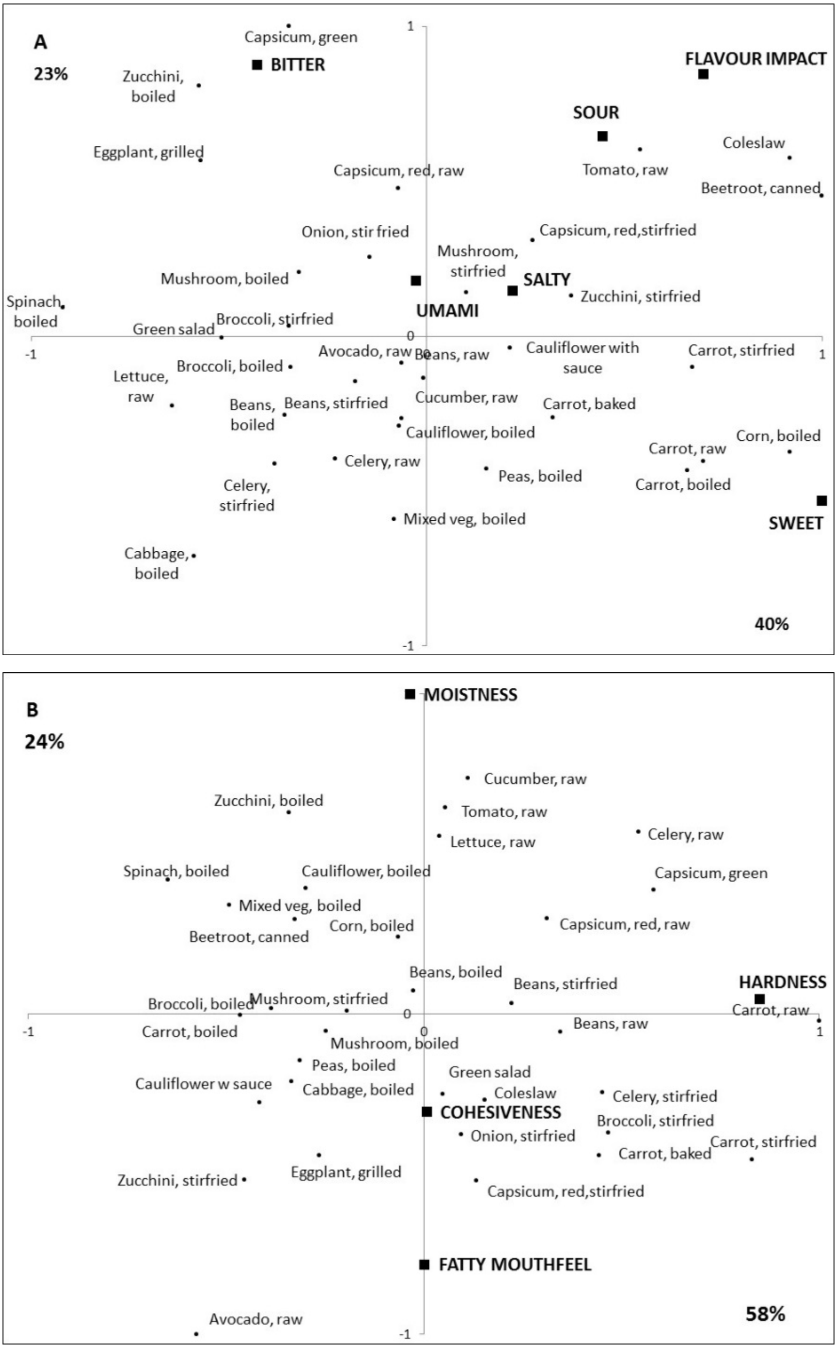

Figure 2.3 Two-dimensional representation derived from Principal Component Analysis describing the sensory properties of vegetables (n = 34); A) flavour attributes; B) texture attributes.

The two-dimensional representation of the texture of vegetables was largely determined by *hardness, moistness* and *fatty mouthfeel* (Fig. 2.3b). *Hardness* and *moistness* were positioned relatively orthogonal towards each other, indicating that there were relatively independent from each other. *Fatty mouthfeel* opposed *moistness*, indicating that vegetables high in *fatty mouthfeel* (e.g. avocado) were relatively low in perceived *moistness*, and vice versa (e.g. cucumber). Several vegetables prepared in different ways were considerably different in their texture properties, e.g. carrot was *hard* when raw and stir fried, and much softer when boiled, and stir fried zucchini was perceived as more *fatty*, whereas boiled zucchini was perceived as more *moist.*

Discussion

This study compared the key flavour and texture properties of vegetables consumed by Australian children to the key flavour and texture properties of other core food groups, using foods representative of the diets of Australian children. The results showed that vegetables more *bitter* in *taste* than any other core food group, and *hard,* whereas they were lowest or amongst the lowest in *flavour intensity*, in *sweet, salty, sour* and *umami taste*, and in *fatty mouthfeel*.

Children’s low liking for vegetables has been attributed to their lack of sweetness, high bitterness, and high flavour intensity [13-17]. However, these insights were not based on a formal comparison of vegetable sensory properties compared to other food categories or the overall diet. Our study confirms that indeed vegetables were more *bitter* than the other core food groups and the overall diet. Vegetables were low in *sweetness* compared to the overall diet, however they were similar in *sweetness* to grains and dairy, which are more readily consumed food groups by children [5,6]. Vegetables were not high in *flavour intensity*. In contrast, vegetables overall were quite low in *flavour intensity*, similar to the food category of meat/fish and grains.

The objective comparison of vegetables with other core food groups provides a more holistic perspective on the sensory properties that differentiate vegetables from other foods. All the other core food groups contained sensory properties that are known to positively influence palatability, i.e. *sweet taste, salty taste, umami taste* and/or *fatty mouthfeel*, [25-28] or *sour taste*, which is a driver of liking to a subgroup of children [29]. Fruit was *sweet* and *sour*, dairy was high in *sweet, salty* and *sour taste,* and in *fatty mouthfeel*, meat/fish was high in *salty taste, umami taste* and *fatty mouthfeel,* and grains were *salty.* In comparison, vegetables did not contain any of the drivers of liking, rather they contained a known driver of dislike (*bitter taste*) [14]. Therefore, the observation emerges that it is the absence of positive drivers in combination with the presence of a negative driver that is responsible for children’s low vegetable acceptance. This is important, as diet is based on choice between options. Thus, choice for vegetables will not only be made on attributes in vegetables that are liked or not liked, but also on what attributes other foods have that are more liked.

Vegetables were also amongst the *hardest* food group, numerically the higher than the other core food groups. Several raw vegetables which were amongst the hardest vegetables, are well accepted by children [(30,31)], therefore it is unlikely that this inhibited intake as a sensory property. However, hard food requires considerable mastication effort, which leads to slower eating rates and as a result limits intake [(32-35)]. Whereas generally slower eating rates are encouraged in public health policies, the relative hardness of vegetables limits their intake and may make it difficult to meet recommended vegetable intakes. Results further show that vegetables were similar to other foods in the other texture properties (*moistness* and *cohesiveness*), therefore these texture properties were unrelated to children's low acceptance for vegetables.

There are few studies with which the results of our study can be compared. Of most relevance is the study by Martin et al [(21)] who analysed the sensory properties of French diets. This study clustered groups on the basis of sensory properties rather than foods, thus a direct comparison cannot be made. Based on the percentage of vegetable dishes that were part of the sensory clusters, they found that vegetables pertained to categories of foods described as relatively intense in salty, bitter and acidic tastes. We also found relatively high bitterness of vegetables, however did not find that salty and acidic taste were important in comparing vegetables to the overall diet. The French study compared dishes, whereas our study compared mostly foods. Despite this different approach, both studies found that the overall diet was characterised by a sweet and a salty dimension. The results together suggest that the flavours of vegetable dishes consumed in Martin et al's study [(21)] were mostly not due to the vegetable properties. Rather, they indicate the use of flavourings in the French cuisine to prepare vegetables, for example in the use of salads with vinaigrettes.

The comparison of sensory properties within the vegetable category showed differentiation in attributes; these included *sweet* and *bitter taste* for flavour, and *hardness* and *fatty mouthfeel* for texture. Differences related to vegetable type as well as preparation, and thus preparation can be used as a means to create more desirable sensory properties for children. Preparation can relate to cooking method (e.g. boiling, stir frying) or the use of other flavourings to mask undesirable flavours or create desirable flavours. This area of research has recently gained interest (e.g. [(36-42)]. However, repeated exposure to a food itself has also been shown to increase acceptance [(43)].

A strength of the current study is the objective comparison of sensory properties of vegetables and other core food groups that comprise Australian diets. The selection of foods was based on their frequency of consumption by Australian children from a national survey, and therefore the food categories have high external validity for representing actual diets. This research measured 10 relatively generic sensory attributes, which was a necessity in order to be able to compare the very diverse range of foods that comprise diets. To describe differences within food categories accurately, more category specific sensory attributes would need to be added. Lastly, by definition of selecting foods on the basis of their high frequency of consumption, no vegetables were included that are not or very rarely consumed by children, such as notoriously bitter vegetables (e.g. Brussels sprouts). Thus, the differences in sensory properties of vegetables compared to those in the overall diet may be underestimated in our research. Further insights could be gained by analysis of considering amount of food consumed in relation to sensory properties, and this could be subject of further research.

This research shows that vegetables have sensory properties that are known to predispose to low liking based on innate likes (sweet taste) and dislikes (bitter taste) [(25)] or preferences acquired within the first few months of life (salty, fatty mouthfeel) [(44)]. They also do not contain other sensory properties that can drive consumer liking (like umami taste or sour taste). Results suggest two potential pathways to increase children's acceptance of vegetables. The first pathway is to change the sensory properties of vegetables to create sensory properties better accepted by children, for example by preparation. The second pathway is by recognising that food preferences are highly malleable early in life, and to using sensory learning strategies, such as repeated exposure strategies, to increase children's acceptance of vegetables.

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Chapter 3

The effect of preparation method and typicality of colour on children's acceptance for vegetables

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Abstract

This research aimed to investigate if children's acceptance for vegetables was influenced by preparation method or typicality of colour. Sweet potato, cauliflower and beans were tested using different cooking methods and using typically or an atypically coloured vegetable. Children's acceptance was measured among a group of 104 five-and-six year olds. A trained sensory panel determined the vegetable samples sensory characteristics. Background information for children was collected from parents. Preparation method affected acceptance for cauliflower and beans, with baked /stir fried samples accepted less than boiled samples. A high *odour intensity* and the presence of a *browned flavour* were found to lower acceptance. Differences in texture and flavour characteristics imparted by different boiling times, as well as small differences observed in sweetness or bitterness, did not affect acceptance. Atypical colour had a positive influence on expected preference but not on acceptance upon tasting. Familiarity, variety in the number of vegetables liked, and reported liking of target vegetables was associated with higher acceptance. Preparation method was more important for acceptance for children who liked fewer vegetables than those who liked many vegetables.

Keywords: children; preference; acceptance; vegetables; preparation methods; colour; typicality; descriptive analysis

Introduction

The consumption of vegetables has been associated with a lower risk of cardiovascular disease [(1)] and certain cancers [(2)]. Vegetables can also play an important role in the prevention of obesity, as increased consumption can reduce energy density, decrease energy intake and promote satiety [(3)]. Consumption of vegetables below recommended levels is typical in most Western countries [(4,5)]. The 2007 Australian Children's National Nutrition and Physical Activity Survey found younger children to consume a little over 1 vegetable serve on the survey day [(4)], whereas two serves are recommended [(6)].

Many factors are associated with consumption of vegetables below the recommended intakes, including socio-economic status [(7,8)], mother's education and parental intake of vegetables [(9)], and availability and accessibility of vegetables [(10-12)], but sensory preferences were a key barrier to consumption [(7,10-13)]. Several studies were successful in increasing children's sensory acceptance and consumption of a vegetable with exposure to the vegetable using daily tastings for two weeks [(14,15)].

Children are born with a preference for sweet and a dislike for bitter foods [(16)]. However, most food preferences are learned and childhood appears to be one of the critical phases in the development of such preferences [(17)]. Physiological factors related to development of oral musculature and dentition are thought to be dominant in shaping attitudes to texture [(18)], and texture appears to be of particular relevance for children's food acceptance [(18-22)]. Based on interviews with mothers of four or more children, children of up to 12 years old were found to dislike textures that are difficult to manipulate in the mouth and to like simple, one-dimensional textures more than textural contrast [(18)]. Six-to-12 year old children's disliked slippery or slimy foods, whereas crispiness became a liked texture for children of this age group [(18)]. These findings are supported by Baxter et al, who found that hard and crunchy vegetables were preferred by 8-10 year olds using repertory grid with vegetable photographs [(19)]. However, the same research group found children to prefer soft, juicy and flavoursome vegetables in another study using the same methodology and age group, but a different set of vegetables [(20)]. These findings demonstrate that it is difficult to determine the contribution of flavour and texture properties to vegetable acceptance by using between-vegetable comparisons and without actual tasting.

Within vegetables, sensory properties can be modified by preparation and several studies suggested preparation method may influence children's acceptance [(7,8,10,18,19,23)]. Baxter et al (1998) [(19)] and Szczesniak (1972) [(18)] found that children preferred raw vegetables to cooked vegetables. Baranowski et al (1993) [(10)] observed that children preferred vegetables served raw with a dip, or cooked with butter or a cheese sauce. Baxter et al (1998) observed that certain vegetable preparations were particularly associated with dislike of textural properties [(19)]. However, none of the above mentioned studies involved actual tasting, and instead were based on interviews or questionnaires only.

Few studies have investigated the effect of preparation on within-vegetable acceptance by actual tasting. Blossfeld, Collins, Kiely & Delahunty (2007) [(24)] presented twelve month old infants with steamed carrots prepared in two ways, chopped and pureed, and found the highest intake and reported enjoyment for pureed carrots. Using apples of three different textures, pureed, lumpy and diced, infants (average age 10 months) were found to respond negatively to complex textures whereas toddlers (average age 17 months) showed more positive head and body movements and more eagerness for complex textures than the infants did [(25)]. Both studies suggested that experience with difficult-to-chew textures could facilitate a preference for a more complex texture. As far as we are aware, only one study investigated the effect of preparation method on sensory vegetable preferences of older aged children by tasting [(26)]. These authors investigated preference for carrots and beans each prepared in six ways among children ranging from 4-12 years, and among young adults. All age groups were found to prefer boiled and steamed vegetables to those that were stir fried, mashed, fried and grilled. Vegetable liking was positively related to uniform surface appearance and typical vegetable taste, moderately to crunchiness and negatively to brown colouring and granular texture.

The role of appearance for children's acceptance of vegetables has received little attention. Baxter et al (2000) [(27)] found size and colour to affect children's acceptance for vegetables. Small, brightly coloured vegetables were preferred to large, dark green (and leafy) varieties. Zeinstra et al (2007) [(21)] found appearance and texture to be the most important determinants for liking and disliking in fruit and vegetables in 4-5 year-olds, whereas a shift towards taste attributes was observed in 11–12-year-olds. The youngest age group categorised fruit and vegetables on the basis of colour and shape; items of the same colour were put in the same group. These studies indicate that colour is important for children's acceptance of vegetables, although results were based on between-vegetable comparisons only and cannot be extrapolated to within-vegetable comparisons. The importance of colour for young children's evaluations was further demonstrated in a study in which drinks with atypical colour/flavour pairings (e.g. a brown drink with orange flavour) were presented. Children of 7 years and below relied on the colour of the drink to make a decision about its taste, whereas identifications of subjects of 10 years and older were predominantly flavour-based [(28)].

Expectation theories (for an overview see Schifferstein, Mojet and Kole, 1999) [(29)] predict that expectations influence subsequent liking. Children who do not like a particular vegetable can be assumed to have low expectations about its taste once they identify it due to previous appearance/flavour associations; the opposite may be the case for children who like that vegetable. In fact, colour has been suggested to affect children's vegetable preferences as a result of previously established colour-flavour associations [(7)]. Most vegetables are commercially available and consumed in one colour (e.g. green beans), although other coloured varieties may exist. Atypically coloured vegetables, such as yellow French beans, due to low availability and thereby low familiarity, may be less associated as belonging to the same vegetable category and may not evoke the same expectations as their typically coloured counterpart. Rather, their evaluation may be less influenced by (prior) expectations. To our knowledge, no studies have been published that examined the role of colour or colour typicality on children's acceptance within the same vegetable type.

This study investigated the effect of cooking preparation and typicality of colour on children's acceptance for vegetables by actual tasting using a within-vegetable, within-subject design. No prior assumptions were made about the relative importance of colour congruency, flavour and texture for acceptance, but a firm, crunchy texture and an atypical colour were hypothesized to positively influence acceptance. Acceptance was related to background characteristics of the children and to objective information on sensory properties of the vegetables. The main focus of this study was on different cooking methods using typically coloured vegetables, as these comprise the large majority of vegetables consumed. Five and six year olds were selected for this study. Food neophobia reaches a peak between three and six years (17,30), and children of the selected age group have the cognitive ability to rate acceptance reliably (31). The objectives of the study were fourfold: 1) to determine children's acceptance for typically coloured vegetables prepared for eating in three different ways; 2) to determine children's acceptance for typically and atypically coloured vegetables prepared in the same way; 3) to determine relationships between preparation methods, sensory attributes and children's acceptance, and 4) to determine if behavioural and socio-demographic factors impact on acceptance.

Materials and methods

Participants

Children, and one of their parents, from the Sydney metropolitan area, Australia, were recruited by a recruitment agency. Children were aged 5 or 6 years and had to attend primary school. Children who strongly disliked two or more of the target vegetables (i.e. sweet potato, cauliflower and French beans), as well as children, or children of parents, with any known food allergies or dietary intolerances were excluded. A total of 104 children participated in the study. All child/parent pairs were paid for their participation. Ethics approval for the study was granted by the CSIRO Human Research Ethics Committee.

Samples

Three vegetables, sweet potato (*Ipomoea batatas*), cauliflower (*Brassica oleracea botrytis*) and French beans (*Phaseolus vulgaris*), were selected as examples of various vegetable categories. Vegetables were chosen that were substantially different in sensory properties, had economic importance in terms of market value in Australia and were not highly liked nor highly disliked by children in a pilot test. The pilot test (n = 18) used the same recruitment criteria and methodologies as the actual consumer test. An additional vegetable, eggplant, was tested, but was disliked and was not selected for further testing.

Each vegetable type was served in four different ways. This study focused mainly on typically coloured vegetables (i.e. orange sweet potato, white cauliflower, and green French beans) since these comprise the majority of consumption and, unlike atypically coloured vegetables, are year round available to the consumer. Three preparation methods for typically coloured vegetables were selected through an iterative process. A range of cooking methods that could easily be applied in households, such as boiling, steaming, micro-wave cooking, mashing, frying, grilling and baking, were trialled for each of the vegetables. Within each cooking method a range of preparation times and, where relevant, other preparation details were trialled. Samples were evaluated by four experienced sensory staff who were aware of the research objectives. The aim was to select preparations in which sensory properties were substantially different. Where practical, similar (cooking) methods were applied to all vegetables under investigation to allow for a comparison across vegetables. To gain insights on the role of typicality of colour, one atypically coloured vegetable (i.e. white fleshed sweet potato, green cauliflower, and yellow French beans) was tested. The final sample set thus included three typically coloured and one atypically coloured vegetable within each vegetable type (Table 3.1). The atypically coloured one was boiled for the same duration as a typically coloured one. The other typically coloured samples comprised of one preparation method using oil (baked or stir fried) as well as one vegetable specific preparation method (short boiled for cauliflower and beans; mashed for sweet potato).

Table 3.1 Description of the samples.

Vegetable	Variant	Preparation
Sweet potato	Boiled	Orange sweet potato boiled for 12 min
	Mashed	Orange sweet potato boiled for 12 min then mashed
	Baked	Orange sweet potato boiled for 5 min, then baked for 15 min
	Colour	White sweet potato boiled for 12 min
Cauliflower	Boiled	White cauliflower boiled for 15 min
	Short boiled	White cauliflower boiled for 5 min
	Baked	White cauliflower boiled for 5 min, then baked for 10 min
	Colour	Green cauliflower boiled for 15 min
Beans	Boiled	Green beans boiled for 12 min
	Short boiled	Green beans boiled for 4 min
	Stir fried	Green beans boiled for 2 min, then stir fried for 3 min
	Colour	Yellow beans boiled for 12 min

Detailed and timed protocols were used to ensure accuracy and consistency in preparation. Samples were prepared fresh for each session and immediately served at approximately 55 ± 5 ºC.

Children were presented with a plate containing the four variants of the same vegetable. The plate contained two pasta spirals in the middle to create a meal context. This presentation enabled a direct comparison of the samples, while not making explicit that they belonged to the same vegetable category. Each sample was placed on a small transparent container. A small portion that enabled at least two bites was served; a triangular piece of 1.5 cm thick for sweet potato, one floret for cauliflower and two pieces of ~4 cm length for beans. Samples for descriptive sensory analysis were presented in the same way.

Procedure

Each child participated in a single session of approximately 50 min duration in which he/she tasted the three vegetables in each of four variants. Sessions were held with six children at a time. Oral instructions were provided to the group, after which children were seated in adjoining test rooms. Two children occupied each room, seated opposite one another with screens on the table to prevent them from interacting. Each child had one-on-one assistance from a trained test administrator who assisted the child and recorded all responses. A test administrator was preferred over the child's parent to ensure consistency and objectivity and to avoid unintended bias [(31,32)]. The parent was seated in close proximity, but not within view of the child. Parents were instructed not to interact with their child during the taste testing.

Children in the same session evaluated the vegetable types in the same order; this order was counterbalanced across the sessions. The tasting order of the four variants within vegetable type was different for each child in one session and was counterbalanced across all children.

Upon receiving a plate, expected preference was first measured by asking the child: "Could you please point out the sample that you think you will like the most?". The children were instructed to base their evaluation only on appearance. Children were not allowed to bring their nose to the plate, which was placed approximately 90 cm away from the child, thereby minimising the contribution of smell to the evaluation of individual samples. Then, the children tasted small quantities of each sample in the required order. Acceptance was measured using a three-point facial hedonic scale [(14,15,31)] printed on A4-sized paper. Three smiley faces represented respectively "yucky", "just okay" and "yummy".

Children were encouraged to taste the vegetable (they did not have to eat the entire sample) and where necessary prompts were provided according to a specified procedure. Using one copy of the scale, the child placed each of the four samples on the smiley face that corresponded to their response. Once all four samples were evaluated, the children ranked them in order of preference. They were allowed to re-taste samples and were asked to do so in the case of ties. This procedure was repeated for the remaining two vegetable types.

Questionnaire

As part of participant recruitment, information from parents was collected on the child's liking for 24 common vegetables using a five point hedonic scale (1 = clearly dislike, 5 = clearly like). A Food Frequency Questionnaire (FFQ), adapted from the vegetable component of the CSIRO FFQ [33], for the same vegetables measured average consumption of the vegetables in the past 3 months and was used to collect consumption data for the target vegetables, as well as the variety of vegetables consumed. Parents completed an additional background questionnaire while their child conducted the test. The parent indicated how they typically prepared the vegetables used in this study for their child by marking one or more pre-listed options, and with the option to describe "other". They recorded preparation times for each method they had marked. Parents marked (yes/no for each vegetable) whether their child had ever consumed the atypically coloured vegetables of the study. The child's Food Neophobia was measured using a validated scale [34,35]. Information on child's age, gender, number of siblings, parent's level of education and breastfeeding history was also collected. In addition, some further, mainly qualitative, data were collected, which are not presented in the present paper.

Descriptive sensory analysis

Descriptive sensory analysis was carried out to determine the sensory differences between and within vegetable samples. The sensory panel consisted of nine experienced assessors (all women, aged 47.2 ± 7.4 years). Training consisted of one session for overall vocabulary development and one session specific to each vegetable type. The procedure used ensured that comparisons could be made within and between vegetable types. A sensory vocabulary consisting of 19 attributes described the differences between the samples (Table 3.2). Attributes were rated on 100 mm unstructured line scales. Evaluations were carried out in triplicate using Compusense (v4.6, 2004).

Data analysis

Consumer study

The acceptance categories "yucky", "just okay" and "yummy" were assigned scores of -1, 0 and 1 respectively. Non-parametric statistical tests were applied as data were not normally distributed. Ranking scores were used as was.
Chi-square goodness-of-fit tests were conducted within each vegetable type to determine any differences in the sample chosen on the basis of appearance.

Table 3.2 Mean intensity[1] ratings of sensory descriptive analysis.

Category	**Odour**		**Appearance**		**Flavour / taste**				
Sample [2]	Odour Impact	Vegetable specific O	Colour Intensity	Shiny	Flavour Impact	Sweet Taste	Bitter Taste	Salty Taste	Sour Taste
SP Boiled	43.24^{d}	46.41^{ab}	58.91^{c}	13.85^{d}	45.74^{de}	23.52^{bc}	0.76^{b}	1.85	2.06^{ab}
SP Mashed	38.94^{d}	43.30^{ab}	51.57^{d}	13.96^{d}	44.06^{e}	22.48^{bcd}	2.87^{b}	0.89	3.26^{a}
SP Baked	67.57^{ab}	43.41^{ab}	62.54^{bc}	48.98^{b}	53.93^{cde}	25.72^{b}	1.41^{b}	2.39	0.63^{b}
SP Colour	39.74^{d}	37.37^{ab}	25.52^{fg}	9.35^{d}	55.56^{cd}	43.80^{a}	0.33^{b}	1.37	0.52^{b}
C Boiled	41.22^{d}	46.19^{ab}	20.00^{g}	6.35^{d}	50.80^{de}	12.93^{cde}	2.61^{b}	1.76	0.30^{b}
C Short boil	46.74^{cd}	51.63^{a}	21.61^{g}	6.59^{d}	54.39^{cde}	14.93^{bcde}	0.61^{b}	1.35	0.37^{b}
C Baked	71.48^{a}	36.98^{ab}	39.39^{e}	7.61^{d}	63.43^{bc}	21.74^{bcd}	2.19^{b}	2.02	0.39^{b}
C Colour	58.07^{bc}	48.54^{a}	62.04^{bc}	6.85^{d}	53.76^{cde}	6.28^{e}	17.57^{a}	1.67	0.76^{ab}
B Boiled	48.50^{cd}	49.44^{a}	73.87^{a}	25.58^{c}	55.31^{cde}	7.77^{e}	3.46^{b}	0.71	0.48^{b}
B Short boil	47.15^{cd}	50.00^{a}	64.40^{bc}	46.48^{b}	67.08^{ab}	9.69^{e}	3.15^{b}	0.85	0.50^{b}
B Stir-fried	77.17^{a}	32.52^{b}	69.40^{ab}	77.79^{a}	75.10^{a}	6.54^{e}	5.85^{b}	1.96	0.42^{b}
B Colour	39.83^{d}	41.56^{ab}	31.35^{f}	15.83^{cd}	46.08^{de}	11.25^{de}	1.04^{b}	0.83	0.27^{b}
F value	27.8	3.0	150.6	103.2	12.4	19.4	14.5	1.1	2.6
P value	<0.001	0.001	<0.001	<0.001	<0.001	<0.001	<0.001	ns	0.004

Category	**Flavour**			**Texture/ mouthfeel**						**Aftertaste**
	Vegetable specific F	Oily flavour	Browned flavour	Crunchi-ness	Firmness	Textural contrast	Masticatio n effort	Moisture release	Oily mouth coating	Aftertaste Impact
SP Boiled	46.35^{bcd}	0.31^{c}	0.70^{b}	12.24^{de}	33.11^{de}	17.70^{cd}	28.22^{def}	16.07^{f}	0.78^{c}	33.13^{ef}
SP Mashed	44.04^{cd}	0.44^{c}	0.89^{b}	1.91^{f}	4.85^{g}	9.20^{d}	8.87^{g}	13.31^{f}	0.52^{c}	29.50^{f}
SP Baked	40.70^{d}	40.04^{b}	1.15^{b}	36.63^{c}	46.15^{bc}	56.44^{a}	45.80^{bc}	14.11^{f}	32.44^{b}	42.28^{cde}
SP Colour	49.15^{bcd}	0.52^{c}	0.59^{b}	9.07^{ef}	26.67^{ef}	15.46^{cd}	25.07^{ef}	8.59^{g}	0.96^{c}	39.00^{def}
C Boiled	55.69^{abc}	0.48^{c}	0.39^{b}	21.22^{d}	21.80^{f}	16.74^{cd}	20.91^{f}	56.81^{a}	0.31^{c}	44.54^{bcd}
C Short boil	55.91^{abc}	0.33^{c}	0.72^{b}	51.39^{b}	54.72^{b}	20.26^{cd}	49.07^{b}	43.89^{bcd}	0.74^{c}	45.19^{bcd}
C Baked	43.06^{cd}	39.43^{b}	9.94^{a}	53.19^{b}	53.35^{b}	24.63^{c}	49.57^{b}	31.39^{e}	34.33^{b}	53.22^{ab}
C Colour	46.57^{bcd}	0.50^{c}	0.57^{b}	39.70^{c}	41.48^{cd}	18.76^{cd}	37.24^{cd}	33.93^{de}	0.74^{c}	43.26^{cd}
B Boiled	58.17^{ab}	0.52^{c}	1.25^{b}	34.56^{c}	34.31^{de}	18.96^{cd}	31.52^{de}	53.60^{ab}	1.46^{c}	44.38^{bcd}
B Short boil	66.69^{a}	0.35^{c}	0.81^{b}	69.00^{a}	65.88^{a}	32.60^{b}	61.40^{a}	48.96^{abc}	1.29^{c}	51.21^{abc}
B Stir-fried	35.73^{d}	66.08^{a}	11.60^{a}	71.69^{a}	69.33^{a}	31.88^{bc}	63.83^{a}	41.44^{cde}	62.81^{a}	59.56^{a}
B Colour	43.63^{cd}	0.44^{c}	0.73^{b}	32.58^{c}	35.10^{de}	17.63^{cd}	30.46^{def}	51.21^{abc}	1.90^{c}	35.42^{def}
F value	8.6	142.5	11.0	99.0	69.0	28.1	52.1	47.8	109.3	15.4
P value	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001

[1] All attributes were measured on intensity scales ranging from 0 to 100

[2] SP = Sweet potato, C = cauliflower, B = beans

[abc] Within each sensory attribute and across all 12 samples, samples sharing the same letter were not significantly different from each other

Post-hoc testing was conducted using pair-wise Chi-square comparisons contrasting one sample to the other three (testing against expected probabilities of 0.25 and 0.75 respectively). Chi-square tests were also carried out to determine differences in ranked preference upon tasting for each sample on the basis of expected preference. Friedman's analysis for related samples was carried out within each vegetable type to determine differences in acceptance or ranked preference upon tasting of samples prepared differently, using Nemenyi's procedure as a post hoc test. Friedman's analysis was also used to compare whether vegetable types of comparable preparation methods (boiled, baked/stir fried and colour) were accepted differently. Analyses were conducted within each preparation method as well as across the three preparation methods.

Relation between children's acceptance and background characteristics

Acceptance was analysed in relation to background characteristics gender, food neophobia, reported liking of target vegetable, reported consumption of target vegetable, variety in number of vegetables liked, variety in number of vegetables consumed, and frequency of vegetable consumption. For each variable, two analyses were carried out. Differences in acceptance *between* groups (e.g. between low and high vegetable consumers) were analysed using Mann-Whitney tests. *Within* each group separately, the effect of preparation on acceptance was analysed using Friedman's analysis for related samples, and the response in the groups was compared (e.g. did preparation method affect low and high vegetable consumers in the same way?). For each variable tested, two groups were compared. Groups were formed as described in the following section.

Home cooking method data were used to determine whether the child was familiar (yes/no) to consuming a vegetable type prepared in the way served. Parental responses about the child's liking for a vegetable were used to create groups of likers (child clearly or somewhat liked the vegetable) and non-likers (child was neutral, or somewhat or clearly disliked the vegetable). For the other variables, participants were categorized into three groups according to the tertile distribution. When more than one participant had a value equal to the tertile point, those participants were all assigned to the group which contained the majority of values. The low and the high tertile group were statistically compared.

The effect of preparation on acceptance and ranked preference data was similar for all groups. For ease of comparison with between-group analysis (where ranked preference data comparisons cannot be made), acceptance results only are reported in relation to background characteristics.

Descriptive sensory analysis and relation with children's acceptance

Mean descriptive scores were calculated for each sensory attribute. Two-way analysis of variance was used to determine which sensory attributes significantly discriminated between the samples, using the Least Significant Difference (LSD) test as a post hoc test. The relation between consumer acceptance and sensory characteristics (standardised values) was determined by PLS-R across all vegetable types and preparation methods.

Analyses were carried out using SPSS (v17.0.0, 2009) and XLSTAT (v2009.3.02). Partial Least Squares Regression (PLS-R) analysis was carried out with Unscrambler (v8.0, 2003). A p value < 0.05 was used as a criterion for statistical significance.

Results

Participant characteristics

Participant characteristics are provided in Table 3.3. The target vegetables of the study were not amongst the most liked nor the most disliked, ranking 7th (sweet potato), 10th (beans) and 13th (cauliflower) out of 24 vegetables. Cooking methods used for preparation were commonly used by parents when preparing these vegetables for their children at home.

French beans (84%) and cauliflower (75%) were mostly prepared boiled or steamed; the second most used method was stir fried (39%) for beans and baked (28%) for cauliflower. Sweet potato was served baked (62%), as a mash (30%) and boiled (11%). Children were largely unfamiliar with the atypically coloured varieties studied, as more than 80% had never consumed them before. Vegetable FFQ data of parents (not further discussed in the present paper) were found to over report substantially. Children's FFQ data were also high, which may suggest similar over reporting, but may also be partially due to a high consumption of vegetables in mixed dishes, such as stir fries and stews. Parents reported a high consumption of these dishes in open ended questions.

Acceptance and preference

Expected preference

Significant differences in expected preference were found within each vegetable type (Table 3.4, sweet potato $p = 0.003$; cauliflower and beans $p < 0.0001$). Post-hoc testing showed that in each vegetable type, the atypically coloured sample was chosen significantly more often (sweet potato $p = 0.01$; cauliflower and beans $p < 0.0001$), and the baked or stir fried sample significantly less often (all p values < 0.007) as the sample the children thought they would prefer. It may be that children had lower expectations about the taste of the familiar typically coloured vegetables and thereby chose them less often.

Table 3.3 Background information relating to the participants in the study.

Age (years)	5.9 ± 0.6		
Boys/girls	55%/45%		
Class			
Kindergarten	52%		
Year 1	48%		
Education level of parent			
Some high school	3%		
Completed high school	26%		
Tech, trade or TAFE qualification	35%		
University	36%		
Number of siblings			
Only child	12%		
One sibling	50%		
Two or more siblings	38%		
Child neophobia score [1]	33.7 ± 10.6		
Reported liking for sweet potato [2]	3.89 ± 0.94		
Reported liking for cauliflower [2]	3.66 ± 1.15		
Reported liking for French beans [2]	3.45 ± 1.10		
Variety of vegetables consumed in past 3 months			
13 vegetables or less	29%		
Between 14 and 17 vegetables	38%		
18 vegetables or more	33%		
Consumption frequency in past three months	Sweet potato	Beans	Cauliflower
Once a month or less	37%	24%	33%
Two to three times per month	18%	15%	19%
Once a week or more	45%	61%	47%

[1] The scale ranged from 10 (most neophillic) to 70 (most neophobic)

[2] Ratings were on a 5-point scale from 1 = “clearly dislike” to 5 = “clearly like”

Table 3.4 Sample chosen on basis of appearance.

Vegetable type	Sample	Number of times chosen	% chosen within vegetable type
Sweet Potato	Boiled	29	27.9
	Mashed	24	23.1
	Baked	14	13.5*
	Colour	37	35.6*
Cauliflower	Boiled	18	17.3
	Short boiled	22	21.2
	Baked	13	12.5*
	Colour	51	49.0*
Beans	Boiled	18	17.3
	Short boiled	18	17.3
	Stir fried	13	12.5*
	Colour	54	51.9*

* Significantly different when tested against an expected probability of 25%

Acceptance and ranked preference upon tasting

Within the three vegetable types, there were significant differences in acceptance and ranked preference for cauliflower (p = 0.0002 and p < 0.0001 respectively) and beans (both p = 0.003). Sweet potato samples were all equally accepted and ranked the same for preference, regardless of the way they were prepared. Post-hoc testing showed that boiled was accepted more than baked white cauliflower (Fig. 3.1). Stir fried green beans were accepted less than yellow boiled beans. Ranked preference data were in agreement, but somewhat more discriminating (data not shown). White and green boiled cauliflower were preferred to baked white cauliflower. The boiled yellow beans and the short boiled green beans were preferred to stir fried green beans.

Across all samples baked or stir fried was less accepted than the remaining preparation methods, whereas difference in cooking time (boiled versus short boiled) and in colour did not affect acceptance.

Statistical analysis across the three vegetable types found no significant differences in acceptance between vegetable types, neither within comparable preparation methods as well as across vegetable type overall.

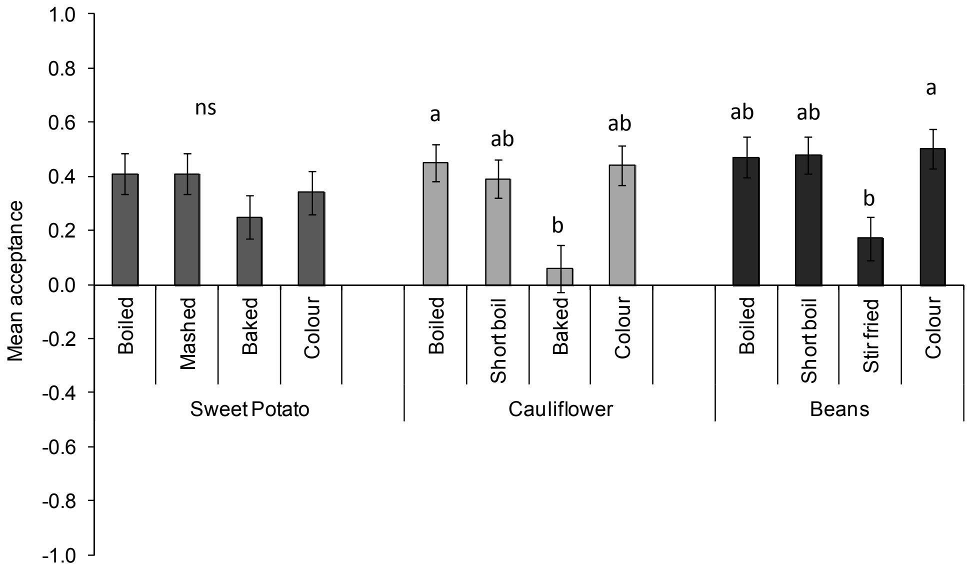

Figure 3.1 Mean acceptance (± SEM) for three different vegetable types each prepared in four different ways. Samples of the same vegetable type sharing the same letter were not significantly different from each other.

Relation between preference before and after tasting the sample

Evaluations on the basis of appearance alone were compared to ranked preference after tasting at an individual child level, to explore to what degree expectations may have affected preference after tasting. A total of 49% of the children preferred upon tasting the same sample that they preferred by appearance, indicating that children's preferences were not driven by appearance alone. Agreement was highest and significantly more than could be expected by chance for mashed sweet potato (71%) and for atypically coloured sweet potato (59%), cauliflower (55%) and beans (67%) (all $p < 0.0001$). Results indicate that children who thought they would like the atypically coloured sample the most, were not disappointed by its taste and largely continued to like it upon tasting.

Descriptive sensory analysis and relation with children's acceptance

With the exception of *salty* and *sour taste*, all attributes significantly discriminated between the 12 samples (Table 3.2).

The main differences within the vegetables types were related to texture, colour and to sensory attributes related to baking or stir frying preparation. The baked and stir fried samples differed from the other samples by having a higher intensity in *odour impact, oily flavour* and *oily mouthcoating.* The baked cauliflower and stir fried beans were also more intense in *browned flavour.* They differed from boiled but not short-boiled vegetables in texture attributes related to chewing (e.g. *firmness, crunchiness, textural contrast, mastication effort*). Short-boiled vegetables (cauliflower and bean) were more *crunchy* and *firm*, required more *mastication effort* and *released* less *moisture* in-mouth than boiled vegetables of the same type and colour, but did not differ in odour/flavour characteristics. Textural differences were also observed between the boiled and the mashed sweet potato sample. The atypically coloured sample was relatively similar to the typically coloured one prepared in the same way in the case of beans; cauliflower and sweet potato differed more, amongst others green cauliflower was more *bitter* than white cauliflower whereas the atypically coloured sweet potato was relatively high in *sweetness*. Sweet potato samples differed in sensory characteristics, but this did not translate into differences in acceptance.

The main differences between the three vegetable types prepared in the same way were related to *colour intensity, shiny appearance, sweet taste, crunchiness, firmness, mastication effort* and *moisture release,* however they did not translate into differences in acceptance.

PLS-R across all twelve samples showed commonalities in sensory properties across vegetables and preparation methods that significantly affected children's liking. Acceptance was well predicted by two attributes: *odour intensity* and *browned flavour* (model parameters: $R_{cal} = 0.87$, $R_{val} = 0.76$, PC's = 1, RMSEP = 0.08). Both attributes were negatively correlated with acceptance, indicating that the more intense the *odour* and the *browned flavour,* the less the sample was liked. Both attributes were highest in the baked and stir fried samples, although *browned flavour* was absent in the baked sweet potato, which may explain the absence of significant differences in liking within this vegetable type. The PLS-R analysis confirms that texture attributes, as well as the small differences in sweetness and bitterness, made no significant contribution to children's acceptance.

Acceptance in relation to children's background variables

First it was determined how background variables affected acceptance for vegetables (*between* group comparisons). Table 3.5 (left column) shows that acceptance was significantly and positively influenced by reported liking for vegetables (all vegetable types), variety in the number of vegetables liked (sweet potato and cauliflower, trend of $p = 0.10$ for beans) and frequency of vegetable consumption (cauliflower only). Familiarity with preparation methods also positively influenced acceptance (data not shown in Table 3.5), with significant effects obtained for baked sweet potato and boiled cauliflower.

Secondly, it was determined whether groups differed in their response to preparation (*within* group comparisons). Cases where preparation method influenced acceptance of subgroups across at least two vegetable types were considered most relevant. Such effects were found for reported liking and for reported consumption of the target vegetable, as well as variety of number of vegetables liked (Table 3.5, right column). The influence of preparation method on acceptance of vegetables was similar for likers and non-likers of a target vegetable. At the same time, children reportedly consuming more cauliflower were more influenced by the way it was prepared than children consuming less cauliflower. Preparation method affected more vegetable types for children who liked fewer vegetables than for children who liked many vegetables.

Fig. 3.2 shows results for the two variables in which significant between as well as within group effects were found. Where preparation/colour affected acceptance, the baked cauliflower and the stir fried bean were liked less than other samples from the same vegetable type. Results pointed in the same direction for sweet potato by those that liked few vegetables, but failed to reach significance.

In all other subgroups where a significant effect of preparation was found, the baked cauliflower and stir fried beans were also liked the least (data not shown). Results in subgroups were thus similar to the overall results of the consumer sample.

Discussion

This study investigated the influence of preparation and colour typicality on children's acceptance for three vegetable types. It is unlikely that our sample was a representative sample of Australian children with regards to vegetable acceptance and consumption, as children with very low acceptance of vegetables are unlikely to volunteer to participate in a taste test on vegetables. However, where differences in preparation influenced acceptance of groups differing in behavioural and demographic characteristics, the vegetables that were liked more and those liked less were the same in each of the subgroups, and these results were similar to the overall group results.

Preparation was found to affect children's acceptance for two of the three vegetable types. Baked and stir fried vegetables were accepted less than boiled vegetables of the same colour. This finding is consistent with other experimental research were children preferred boiled and steamed vegetables over the same vegetables prepared stir-fried, mashed, grilled or deep-fried (26). Previous studies suggesting that preparation was important for children's acceptance of vegetables were based on interviews in which no actual tastings were conducted and which mostly focused on comparisons between and not within vegetables and / or differences between raw and cooked vegetables (7,8,10,18,19,21). This study, and that of Zeinstra et al (2010) (26), showed the importance of preparation method for children's acceptance of vegetables in an experimental setting and by actual tasting.

Colour typicality was found to affect expected but not actual preference. Expected preference was higher for atypically than typically coloured vegetables. However, samples of different colours and prepared in the same way were liked the same after tasting.

Table 3.5 Effect of background variables on acceptance for vegetables – significance (*p* values) of between and within group comparisons.

	Significant difference (*p* values) in acceptance *between* groups			Significant effect (*p* values) of preparation on acceptance *within* a group		
	Sweet potato	Cauliflower	Beans	Sweet potato	Cauliflower	Beans
Gender						
Boys (*n* = 57)				ns	ns	0.05
Girls (*n* = 47)	ns	ns	ns	ns	0.01	ns
Food Neophobia						
Neophobics (FNS≥38) (*n* = 33)				ns	0.007	ns
Neophillics (FNS≤30) (*n* = 33)	ns	ns	ns	ns	ns	ns
Reported liking for target vegetable [1]						
Dislike or neutral				ns	0.03	0.04
Like	0.003	0.006	0.002	ns	0.03	0.004
Reported consumption of target vegetable [2]						
Low				ns	ns	0.05
High	ns	ns	ns	ns	0.004	0.02
Variety in number of vegetables liked						
Few (10 vegetables or less) (*n* = 36)				ns	0.008	0.005
Many (15 vegetables or more) (*n* = 33)	0.03	0.03	ns	ns	ns	0.007
Variety in consumption of vegetables						
Low (≤ 14 vegetables) (*n* = 40)				ns	ns	ns
High (≥ 18 vegetables)(*n* = 35)	ns	ns	ns	ns	ns	<0.001
Frequency of vegetables consumed						
Low (<20/week) (*n* = 34)				ns	0.02	ns
High (>31.5/week) (*n* = 35)	ns	0.02	ns	ns	ns	<0.001

[1] Reported liking for sweet potato in relation to acceptance of sweet potato; same for cauliflower and beans; *n* for likers were 65, 51 and 56 respectively

[2] Sweet potato and cauliflower: low = once a month or less, (*n* = 38 and 34 respectively); high = once a week or more (*n* = 44 and 48 respectively); beans: low = once a fortnight or less (*n* = 37); high = more than once a week (*n* = 32).

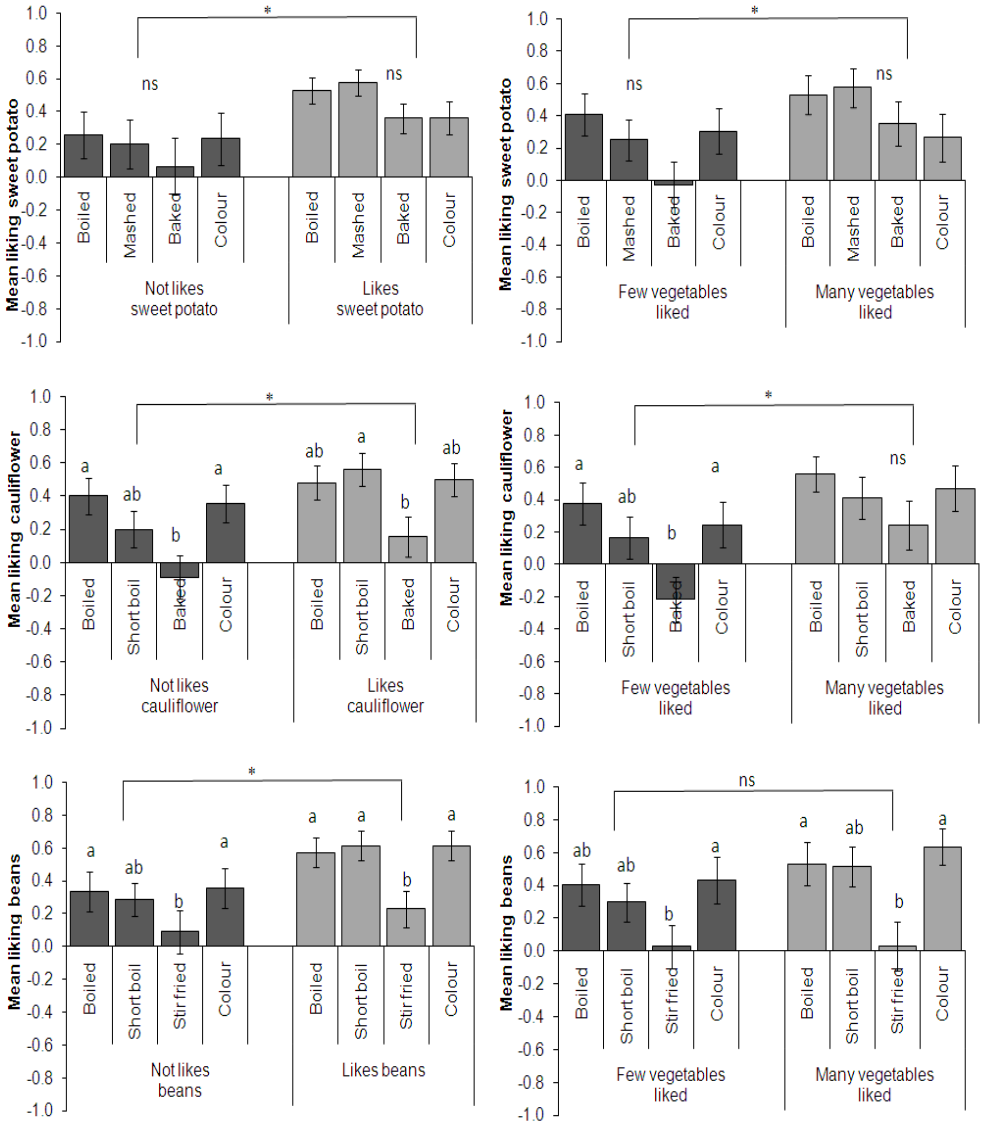

Figure 3.2 Acceptance (± SEM) for sweet potato, cauliflower and beans prepared in different ways by reported liking of the target vegetable (left column) and by groups of children differing in the number of vegetables they liked (right column).

Samples sharing the same letter *within* a group were not significantly different from each other. The asterisks indicate significant differences *between* groups. For details of groups see Table 3.5.

Colour was suggested to affect children's acceptance for vegetables [10,21,26,27] and the present findings enhance our understanding of the role of colour. Baxter et al (2000) [27] found brightly coloured vegetables to be preferred to dark green vegetables. This study found that it was the unfamiliarity or typicality of the colour that raised expectations rather than specific colours. The findings are in accordance with the notion that colour/flavour associations play a role in shaping expectations [27]. It may be that unfavourable associations have been established in children for typically coloured vegetables and that such associations are not present for the atypically coloured vegetables, which were novel to most children. This is consistent with the view that visual assessment provides predictive signals for the other senses based on previously learned associations. Regardless of the exact mechanisms involved, it is clear that atypically coloured vegetables created positive expectations about the taste and may thereby encourage "trying" of vegetables.

The sensory characteristics *odour intensity* and *browned flavour* were related to differences in acceptance. Both attributes contributed negatively to acceptance and thus, acceptance was driven more by dislikes than likes. Zeinstra et el (2010) [26] found "brown-colouring" to be an undesirable attribute and although no odour terms were rated in their study, others suggested that odour may negatively impact on vegetable acceptance [7,10]. Atypical colour was not a sensory attribute that was rated and its contribution to acceptance could therefore not be determined by PLS-R.

Texture attributes, including firmness and crunchiness, did not affect consumer acceptance. This seems to be in contrast with Zeinstra et al's study (2010) [26] who reported that crunchiness had a moderate positive effect on acceptance. However, their observation was based on interpretation of a PCA plot, and was not substantiated by PLS-R or mean sample data. Other studies in which firm and crunchy vegetables were preferred over softer, mushy ones [18,20] were not based on actual tasting of within-vegetable variations. With the vegetable types and preparation methods in this study, textural differences existed between samples, but their importance for consumer acceptance could not be confirmed. Perhaps reported vegetable likes and dislikes have their foundations in more complicated interactions between flavour and texture properties. Two findings support this hypothesis. First, the stir-fried and baked vegetables in the present study had a firmer and crunchier texture than (long) boiled samples, but they were less accepted because of their odour / flavour properties. Baxter et al (1999) [20] suggested that the texture of the vegetables in a (mixed dish) such as in a stir-fry may be appealing to children, with the strong flavour of the meal concealing the flavour of the vegetables being another appealing factor. In our study "flavour-masking" could not occur as vegetables were prepared without other ingredients. Second, in two very similar studies with different vegetables, hard, crunchy vegetables were preferred over soft vegetables in one study [19], but opposite results were found in the other study [20]. Results indicate that more insight is needed in the sensory factors affecting children's acceptance, and context of evaluation needs to be taken into account when generalising results.

Differences in acceptance were found within cauliflower and bean, but not within sweet potato samples. Apparently, children's acceptance of preparation methods depends on the type of vegetable. *Browned flavour* was absent in the baked sweet potato sample, and this may have contributed to the absence of differences in acceptance for this vegetable, however it may also be caused by other as yet unknown factors. A better understanding of factors underpinning differences in vegetable acceptance is needed before generalisations to the wider category of vegetables can be made.

Familiarity was found to influence vegetable acceptance, which is in line with previous studies (see Cooke, 2007 [36] for a review). Food neophobia was found to influence vegetable acceptance somewhat and similar results were found by others [9]. Children consuming more of the target vegetable were found to be more influenced by preparation method than children consuming less of the target vegetable. Familiarity with all preparation methods was higher for those consuming more of the target vegetable, thus cannot account for the observed differences, although it cannot be excluded that minor differences in preparation compared to the home environment may have influenced those consuming more of the vegetable more strongly. In addition, perhaps a high consumption frequency of vegetables in mixed dishes, which conceals the sensory properties of the vegetable considerably, makes the relationship between acceptance and consumption less straightforward.

The present study found that children who reportedly liked few vegetables were more influenced by to the way a vegetable was prepared than children liking many different vegetables. As these children also accepted vegetables less, they would need particular encouragement and may be a worthwhile target group for interventions aimed to increase vegetable acceptance.

No difference in acceptance between vegetable types was found, despite considerable sensory differences between them. This finding may be partially due to the experimental design, in which only vegetables of the same type were evaluated together by the children, thus focusing more strongly on within than between-vegetable comparisons.

Our study was unbalanced with regards to colour. The atypically coloured vegetable was the "odd one out" of the four samples presented simultaneously. Whereas this choice in design was motivated by the small sales volume of atypical coloured varieties¸ it cannot be excluded that this factor has affected children's choice and therefore results should be interpreted with some caution. The seemingly positive role that colour atypicality has on expected preference would warrant further research. Such future research should provide balanced designs for colour typicality to confirm findings and should aim to enhance the understanding of the role that colour plays in children's acceptance for vegetables.

The vegetable type specific results obtained in our study also show that there is a need for more comprehensive and systematic testing of children's acceptance for vegetables prepared in different ways.

Trained descriptive analysis was conducted with adult assessors. Although so far research is scarce and inconclusive, studies have found that children perceive a lower supra threshold sweet taste intensity than adults [31,37]. Although this may indicate that children perceived the sensory differences between the products to be smaller than the trained panel did, the results showed that the differences between samples impacted on their acceptance for them.

Results of this study could be used by health professionals as well as vegetable industries. Health professionals and other agencies who give advice to parents are recommended to consider how something as simple as preparation may positively influence acceptance. Atypically coloured varieties may be used to overcome established negative expectations. Boiling results in vegetables with sensory properties that are more acceptable, whereas baked or stir fried vegetables are more often disliked. Vegetable industries or other bodies representing growers may consider marketing and/or developing novel or atypically coloured vegetable varieties for children.

In conclusion, baking and stir frying processes imparted a more intense *odour intensity* and *browned flavour* for two of three vegetables, which were a barrier to consumption. Texture differences as a result of different preparation methods, were neither a barrier nor a facilitator to consumption. Differences in sweetness or bitterness as a result of differences in preparation or variety did not affect acceptance either. Colour may be a promising facilitator to increase children's vegetable consumption through its positive effect on expectations and thereby willingness to try. Differences between children need to be taken into account and in particular children who like few different vegetables could benefit from interventions aimed at increasing vegetable acceptance.

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Chapter 4

Cooking time but not cooking method affected children's acceptance of *Brassica* vegetables

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Abstract

The home environment potentially presents a simple means to increase acceptance of sensory properties of vegetables by preparation. This research investigated how preparation can effectively impact upon children's acceptance for vegetables. Five-and-six year old children (n = 82, balanced for vegetable consumption) tasted and evaluated two *Brassica* vegetables, broccoli and cauliflower, each prepared in six different ways via variations in cooking method (boiling versus steaming) and cooking time (3 levels, ranging from 2 to 14 min). Children rated samples for liking and a trained descriptive panel assessed the samples' sensory properties. Across vegetable types, medium cooking times were liked more than short and long cooking times ($p < 0.0001$), and these samples were medium *firm* and *cohesive*, with a balance of *green* and *cooked flavour* notes. Boiled samples were less intense in flavour and taste than steamed samples, but overall did not differ in acceptance. Significant interactions were found. Cooking method played a role in acceptance of broccoli but not cauliflower, with medium steamed broccoli liked the most. There was no difference in acceptance between low and high vegetable consumers, although high vegetable consumers were more discriminating in acceptance for cauliflower. In conclusion, children's acceptance of *Brassica* vegetables may be altered by preparation. There may be advantage in promoting steaming of *Brassica* vegetables to children, as they do not object to the flavour, and steaming is nutritionally preferable to boiling. Very short cooking times lead to an undesirable sensory profile and should be avoided. Recommendations are applicable to children regardless of their vegetable intake.

Keywords: children; acceptance; vegetable consumption; preparation; steaming; descriptive analysis

Introduction

A high intake of *Brassica (B. oleracea*) vegetables, such as broccoli and cauliflower, reduces the risk of several types of cancer and cardiovascular disease [(1)]. There is evidence that sensory properties are a key determinant to *Brassica* consumption [(2)]. This is particularly relevant for children, who are not receptive to health messages [(3)], and for whom sensory preferences are a key driver to food consumption [(4-6)].

Preparation affects children's acceptance for vegetables [(7-11)]. Sensory studies with various vegetables have shown that children prefer preparation methods using water (i.e. boiling or steaming) to preparation methods using heat with or without oil (i.e. baking, stir frying or grilling), which was related to a dislike of brown colour, browned odour and browned flavour [(9,11)].

There is some evidence that adults prefer steamed to boiled vegetables [(11,12)], but little is known about children's preferences in this regard. Zeinstra et al (2010) [(11)] found that steamed and boiled carrots and beans were equally liked by 4–12 year old children. To our knowledge, no studies have investigated children's preferences for *Brassica* vegetables in relation to boiling and steaming.

Steaming requires a longer cooking time than boiling to reach a similar texture [(13,14)]. Controlled for texture differences, boiled vegetables are less intense in flavour than steamed vegetables [(15,16)], due to leaching out of water soluble flavour compounds [(15,17,18)]. Cooking time impacts on sensory properties of *Brassica* vegetables also. Increased cooking leads to decreased firmness and associated texture attributes [(9)], can lead to flavour loss [(16)], and affects colour [(19)]. Children reportedly like crunchy, hard textures [(8,10,11)], whereas flavour is assumed to be a barrier to consumption [(20,21)]. Therefore children may prefer the relative blandness of boiled to steamed vegetables, and may prefer shorter to longer cooking times.

From a nutritional perspective, shorter cooking times have benefits over longer cooking times, primarily for boiling, where two-third losses in vitamin C and phenolics were observed after 5 min boiling [(22)]. Steaming of *Brassica* vegetables has advantages over boiling, in retention of water soluble nutrients such as vitamin C [(13,14,16,18,23)], and glucosinolates, which also leach into cooking water [(14,17,18,23)]. There is also evidence that steaming retains or even increases carotenoids, a fat soluble compound [(14,18,23)]. Benefits are reflected in Australian government policies, by recommending to steam rather than to boil, and to boil for a short time when boiling [(24)]. However, it is not known which preparation method is most accepted by children.

Preparation is an easy way by which parents can influence sensory properties, and may be able to optimise acceptance of vegetables for their children. The current study aimed to investigate to what degree cooking time and cooking method affects children's acceptance of two common *Brassica* vegetables, broccoli and cauliflower. The study compared high and low vegetable consumers. From a public health perspective, identifying ways to increase vegetable acceptance of low vegetable consumers is most relevant.

Materials and methods

An experimental taste test was conducted in which 5-6 year old children tasted and evaluated two *Brassica* vegetables each prepared in six different ways by systematically varying cooking method and cooking time.

Participants

Eighty-two children (41 boys, 41 girls) and one of their parents participated in the study. Five and six year old were chosen as a study group, as they are part of the age category of 3-6 year old where food neophobia reaches its peak [25], and they have the cognitive abilities and attention span to rate samples for acceptance [26,27]. Children were recruited by advertising in local media, schools, childcare centres and nearby worksites, and partially via an external recruitment agency. The group was balanced for vegetable consumption, with the criterion chosen a priori as ≤ 1 serve/day for low and ≥ 2 serves/day for high vegetable consumers, using a validated measure for vegetable intake [28]. Australian children consume an average of 1.3 serves of vegetable per day [29], whereas 2 serves are recommended [30]. Children were excluded if they or one of their parents had any food intolerance or food allergy. Children who had never consumed the target vegetable(s) were excluded only if they had never consumed and/or clearly disliked at least half of the vegetables from a list of 24 common vegetables. In practice the latter criterion did not lead to exclusion of any child. Written consent was obtained from the parent for their child and themselves prior to the start of the test. Children/parent pairs received a $50 retail gift voucher for participation. The research was approved by the CSIRO Human Research Ethics Committee.

Samples

The target vegetables in this study were two common types, broccoli and cauliflower, from the *Brassica* family. Six variations of each vegetable were created using two cooking methods, boiling and steaming, with three times of cooking for each, short, medium, and long. The cooking times were developed on the basis of iterative pre-tasting of samples by four staff, two of which were experienced in sensory descriptive analysis. The aim was to select cooking times that were sufficiently different in sensory properties to potentially lead to differences in acceptance, within a range used in domestic cooking [31]. For each cooking time point, boiled and steamed vegetables were matched for *firmness*, so that any flavour differences between samples of different cooking methods could be attributed to this cooking method, without being confounded by firmness differences. Boiling times were 2-6-10 min for broccoli and 2-7-12 min for cauliflower; steaming times were matched to provide the same sensory *firmness* perception in-mouth, i.e. 3-7.5-12 min for broccoli and 3-8.5-14 min for cauliflower (Table 4.1).

Steaming was conducted using steamer baskets in pots on a gas stove. Samples were cooked fresh for each session in separate pots. Cooking start times of all six samples within a vegetable type were staggered with the use of detailed, timed, cooking protocols in such a way that all samples finished at the same time, and were served immediately. Two florets (approximately 4 cm in diameter, 1 cm stalk, weight 14-15g) for each sample were served in polystyrene foam cups with a lid, and consumed hot at approximately 60 °C.

Table 4.1 Vegetable cooking times by cooking method for the two vegetable types.
After selection of boiling times, steaming times were adjusted so that samples matched in terms of sensory *firmness*. Statistical analysis (ANOVA) confirmed this was successful (p >0.05 for each boiled/steamed pair of the same cooking time).

Vegetable	Cooking method	Cooking range		
		Short (min)	Medium (min)	Long (min)
Broccoli	Boiling	2	6	10
	Steaming	3	7.5	12
Cauliflower	Boiling	2	7	12
	Steaming	3	8.5	14

Procedure

Research took place in the sensory research facilities of CSIRO, Sydney, Australia. Children, and one of their parents, took part in a single 45 min session, with a maximum of three children per session. Oral group instructions were provided first, after which child/parent pairs were seated in separate, adjoining rooms. Each child had one-on-one assistance from a research staff member. Parents were seated so that they were not in viewing distance of the child. They completed a questionnaire and were instructed not to interact with their child during the test.

Within one session all children started with the same vegetable type for logistical reasons. Across sessions the design was balanced for serving order of vegetable type, by alternating sessions in which all children started with broccoli with sessions in which all children started with cauliflower. The child was first served with a tray containing the six samples of one vegetable type. The sample order of the six samples on the tray was randomised. The child tasted and evaluated the vegetable samples one by one as provided to them by the research staff member. They were instructed to taste the sample by biting a part of the floret and the stem. Then they placed the sample below the appropriate image of a five point hedonic facial scale [26], which was printed across two A4 sized sheets. The sample remained in this position, and the procedure was repeated for the remaining samples. Ties were allowed. When the child had evaluated all six samples, this sample rating positioning was used to rank the samples in order of preference. Children were asked to line up the samples from most preferred to least preferred. They re-tasted the tied samples until a full ranking order was obtained. Then all samples were removed, and after a short break the whole procedure was repeated for the second vegetable type. Children were provided with water and plain crackers to refresh their palate between sample tastings, both between and within vegetable type tastings.

Questionnaire

During participant recruitment, information from the parent was collected on the child's gender, age and usual vegetable consumption in servings per day [28]. Information was also collected on liking for 22 common vegetables, and consumption frequency of several vegetables ('less than once a month', '1-3 times per months' and 'once a week or more'), and both measures included the target vegetables. During the taste test, information from the parent was collected, including information on home preparation habits for the target vegetables, more specifically how often the child consumed the vegetable prepared by boiling and by steaming (1 = very rarely, 5 = very frequently, 0 = never consumed it prepared in this way), and detailed cooking times (in min) for each method used. Validated scales were used to measure the child's Food Neophobia [32,33] and pickiness [34]. Food Neophobia is a willingness to try new foods (10 item scale, Cronbach alpha 0.92 in our sample), whereas pickiness is a reluctance to consume familiar foods (3 item scale, Cronbach alpha 0.83 in our sample), with higher scores indicating a higher reluctance to consume in both scales. In addition, parents rated how difficult they found it to get their child to consume vegetables (1 = not difficult at all, 9 = very difficult), and provided family background information.

Descriptive sensory analysis

A trained sensory panel (10 women, aged 47.3 ± 7.7 years) conducted sensory descriptive evaluation of the samples. During three 2 h training sessions, the panel developed a sensory vocabulary (Table 4.2), and was familiarised with the method of assessment, which was the same as that for the children. The same terms were used for both vegetable types where possible. Evaluations were carried out in duplicate using 100 mm unstructured line scales, and using a randomised block design (blocked by vegetable type). Evaluations took place in individual booths, using sensory data acquisition software Compusense ® *five* (release 5.2, Compusense Inc., Guelph, ON, Canada).

Table 4.2 Sensory attributes, definitions and anchors used for descriptive analysis.
The column 'vegetable type' lists for which vegetable the attribute was used (B=broccoli, C=cauliflower)

Attribute	Vegetable type	Definition	Anchors
Odour			
Odour impact	B, C	The intensity of the overall aroma of the sample.	low - high
Green odour	B, C	The intensity of a raw, green, grassy odour.	low - high
Cooked broccoli/ cauliflower odour	B, C	The intensity of odour typical of cooked broccoli/cauliflower. High intensity is overcooked.	low - high
Appearance			
Brightness	B	The purity of the colour of the floret (looked at from above) ranging from dull, muddied to pure, bright green colour.	dull - bright
Colour floret	B	The colour of the floret from green to olive green/brown.	green - brown
Uneven colour	B	The degree to which the top (and not side) of floret and the stalk are uneven, blotchy or patchy in colour.	even - uneven
Colour floret	C	The actual colour of the floret. Low in colour is white and light, whereas high in colour is creamy / darker.	white - creamy
Colour stalk	C	The colour of the stalk of the sample.	cream - green
Moistness	B, C	The degree to which the sample has a moist, wet, glossy, shiny appearance.	dry - moist
Flavour			
Flavour impact	B, C	The overall flavour intensity of the sample.	low - high
Green flavour	B, C	A green, grassy, raw-like flavour associated with peas and green beans.	low - high
Cooked broccoli/ cauliflower flavour	B, C	The flavour typical of cooked broccoli/ cauliflower. High intensity is overcooked.	low - high
Sweet taste	B, C	The perceived intensity of the sweet taste - defined by basic taste solution for sweet (sucrose).	low - high
Bitter taste	B, C	The perceived intensity of the bitter taste - defined by basic taste solution for bitterness (caffeine).	low - high
Texture			
Firmness	B, C	The force required to chew the sample. Assessed after two chews.	soft - firm
Moistness	B, C	The moistness or wetness of the sample. Assessed after two chews.	dry - moist
Chewing resistance	B, C	The resistance encountered while chewing down the sample.	not chewy - chewy
Cohesiveness	B, C	The degree to which the sample forms a ball or paste and is easy to swallow. A sample low in cohesiveness breaks down in little particles that are difficult to swallow.	grainy - pasty

Data analysis

Acceptance scores were coded from –2 to +2. Refusals, which were rare, were coded as a missing value. To determine whether preparation method affected acceptance, repeated measures analysis of variance was conducted for each vegetable type, with cooking method (2 levels) and cooking time (3 levels) as within-subject factors. To determine whether low and high vegetable consumers responded differently to the treatments two analyses were conducted: (1) repeated measures ANOVA on acceptance scores with vegetable type, cooking method and cooking type as within-subject factors and vegetable consumption (low or high) as between-subject factor.

Food neophobia and pickiness were also added to the model as between-subject factors, using a median split to define low and high groups, to determine their effect on acceptance for preparation methods; (2) an unpaired *t*-test to test the difference between low and high vegetable consumers on acceptance range within vegetable type (i.e. highest minus lowest acceptance rating of the six samples rated; calculated per participant).

To determine whether consumption frequency of the target vegetables at home effected acceptance for preparation methods, a separate repeated measures ANOVA was conducted for each vegetable type, using the same factors as above, and using consumption frequency of the target vegetable (low or high) as between-subject factor. Friedman's analysis for related samples was carried out within each vegetable type to analyse differences in ranked preference. Results were similar to acceptance data, and are not further discussed.

Difference in background characteristics between low and high vegetable consumers was analysed with unpaired *t*-tests and Chi-square tests. Descriptive sensory data were analysed using ANOVA for each vegetable type, with cooking method, cooking time and assessor as fixed factors, and Bonferroni as post-hoc test.

Data were analysed using SPSS (v20.0.0, 2011) and The Unscrambler (v8.0, 2003). A p value < 0.05 was used as a criterion for statistical significance.

Results

Participants

The mean age of participants was 6.0 ± 0.5 years, with an equal number of boys and girls participating, from parents of a relatively high educational level (Table 4.3). Low (50%) and high (50%) vegetable consumers were comparable in terms of age, gender, degree of schooling, and preparation practices at home.

Table 4.3 Background information of the participants in the study.

	Low vegetable consumers (n = 41)	High vegetable consumers (n =41)	p value[1]
Age (years)	6.1 ± 0.5	5.9 ± 0.6	0.41
Boys/girls	49% / 51%	51% / 49%	0.83
Class			0.20
Did not attend school yet	17%	24%	
Kindergarten	49%	59%	
Year 1	34%	17%	
Education level of parent accompanying the child			0.02
High school, Tech, Trade or TAFE	46%	22%	
University or post grad	54%	78%	
Food Neophobia Score Child (range 10-70)	38.2 ± 14.5	30.6 ± 9.1	0.006
Pickiness (1=disagree; 5=agree)	2.9 ± 1.3	2.0 ± 0.8	0.001
Difficulty to get child to consume vegetables (1=not difficult at all, 9=very difficult)	4.6 ± 2.9	3.1 ± 2.1	0.002
Vegetable intake child (serves/day)	0.83 ± 0.26	2.29 ± 0.56	<0.0001
Consumption frequency broccoli /cauliflower			0.22 / 0.08
Less than once a month	19% / 61%	7% / 47%	
1-3 times month	22% / 29%	20% / 24%	
Once a week or more	59% / 10%	73% / 29%	
Frequency of preparation method used at home for broccoli / cauliflower (1=very rarely, 5=very frequently)			
Boiling	2.9 ± 1.3/2.2 ±	3.3 ± 1.2/2.8 ±	0.18 / 0.08
Steaming	3.6 ± 1.3/2.7 ±	3.8 ± 1.2/2.9 ±	0.50 / 0.56
Preparation times used at home for broccoli	Boiling/Steaming	Boiling/Steaming	0.20 / 0.92
4 min or less	33% / 39%	48% / 41%	
Between 5-8 min	38% / 36%	41% / 38%	
More than 8 min	29% / 25%	11% / 21%	
Preparation times used at home for cauliflower	Boiling/Steaming	Boiling/Steaming	0.52 / 0.83
5 min or less	41% / 45%	52% / 54%	
Between 6-10 min	36% / 40%	37% / 35%	
More than 10 min	23% / 15%	11% / 12%	

[1] Significance of statistical difference between low and high vegetable consumer group (using either t-test or Chi-square).

Low vegetable consumers were more neophobic ($p = 0.006$), more picky ($p = 0.001$), and their parent reported more difficulty to get their child to eat vegetables ($p = 0.002$). Parents of high vegetable consumers were more often highly educated than those of low vegetable consumers ($p = 0.02$). Broccoli was more frequently consumed than cauliflower, with about two-thirds of children consuming broccoli once a week or more. Boiling and steaming were frequently used methods for both vegetables, and the range of cooking times in our study were also used in home preparation (average 6.3 min for broccoli and 8.0 min for cauliflower across both cooking methods, no significant difference between boiling and steaming times for either vegetable).

Consumer acceptance

Broccoli

Taken over the three cooking times, no difference in acceptance was found between boiled and steamed broccoli (i.e. no main effect of cooking method, $F_{1,80} = 0.01$, $p = 0.94$). Acceptance was significantly affected by cooking time ($F_{2,160} = 6.2$, $p < 0.003$), and post hoc testing showed that a medium cooked broccoli was liked more than short ($p < 0.002$) or long ($p < 0.003$) cooked broccoli. The interaction between cooking time and cooking method was also significant ($F_{1.83,\ 146.34} = 9.9$, $p < 0.001$). Children liked medium steamed broccoli more than short cooked (either steamed or boiled) ($p < 0.01$) and long steamed broccoli ($p < 0.001$) the least (Fig. 4.1).

Cauliflower

Similar to broccoli, no difference in acceptance was found between boiled and steamed cauliflower taken over all cooking times (i.e. no main effect of cooking method, $F_{1,\ 80} = 1.2$, $p = 0.28$). Cooking time significantly affected acceptance ($F_{1.66,\ 132.88} = 11.9$, $p < 0.0001$), with post hoc tests showing that medium ($p < 0.0001$) and long ($p < 0.0001$) cooked cauliflower was more accepted than short cooked cauliflower. There was no significant interaction between cooking time and method ($F_{2,\ 160} = 1.2$, $p = 0.30$), indicating that high acceptance for medium and long cooking times was the same regardless of whether samples were boiled or steamed (Fig. 4.1).

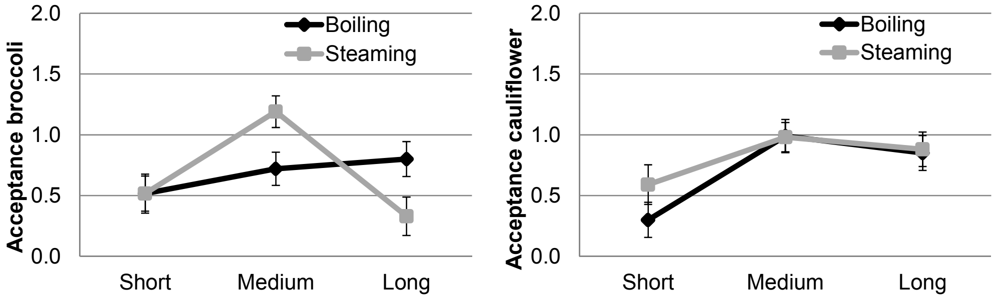

Figure 4.1 Mean acceptance scores (± SEM) by the total group of children for broccoli (left) and cauliflower (right) as a function of cooking time (short, medium, long) for the two cooking methods boiling (●) and steaming (■). Acceptance was assessed on a 5 point hedonic scale, which was coded from -2 to +2.

Acceptance of low and high vegetable consumers

Repeated measures analysis taken over both vegetable types, and using low/high vegetable consumption as a within-subject factor, found significant effects of cooking time, with medium cooked samples liked more than short and long cooked samples ($F_{2,154} = 16.0$, $p < 0.0001$). Significant effects were also found for the interactions cooking method by cooking time, and vegetable type by cooking method by cooking time, with results following what was described in the previous section. Overall, no significant difference in acceptance was found between low and high vegetable consumers (i.e. no main effect of vegetable consumption, $F_{1,77} = 2.6$, $p = 0.11$). None of the interaction effects with vegetable consumption were significant either, indicating that low vegetable consumers did not have different acceptance for preparation methods than high vegetable consumers.

Food Neophobia ($F_{2,154} = 5.9$, $p = 0.003$) and pickiness ($F_{2,154} = 6.0$, $p = 0.003$) each had a significant effect on acceptance in interaction with cooking time, but not with any other factors. Post hoc analysis showed both neophillic and neophobic children had the same most and least liked cooking times, following results of the overall group, but cooking time had a larger effect on neophillic than on neophobic children, in the sense that they had a lower acceptance for short cooked vegetables, and a higher acceptance of medium and long cooked vegetables than neophobic children. The same pattern was observed for pickiness, but although the results were statistically significant, the differences were so small as to not have practical relevance.

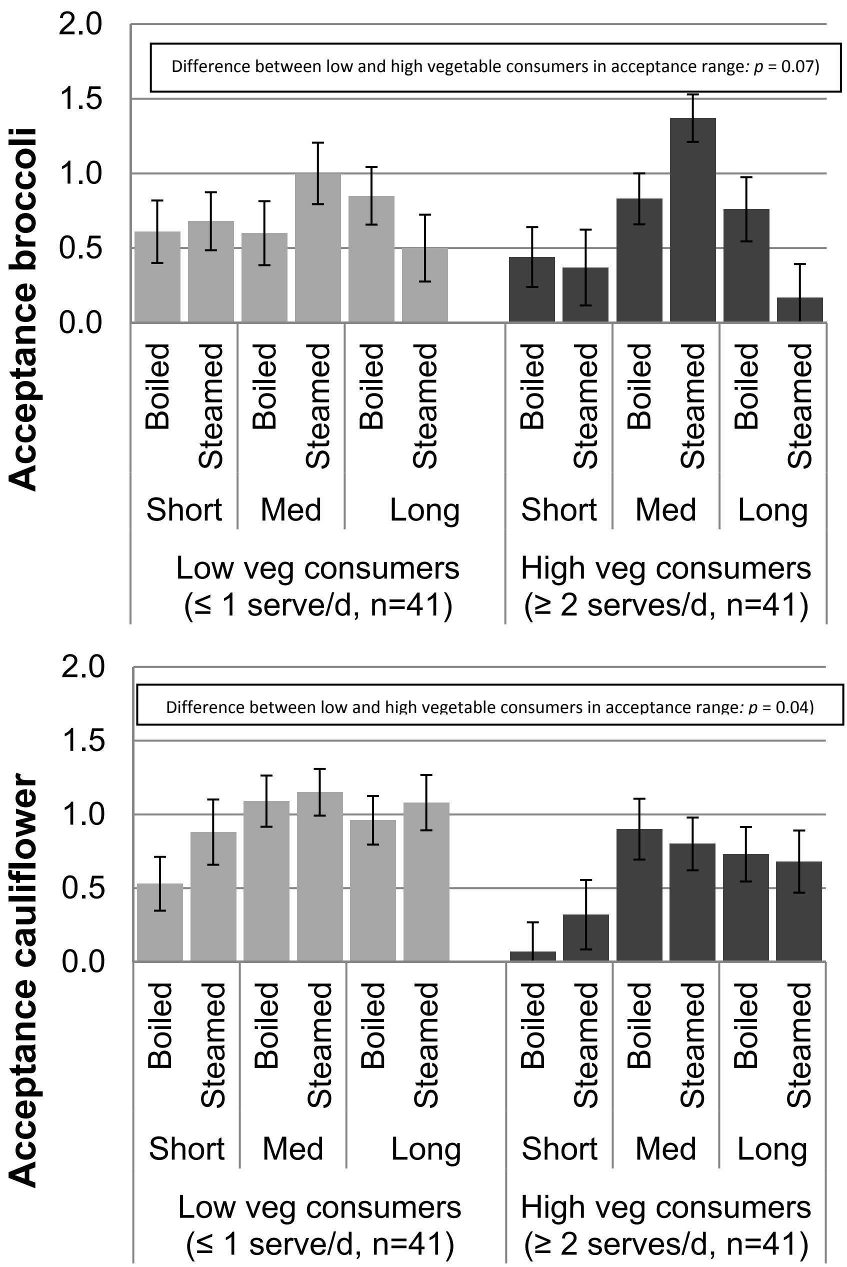

Figure 4.2 Mean acceptance scores (± SEM) for broccoli (top) and cauliflower (bottom) as a function of preparation method for low (grey bars) and high (black bars) vegetable consumers. Acceptance was assessed on a 5 point hedonic scale, which was coded from -2 to +2.

Fig. 4.2 shows that although trends in the most and the least liked samples were the same for low and high vegetable consumers, differences in acceptance were larger for high vegetable consumers. Results were confirmed when comparing the range of scores that children used for rating the samples. High vegetable consumers used a larger range in acceptance ratings (t_{79} = -2.09, p = 0.04) for cauliflower than did low vegetable consumers (mean acceptance range 2.5 ± 1.2 *vs* 1.9 ± 1.3, respectively). Thus, high vegetable consumers were significantly more discriminating by acceptance than were low vegetable consumers. The same tendency (t_{80} = -1.87, p = 0.07) was observed for broccoli (2.8 ± 1.3 *vs* 2.1 ± 1.4, respectively), although results only approached significance in this case.

Analysis on the basis of consumption frequency of cauliflower and broccoli yielded similar results, and no significant interactions were found between consumption frequency of target vegetables at home and acceptance for any preparation factors (data not shown).

Sensory profile and relation with acceptance

Cooking time had a large effect on the sensory properties of both vegetable types. With increased cooking time, a decrease in *firmness* and *chewing resistance*, and an increase in *cohesiveness* were observed, as well as a shift from *green* to *cooked* odour and flavour notes (all p values < 0.001, Fig. 4.3). Vegetable specific changes were observed also, in particular that broccoli became darker with cooking time (p < 0.001).

Cooking method affected odour, flavour and appearance. Boiled samples were lower in *flavour impact* than steamed samples (intensity of 48 *vs* 53 for broccoli, and 48 *vs* 56 for cauliflower, both p < 0.05), and the same was observed for *odour impact* (intensity of 53 *vs* 65 for broccoli, and 53 *vs* 56 for cauliflower, both p < 0.05), whereas cooking time did not affect these attributes. The lower *odour* and *flavour impact* of boiled samples coincided with less intense *cooked vegetable* notes and *sweet taste.* Effects of cooking method were smaller than the effect of cooking time. Due to *firmness* matching, cooking method was found not to affect texture, with the exception of *moistness*, which was higher in boiled than steamed samples (p < 0.001 and p <0.05 for broccoli and cauliflower respectively).

Sweet taste decreased with cooking time (from 23 to 9, p < 0.05) in boiled broccoli, but did not change in steamed broccoli. At the same time, *bitter taste* slightly increased with cooking time with both boiled (from 11 to 25, p < 0.05) and steamed broccoli (from 20 to 32, p < 0.05), but did not change in cauliflower.

Relationships between acceptance and sensory attributes were mostly non-linear. Acceptance for broccoli was driven by a combination of texture and flavour. Medium steamed broccoli, which was liked the most, was characterised by medium *firmness, chewing resistance* and *cohesiveness*, and both *green* and *cooked vegetable* notes (*odour and flavour*). Short cooked (both boiled and steamed) and long steamed broccoli were liked the least. Short cooked

samples were characterised by *green flavour* notes and high *firmness*, high *chewing resistance* and a separation into *particles in the mouth* upon chewing.
Long steamed broccoli was the darkest in *colour*, intense in *cooked broccoli odour* and *flavour* and also relatively intense in *bitter taste*.

Acceptance for cauliflower was similarly driven by a combination of texture and flavour. Children liked cauliflower samples without an intense *green odour* and *green flavour*, and medium to high intensity in *cooked cauliflower flavour*. They liked a texture that was not too *firm* or *chewy*, and liked medium to high *cohesiveness*. The lower *sweetness* of the boiled samples, compared to their steamed counterparts, did not affect acceptance negatively.

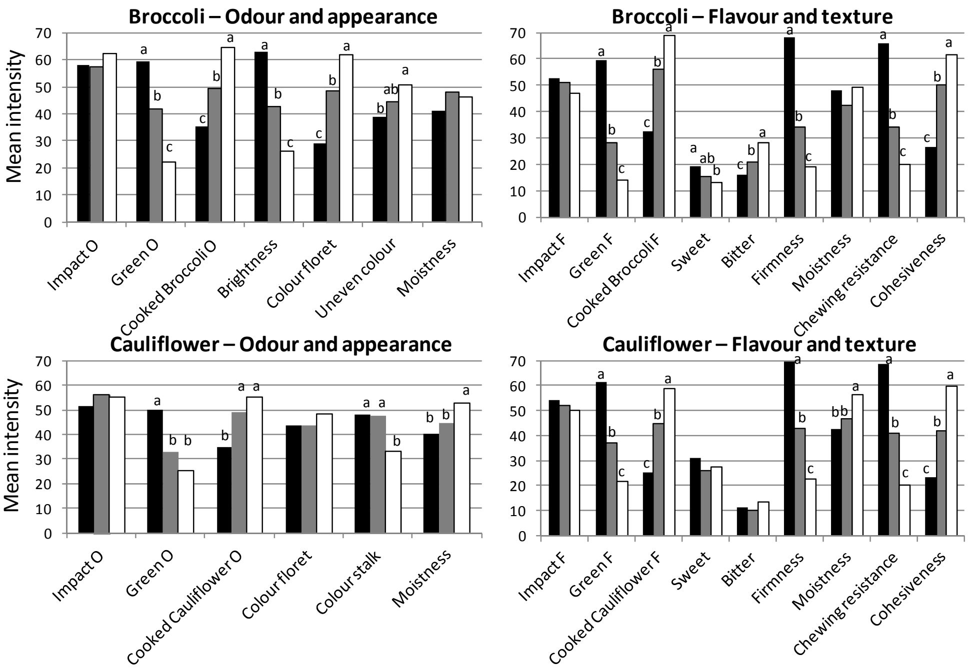

Figure 4.3 Mean intensities of sensory attributes of broccoli and cauliflower as a function of short (black bars), medium (grey bars) and long (white bars) cooking time. All sensory attributes were measured on intensity scales ranging from 0 to 100.
All attributes significant at $p < 0.05$ (ANOVA), with exception of attributes without letters.
Within each attribute, samples sharing the same letter were not significantly different from each other at $P < 0.05$.
Abbreviation: O=odour, F=flavour.

Discussion

The current study showed that children's acceptance for *Brassica* vegetables was affected by the way they were prepared. Cooking time had a larger effect on acceptance than cooking method, and an interaction between cooking time and cooking method was observed in case of broccoli.

Overall, children equally accepted boiling and steaming as the preparation method for *Brassica* vegetables. Although this study was the first to examine *Brassica,* another study obtained the same results with children for carrot and beans [11]. At the same time, adults were found to prefer steamed to boiled vegetables in Zeinstra et al's (2010) [11] and another study [12]. Our research and others [15,16] showed that steamed vegetables were more flavoursome than boiled vegetables. Whereas perhaps adults *prefer* steaming because vegetables remain more flavoursome, our results show that children did not object to the stronger flavour properties, regardless of their vegetable intake or their degree of food neophobia or pickiness.

Humans are born with a preference for sweet taste and an aversion for bitter taste [35]. *Bitterness* in *Brassica* vegetables derives primarily from phytonutrients, including glucosinolates [36], and is thought to be a barrier to *Brassica* acceptance [2,37]. These results were confirmed in our study for broccoli. Long steamed broccoli was highest in *bitter taste*, which contributed to the low liking for this preparation method. However, small increases in *bitter taste* of cauliflower did not impact on acceptance, perhaps because bitterness was relatively low for this vegetable regardless of how it was prepared.

Cooking time had a large effect on children's acceptance, with medium cooking times liked the most across the two vegetable types. This result enhanced the understanding of the role that texture plays in children's acceptance of vegetables. Children reportedly like hard, crunchy textures and prefer raw to cooked vegetables [8,10], although these studies were based on between-vegetable comparisons only. On the basis of within-vegetable comparisons, no [9] or weak [11] evidence for the positive contribution of hardness and crunchiness to children's liking was found. Our study included a cooking time shorter than previously investigated. These short cooked, most 'raw-like', samples had the *firmest* texture, but were the least liked by the children. Rather, the relationship between *firmness* and acceptance was inversely U-shaped, with a medium cooking time and medium *firmness* leading to optimal acceptance.

It seems likely that it is the combination of flavour and texture attributes, rather than texture attributes alone, that determines children's acceptance for vegetables. Flavour properties differ at least as much as texture properties in the case of between-vegetable comparisons. Moreover, the reported preference for raw vegetables is based on few vegetable types, notably carrot, which is sweet tasting [8]. Potentially the flavour of the short cooked samples in our study was not well accepted. Flavour profile changes with cooking due to enzymes present or denaturized, and a relative shift was observed from green to cooked flavour notes. A dominance of green over cooked notes was not liked. Medium cooked samples were the most liked, and these samples were characterised by a medium firm texture, as well as a mixture of green and cooked notes.

High and low vegetable consumers in our study were comparable in terms of several socio-demographics, but parents of high vegetable consumers were more often highly educated than those of low vegetable consumers. This relationship between educational level and vegetable intake is well documented [5,38]. High vegetable consumers, by definition, had higher vegetable intake than low vegetable consumers, and therefore have had more exposure to the sensory characteristics of vegetables. Our data showed that high vegetable consumers were more discriminating in acceptance of cauliflower than low vegetable consumers. According to perceptual learning theory, discriminatory ability improves with exposure [39], and in this case has affected discrimination by acceptance, i.e. high vegetable consumers have learned what they like and what they do not like in cauliflower. Therefore, perhaps preferences of low vegetable consumers also become more pronounced if their vegetable consumption increases.

Regardless of the mechanism involved, although high vegetable consumers were more discriminating by acceptance than low vegetable consumers, trends in acceptance for preparation methods pointed in the same direction for both groups. Thus, preferences of high vegetable consumers can be used as recommended preparation guidelines for optimal sensory acceptance regardless of the vegetable intake of the child.

Brassica vegetables are an important source of antioxidants in the diet [40], are low in energy density and a good source of dietary fibre. For optimal nutritional value, steamed vegetables are recommended over boiled vegetables [13,14,16,17,23], and our study found that children do not object to its stronger flavour. Steaming time has little influence on nutrient retention within the range of cooking times used in our study [17], and recommendations can therefore focus on cooking times that enable optimal sensory acceptance. Vegetables should not be steamed too short, to avoid an undesirable flavour and texture, and not too long to avoid undesirable texture, flavour and colour.

Our study showed that although preparation affected vegetable acceptance for low vegetable consumers, acceptance was not the critical barrier to consumption for this group, as none of the samples were (highly) disliked. It is recommended to further investigate to what degree sensory and non-sensory factors contribute to low vegetable consumers' intake of vegetables, in order to determine how their consumption can be most effectively increased.

A major disadvantage of many studies on children's acceptance for vegetables is that they are based on between-vegetable comparisons, which makes it difficult to determine the contribution of flavour and texture properties to acceptance, and makes it difficult to validate statements such as "children like crunchy vegetables". Acceptance in our study was investigated within vegetables by systematically varying two aspects of their preparation. Even in this case the opportunity to determine the individual contribution of sensory properties to acceptance was limited. Cooking time affected texture, but altered the flavour profile at the same time. The contribution of specific taste and perhaps flavour aspects to vegetable acceptance could be determined in studies using cultivars with known taste or flavour differences, but changing texture without changing flavour does not seem feasible for vegetables.

A key strength of our study was that children's acceptance for vegetables was based on actual tasting rather than reported liking. A strength was also that acceptance was studied as a function of within- rather than between-vegetable comparisons, thereby enhancing the understanding of the importance of flavour and texture for children's acceptance of vegetables. A limitation of our study was that the design required children to taste the samples at our research facilities. Although children across all vegetable intakes took part in the research, visiting a lab may have been a hurdle for some children, especially for children with severe difficulties eating vegetables, and limited the sample to those within a reasonable travel distance to the facilities. Children tasted small portions of each sample, which allowed for insights across a range of variables. However, further research is needed to validate the findings when whole meal vegetable portions are consumed.

In conclusion, vegetable acceptance of children may be altered by preparation method. There may be advantage in promoting steaming of *Brassica* vegetables for children, and communication needs to include cooking times for optimal sensory acceptance. Recommendations are applicable across different levels of vegetable intake.

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Chapter 5

Vegetable preparation practices for 5-6 year old Australian children as reported by their parents; relationships with liking and consumption

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Abstract

Vegetables are the food category least accepted by children, which is a key reason for their low intake. Common sense suggests that vegetable preparation, liking and consumption is idiosyncratic to each vegetable, e.g. carrots may be eaten raw, but raw broccoli may be unacceptable, however scientific evidence is largely lacking. This study measured children's experiences, liking and consumption of vegetables in relation to preparation practices at home. Questionnaire data were collected for a comprehensive range of preparation methods (raw, boiling, steaming, frying, roasting, and seven ways of preparing it with other dishes (e.g. soup)) across five common vegetables, i.e. carrot, potato, broccoli, cauliflower, and green beans. Measures included experience with preparation methods (yes/no), liking (9 point hedonic scale) and consumption frequency (5 point scale). Data were reported by parents for their child (n = 82, 5-6 years, low and high vegetable intake), and child/parent pairs were recruited from the Sydney metropolitan area. Parents reported that children consumed an average of 6.8 (SD 3.4) different preparation methods for vegetables at home, including many mixed dishes. The number and type of preparations the child consumed depended on the vegetable type ($p < .0001$). Preparation method was associated with liking of carrot and potato (both $p < .0001$), and with consumption frequency of all vegetables (all $p < .05$). The most and least liked preparations were vegetable specific. Parents reported that vegetables in mixed dishes were generally well accepted by their children, and flavourings were added on average by 54%. The results also showed that a higher vegetable consumption was related to a higher liking, and exposure to more preparation methods. This study demonstrates the potential for further experimental research into preparation practices to increase vegetable acceptance and intake in children. A vegetable by vegetable approach is recommended, with potential cross-vegetable opportunities for flavour-flavour learning and flavour masking strategies including the use of mixed dishes.

Keywords: Child; Vegetables; Food preparation; Home; Consumption and liking

Introduction

It has been well established that vegetables are essential for good health, but vegetable intake of children is below recommendations in Australia [1] and elsewhere [2,3]. Recommended intake for children (4-8 years) in Australia is 2 serves of vegetables per day, but 78% of children do not meet these recommendations [1]. Sensory acceptance is a key determinant of children's consumption of vegetables, and of foods in general [4-6], and vegetables are the food category least accepted by children [7-9]. The burden of non-communicable disease could be considerably reduced by increased vegetable intake [10]. From this perspective, increasing children's vegetable acceptance is important, as food preferences and dietary behaviours developed in childhood often carry through to adulthood [11,12].

Several studies suggest that the way vegetables are prepared influences acceptance and intake in children [7,9,13,14]. Recently several experimental taste studies investigated the effect of preparation on children's liking of vegetables. Steaming and boiling without added condiments were equally acceptable [15,16], and liking for raw vegetables depended on the vegetable type [17]. Boiling and steaming were accepted better than preparations in which heat, or heat and oil, were applied (e.g. baking or frying) in most vegetables when no condiments where added [15,18]. However, Donadini et al (2012) [17] found oven baking with added cheese equally acceptable to boiling across several vegetables, suggesting other ingredients interact with liking for preparation methods.

Low liking for vegetables has in particular been attributed to their flavour, including strong vegetable flavour and bitter taste [19,20]. Other ingredients in a dish may make these disliked flavours more desirable either by 1) direct masking, whereby the perception changes; 2) by flavour-flavour learning, whereby the positive valence of other ingredients transfers to the vegetable [21,22], or 3) by flavour-nutrient learning, whereby positive post-ingestive feedback from energy-providing ingredients increase appreciation. Some first attempts have been made to investigate condiments as a means to increase children's liking for vegetables. Added salt increased green bean intake of toddlers, whereas added fat did not [23]. Addition of a plain or herb-flavoured reduced-fat dip improved vegetable intake in preschoolers [24], and Fisher et al (2012) [25] found the same result using a salt and fat containing dip, but only in bitter sensitive children. However, the use of condiments contributing energy, salt and fat to increase vegetable acceptance needs to be carefully considered, due to their potential adverse effects on energy intake and health when consumed in excess.

Overall, these results suggest that the liking for particular vegetables is highly idiosyncratic on preparation method and interaction with other ingredients. There are many different preparation methods, and so far only a small number have been investigated. For example, use of mixed dishes has been suggested as a viable way to increase children's vegetable liking due to its masking effect on flavour [26], but as far as we know, has not yet been formally investigated. We sought to explore the influence of preparation method on acceptance using a survey questionnaire so we could include a comprehensive range of preparation methods across several vegetables. Insights from this research can help guide the direction for further experimental research, which by its nature is limited in the number of vegetables and/or preparation methods that can be studied simultaneously, especially in children, who have limited attention span.

The objective of the current study was to explore the association between vegetable preparation practices used by the parent in the home environment, and the child's liking and consumption of 5 commonly consumed vegetables. The hypotheses were that preparation influences vegetable acceptance and intake in children, and that the effect of preparation is vegetable-specific. This study aimed to provide insights to inform parents and practitioners how best to promote vegetable intake in children. Children with low and high vegetable intake were included to determine whether they differed in the role that preparation had on their vegetable acceptance, which can help design tailored strategies to increase intake in low vegetable consumers.

Material and methods

Participants

Data were collected from 82 parents from the Sydney metropolitan area, Australia, (75% female, mean age 39.2 ± 3.9 years) whose child participated in an experimental taste test. Children were 5 or 6 years old (mean age 6.0 ± 0.5 years), and the children's sample was balanced for gender. As we also sought to understand whether different preparation advice was needed for children differing in their vegetable intake, we balanced the sample for vegetable intake. Average daily consumption of vegetables of Australian children between 4-8 years is a bit over 1.2 serves [27], and recommended vegetable intake for this age group is 2 serves /day or more in Australia. Therefore we adopted the criteria of ≤ 1 serve as low vegetable intake since it was below average, and 2 serves or more as high vegetable intake, as above average and meeting recommendations. Children with an average intake between 1 and 2 serves were excluded. Children/parent pairs were recruited by advertising in local media, schools, childcare centres and nearby worksites, and partially via an external recruitment agency. Results of the taste test are presented elsewhere [16]. The study protocol was approved by the CSIRO Human Research Ethics Committee. Written informed consent was obtained, and each parent/child pair received a $50 retail voucher for their participation.

Questionnaire

The questionnaire addressed acceptance and consumption frequency of a comprehensive range of preparation methods across 5 commonly consumed vegetables; carrot, potato, broccoli, cauliflower and green beans. For each vegetable, the parent responded for 12 preparation methods how often their child had consumed the vegetable prepared in this way at home (using a 5-point scale ranging from ‘very rarely’ to ‘very frequently’), and how much their child liked the vegetable prepared in this way (using a 9-point hedonic scale [28]). The measurement of consumption frequency was subjective, and may have been interpreted by different parents in a slightly different way. However, it allows comparing frequency of consumption of different vegetable preparations relative to each other, which was the main objective of this study, and as such it was analysed as an ordinal variable. If the child had never consumed the vegetable prepared in this way before, they ticked the box “Never consumed it” for this preparation method (Fig. 5.1).

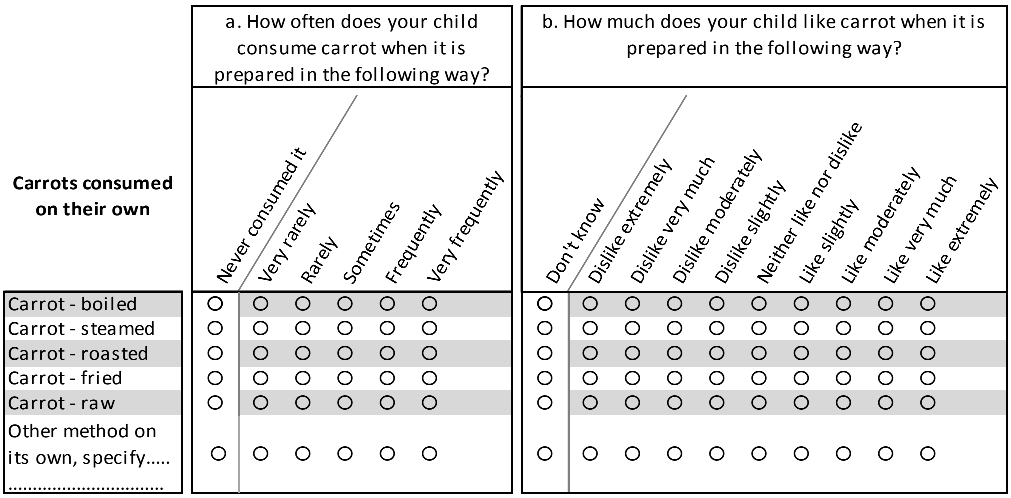

Figure 5.1 Measurement of consumption frequency and liking for vegetable preparation combinations in the questionnaire.

Instructions to parents were given to consider their child’s experiences in the home environment. Example provided for carrots consumed ‘on their own’, i.e. consumed as part of a meal but separate on the plate. A second block collected data for seven preparation methods (pasta, curry, stew, stir fry, soup, salad and mixed vegetables) where the vegetable was consumed as part of a mixed dish. The same two blocks were used for the other four vegetables.

The preparation methods were generated from earlier data on vegetable home preparation practices [29]. Five preparation methods were listed in which the vegetable was consumed “on its own”, as part of the main meal served separate on the plate from other meal components e.g. meat/fish: boiled, steamed, roasted, fried, raw; and seven preparations where the vegetable was consumed as part of “a mixed dish”, i.e. ingredients of the meal are mixed together: pasta, curry, stew, stir fry, soup, salad and mixed vegetables. For consistency and comparison all preparations were listed for all vegetables (with exception of ‘raw’ for potato). Respondents could also list and rate other preparations they used. For vegetable preparations “on its own”, information was further collected on whether flavourings and/or condiments were added, and if so, what type (e.g. salt/butter).

The vegetables in the study were selected on the basis that they could potentially be prepared at home in a multitude of ways (thereby excluding salad vegetables), they were commonly consumed by children [(29)], and were available year round. The main focus of this study was on preparation practices, and to keep consumer burden to an acceptable level, the study was limited to five vegetables. Potato is a vegetable for Australian Healthy Eating guidelines [(30)], although it is recognised that its nutritional composition differs from many other vegetables. Parents completed the questionnaire whilst their child took part in a taste test. Parents received oral instructions how to complete the questionnaire, which included instructions to focus on the preparation methods they had used themselves in the home environment for their child. The parent completed preparation information for all five vegetables, then completed a short background questionnaire, which collected information for both parent and child on gender, age, usual vegetable intake in servings per day [(31)], food neophobia [(32,33)] and educational level (parent only). The full questionnaire took 25-30 min to complete.

Data analysis

Data were analysed using SPSS Statistics version 20 (IBM Corp) with a significance level of $p \leq 0.05$. The number of different preparation methods that each child had consumed at home (regardless of the frequency with which it was being consumed) was calculated for each vegetable. A repeated measures ANOVA was used to determine whether or not the number of preparations differed for vegetables and between children of different vegetable intake, using the number of preparations the child had experienced as dependent measure, vegetable as repeated factor and vegetable intake group as between-subject factor using a full-factorial model.

For the other analyses, vegetable preparation combinations with very low usage (less than 10% of children) were excluded. To study the association between preparation method and liking, a univariate ANOVA analysis was done using liking as dependent variable, and preparation method, vegetable intake group as well as their two-way interaction as independent variables, and a Bonferroni as post hoc test. The same independent factors were used to analyse the association between preparation method and consumption frequency. Since consumption frequency was measured on an ordinal level, the model used in this case was a generalized linear model, with Wald Chi-square as post hoc test. These analyses were done per vegetable type to accommodate for the fact that different preparations were used for different vegetables. The relation between liking and consumption frequency of vegetables was calculated using Spearman's correlation coefficients for groups of children with low and with high vegetable intake.

A generalized linear model was used to test frequencies with which any flavouring (yes/no) was added, with vegetable type, preparation method, the child's vegetable intake and two-way interactions as factors.

Results

Participants

Parents of children with high vegetable intake reported that their children consumed on average 1.5 serves of vegetables per day more than those of parents with children with low vegetable intake, and they were less neophobic (Table 5.1). Parents of these children were more highly educated, and had a higher vegetable intake themselves.

Table 5.1 Characteristics of participants.

	Children with high vegetable intake (*n* = 41)		Children with low vegetable intake (n = 41)		
	Mean [1]	SD	Mean [1]	SD	*p* [2]
Participating parent					
Age (years)	39.1	3.7	39.3	4.2	0.78
Vegetable intake (serves/day)	3.1	1.1	2.6	1	0.02
Food neophobia score [3]	20.6	7.3	22.3	8.2	0.34
Gender, female (%)		73		76	0.8
Education level (%)					0.02
High school, tech, trade, TAFE		22		46	
University or post grad		78		54	
Child					
Age (years)	5.9	0.6	6.1	0.5	0.41
Vegetable intake (serves/day)	2.3	0.6	0.8	0.3	<0.0001
Food neophobia score [3]	30.6	9.1	38.2	14.5	0.006
Gender, female (%)	49		51		0.83

[1] Mean for continuous variables and percentages for categorical variables.
[2] $\chi 2$ and t tests.
[3] Range from 10 (neophillic) to 70 (neophobic).

Experience of children with preparation methods

Parents reported that children had experience with consuming an average of 6.8 (SD 3.4) preparation methods at home for each vegetable. The number of preparation methods parents reported that children consumed depended on the vegetable type ($p < 0.0001$), and Fig. 5.2 shows that children had experience with more preparation methods for carrot and potato than for the other three vegetables.

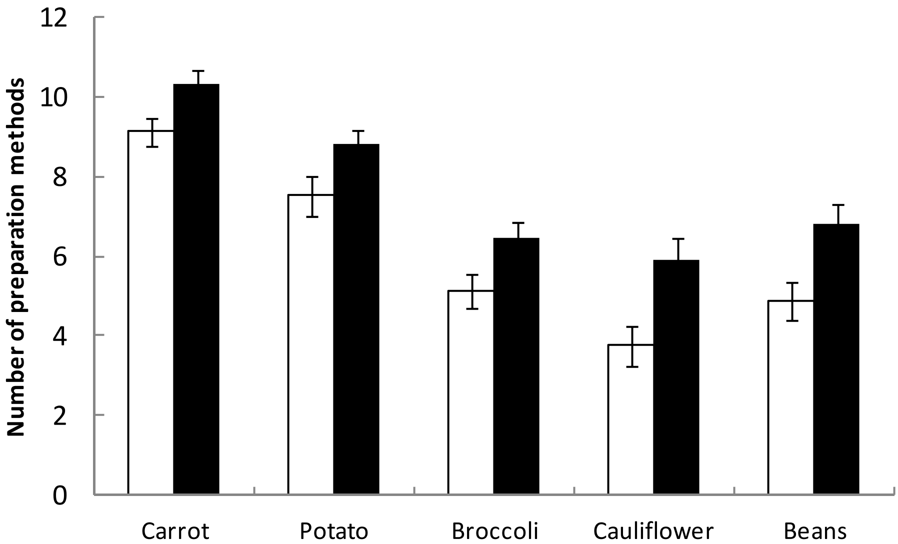

Figure 5.2 Number of different preparation methods that the child has consumed at least once at home; white and black bars represent children with low (≤ 1 serve/day) and high (≥ 2 serves) vegetable intake, respectively.

Table 5.2 Percentage of children that have consumed the vegetable preparation combination before.

	Carrot (%)	Potato %)	Broccoli (%)	Cauliflower (%)	Beans (%)
Boil	85	93	73	67	68
Steam	93	62	89	67	79
Roast	78	93	16	23	7
Fry	35	80	30	22	29
Raw	99		5	16	46
Mixed veg	87	83	82	70	76
Pasta	80	34	57	30	46
Curry	56	62	30	34	44
Stew	77	74	33	32	50
Stir-fry	88	28	80	52	67
Soup	71	67	33	38	23
Salad	90	66	32	16	39

Children with high vegetable intake had experience with more different preparation methods than children with low vegetable intake (p = 0.002). The specific preparations that children had experience with (as reported by their parents) are shown in Table 5.2. All preparation methods were frequently consumed in the case of carrots. Boiling, steaming, mixed with other vegetables, and vegetables consumed in a stir fry were the most familiar preparations across all vegetables, and other methods were more vegetable specific. For example, salad and soup were familiar preparations for carrot and potato, and relatively unfamiliar for broccoli, cauliflower and beans.

Association between preparation method and liking/consumption frequency

Fig. 5.3 shows that the most liked preparation methods differed per vegetable type, but parents reported that generally boiling and steaming were well accepted by their children, as were mixed dishes. A significant effect of preparation method on liking was found for carrot and potato, and not for the other three vegetables (Table 5.3). Fig. 5.3 and post hoc testing showed that raw carrot, and carrot in salad and pasta were liked the most, and roasted and fried carrot were liked the least. For potato, fried and roasted preparations were liked significantly more than all other preparations. There was a significant effect of preparation method on consumption frequency as reported by the parent for their child for all vegetables ($p < .05$) (Table 5.3). Preparations that were consumed significantly more than others within vegetable types (post hoc testing, see also Fig. 5.3) were raw, in salad and steamed for carrot, roasted, fried and boiled for potato, steamed for broccoli, steamed for cauliflower, and steamed and in a stir fry for green beans (all $p < .05$).

Table 5.3 Effect of preparation method on liking (F value, p value) and on consumption frequency (Wald Chi-Square, p value) of the five vegetables measured in the study. Vegetable preparation combinations consumed by less than 10% of children were excluded.

	Liking		Consumption frequency	
	F value	*p* value	Wald Chi-Square	*p* value
Carrot	5.8	< .0001	104.0	< .0001
Potato	6.9	< .0001	69.4	< .0001
Broccoli	1.2	ns	73.9	< .0001
Cauliflower	0.4	ns	22.7	0.02
Beans	1.1	ns	34.5	< .0001

Low vegetable consumers had significantly lower reported acceptance ratings than high vegetable consumers for all vegetables (all $p < .05$), and they consumed carrot less often ($p = .007$). There were no significant two-way interactions with the child's vegetable intake, indicating that associations between preparation method and liking / consumption were the same for children with low and high vegetable intake.

There was a significant correlation between parent reported measures of vegetable liking and consumption frequency in children with low (ρ 0.70, $p < .0001$) and high (ρ 0.58, $p < .0001$) vegetable intake, indicating that the more a vegetable preparation combination was liked, the more frequently it was consumed.

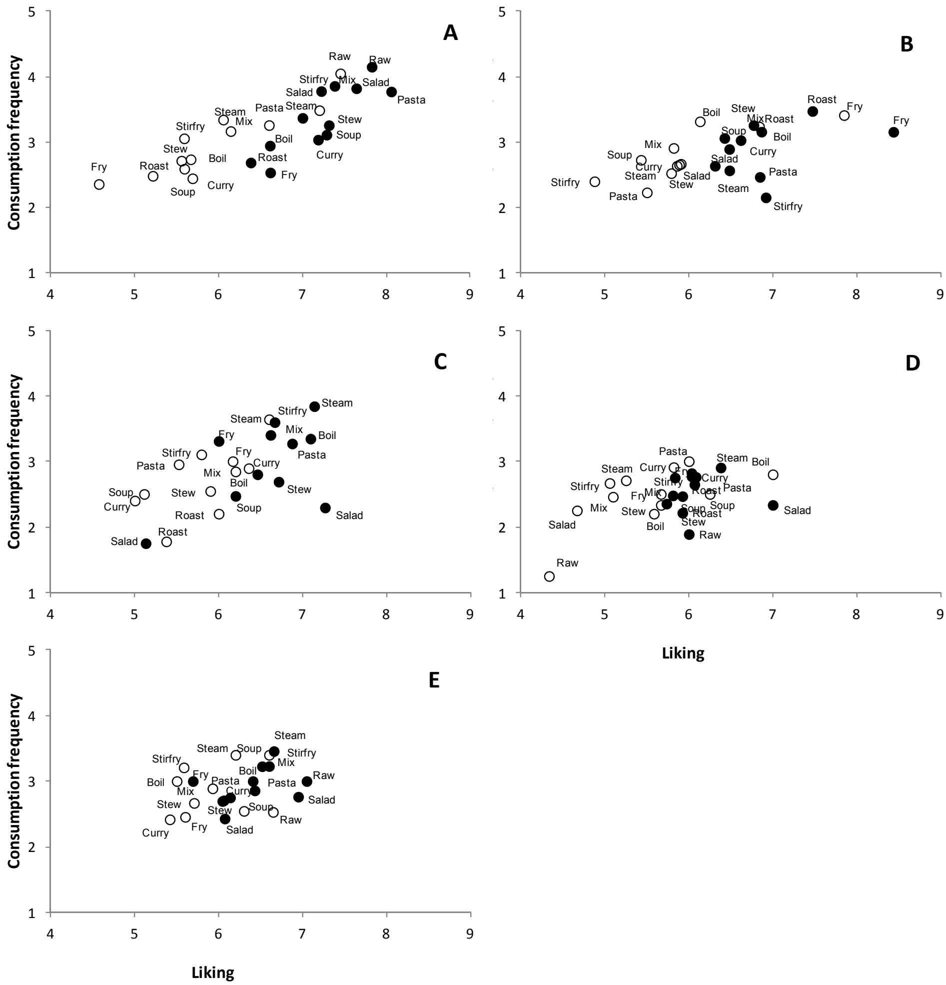

Figure 5.3 Liking (9-pt scale from 1='dislike extremely' to 9='like extremely') *v.* consumption frequency (5-pt scale from 1='very rarely' to 5='very frequently') of vegetable preparation combinations by children with low (≤ 1 serve/day, open circles) and high (≥ 2 serves/ day, closed circles) vegetable intake. Panels present vegetable types with A) carrot, B) potato; C) broccoli, D) cauliflower, and E) beans.

Vegetable preparation combinations consumed by less than 10% of children were excluded. Preparation: mix = mixed vegetable, rest as is.

Addition of flavourings

Parents reported that a total of 54% of vegetables consumed on their own by their child were flavoured with some type of flavouring or condiment, such as salt, pepper, butter, oil, sauce, dressing, or spices. Whether or not flavourings were added, significantly depended on preparation method ($p < .0001$), vegetable type ($p < .0001$) as well as their interaction ($p = .007$). Flavourings were frequently added to roasted and fried preparations, and rarely to raw (Table 5.4). The type of flavourings or condiment added most often were salt, butter and oil, but spices, sauces and dressings were also frequently added (data not shown).

Table 5.4 Proportion of children adding flavourings to each of the five vegetables studied. Vegetable preparation combinations consumed by less than 10% of children were excluded.

	Carrot (%)	Potato (%)	Broccoli (%)	Cauliflower (%)	Beans (%)
Boil	36	84	39	56	44
Steam	27	61	36	43	35
Roast	81	93	70	78	
Fry	79	89	72	80	65
Raw	8			10	9

Discussion

This study showed that preparation method was associated with liking and consumption frequency of vegetables by children as reported by parents for vegetables consumed at home. This study also showed that children consumed vegetables prepared by their parents in many different ways, and flavourings were frequently added.

The way foods are prepared and combined in meals impact on our sensory enjoyment [34,35]. Our study found that preparation method was associated with liking of carrot and potato, and with consumption frequency of all vegetables. The most and least liked preparations were vegetable specific. Thus, preparation had a larger effect on some vegetables than others, and no preparations were liked more than others across all vegetables. These findings are consistent with experimental taste studies. Poelman and Delahunty (2011) [18] found that boiling was preferred to baking or stir frying by 5-6-year-olds in two of three vegetables only, and Donadini et al (2012) [17] found that preparation affected preschoolers' liking only for three of six vegetables, with the most preferred preparations being dependent on the vegetable type.

Most of the vegetable preparation combinations measured in our study have not been experimentally tested. Where specific experimental taste test data is available, our findings are in agreement. For example, our study supports the finding that steaming and boiling were liked more than frying and roasting in carrots [15], and that boiling and steaming were equally accepted in carrot, beans, cauliflower and broccoli [15,16]. Roasting and frying were the most liked preparations for potato. Although no experimental taste test data are available, previous studies found that roasting was accepted for sweet potato but not for carrots, beans and cauliflower [15,18]. Thus, children's liking for preparations such as roasting and frying may be specific to starch-rich vegetables.

This study shows that parents use a wide variety of preparation methods for vegetables consumed at home by their child, both as vegetables prepared on their own as well as vegetables consumed as part of a mixed dish. Parents also frequently add flavourings, including salt, fat, sauces and spices, when preparing these vegetables. Preparation practices may include culturally specific preparations, parental preferences and/or habits; in our study an Australian context was studied. Our study cannot tell whether versatility in preparation methods and flavour masking strategies were used as an attempt to get vegetables included in the diet of their children. Regardless, the current versatility in practices may be viewed as positive for promoting uptake of new preparation practices that have demonstrated positive effect on acceptance.

Both hypotheses in our study were confirmed; preparation influenced vegetable acceptance and intake in children, and its effect was vegetable specific. This study provides strong support for further systematic and experimental taste research to determine how preparation can be used to make vegetables more acceptable to children. Our results support continuing to conduct research on a vegetable by vegetable basis. There may be opportunities for cross-vegetable research into flavour masking, flavour-flavour learning and/or flavour-nutrient learning strategies. Salt and salt-containing dips increased vegetable liking in a number of studies [(23-25)], whereas added fat alone did not [(23)], and such effects may be explained by salt masking bitterness [(36)], thus potentially having applicability across a range of bitter tasting vegetables. Further research on use of flavourings to increase vegetable acceptance is recommended, in particular the potential for flavour-flavour learning by use of flavourings of which use is not discouraged in public health messages. It is also recommended to conduct further research on mixed dishes. Mixed dishes were frequently used, and vegetables in mixed dishes were mostly well accepted, and this area is currently unexplored in experimental taste research. In these dishes, it is likely that a combination of flavour masking, flavour-flavour learning and/or flavour-nutrient learning have contributed to their good acceptance. Flavour masking and flavour-flavour learning have both been found effective mechanisms to increase vegetable acceptance [(21,22)], however the potential of flavour-nutrient learning on increasing vegetable acceptance is less well understood [(22)]. The many idiosyncratic ways to flavour vegetables offer plenty of potential for research to increase vegetable acceptance and intake, and this area of research is largely unexplored.

Liking and consumption frequency were correlated, regardless of the child's vegetable intake. Causality cannot be established due to the observational nature of this study. Nonetheless, the correlation supports other research that demonstrates that increasing liking is a viable way to increase consumption of vegetables [(4,5)].

Our study included children of low and high vegetable intake. Parents of children with low vegetable intake reported lower overall liking by their child than parents of children with high vegetable intake, but children did not differ in preparations most and least liked. Thus, the same preparation advice to increase acceptance applies to children of low and high vegetable intake. At the same time, children with low intake had experience with fewer different vegetable preparation combinations across all vegetable types. As exposure is a key mechanism of food preference acquisition [37], and effective in increasing liking and intake for vegetables [38,39], the hypothesis could be derived that children with low vegetable intake like vegetables less because they lack sufficient exposure. Consequently, increasing the variety and frequency with which vegetables and preparations are offered, may be a promising way to increase their liking of vegetables. Increasing variety has two additional benefits. Firstly, fewer exposures are needed to increase liking with increasing variety in the diet [40]. Secondly, high variety in consumed vegetables persists through to adulthood [41], and is in itself an indicator for a higher quality diet [42].

Parents of children with high vegetable intake were more highly educated and consumed more vegetables themselves, which is in agreement with other studies [43]. Similarly, others have found that higher neophobia was associated with lower vegetable consumption in children [44]. In order to be successful, interventions to increase vegetable intake in children should acknowledge family characteristics, and address the different difficulties that parents may have in implementing strategies to increase vegetable consumption at home.

Several aspects of this study warrant discussion. A key strength of this study was the investigation of actual experiences in the child's home environment across many preparations and several commonly consumed vegetables. Such a wide scope would have been impossible to investigate in experimental research. Data were supported by experimental taste research, providing support for the validity of the methodology. The sample size was small, limiting generalizability of the findings. The methodology is suitable for on-line data collection, and may be used to validate findings using a larger sample, as well as collect data from more diverse consumer samples, including cross cultural comparisons.

Data were collected from parents for their child. We chose this method as children of the age group studied do not have the cognitive skills to complete a questionnaire of this scale. There are limitations in extrapolating and analysing data from parental perceptions into children's actual behaviour, and bias from parents cannot be excluded. However, parents have been found to be well capable of reporting their child's food acceptance and preferences [7,45]. Moreover, the similarity of our findings with experimental taste tests on children supports the robustness of the data. This study measured consumption frequency as a measure of vegetable consumption, which is most relevant in relation to exposure. However, our study was limited in measuring actual intake.

In conclusion, parental reports show that preparation practices are associated with their children's liking and consumption frequency in a vegetable specific way. Further research into this area is warranted, and increased knowledge on preparation practices that promote acceptance, when combined with nutritional recommendations, may be used to help design public health interventions aimed to increase vegetable intake in children.

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Chapter 6

The effect of multiple target versus single target exposure with reward to increase vegetable intake in children. A pilot study.

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In preparation

Abstract

Exposure to multiple vegetables during weaning positively influences vegetable intake in infants. This study evaluated the effectiveness of repeated exposure to multiple target vegetables compared to a single target vegetable in increasing vegetable intake in older children. A pilot three-group randomised controlled trial was conducted with children aged 4-6y (n = 34), using baseline, post-intervention and three-month follow up measurements. Two home-based parent-led intervention groups were exposed, using a reward, to a small amount of either one (single target intervention) or three (multiple target intervention) vegetables for 15 days over five weeks. A control group did not change their eating habits. Vegetable intake was measured: 1) in an actual meal consumed, 2) using three-day food records, and 3) as usual vegetable intake reported by the parent. Children's vegetable acceptance, food neophobia and exposure to vegetables as reported by the parent were also measured. Repeated measures ANOVA was used to analyse differences in outcomes between groups, time and group-by-time. Usual vegetable intake increased in the multiple target intervention group from 0.6 to 1.2 serves/day ($T = -2.91$, $p = 0.02$) and did not change in the other groups. No group-by-time differences were found in the other vegetable intake measures, but directionally food record data supported usual vegetable intake. Vegetable acceptance increased for target vegetables in both intervention groups (both $p < 0.01$) and an overall reduction in food neophobia ($F = 5.41$, $p < 0.05$) was observed. This pilot study showed that multiple vegetable exposure may be more effective than single vegetable exposure to increase vegetable intake in children. Research using a larger sample size should be undertaken to validate findings.

Key words: children; multiple target; repeated exposure; vegetable intake; vegetable acceptance; variety

Introduction

Vegetables play an important part in a healthy diet. Increased vegetable intake reduces the risk of chronic disease, including coronary heart disease and stroke [(1-3)]. In Australia, recommended vegetable intake for children between 4-8 years old has recently changed from 2 to 4.5 serves per day (a serve representing 75g of vegetables)[(4,5)], whereas vegetable intake in this age group is only 1.2 serves [(6)]. As children's vegetable consumption is below recommendations in most Western countries [(7,8)], strategies to increase consumption are needed.

Low acceptance is a key reason for low vegetable intake in children [(9,10)]. Children are born with an innate liking for sweet taste and a dislike for bitter taste, and after a period of sensory maturation, acquire a liking for salty and energy dense (fatty) foods [(11,12)]. Vegetables have a low energy density, are mostly not sweet, and some of them are bitter. This means that liking for vegetables is largely a learned behaviour, with childhood being a critical phase in the development of food preferences [(12-15)].

Parents seem largely unaware of this plasticity of food preferences. The child's disliking of a food is one of the main reasons parents stop offering [(16)] or do not serve [(17,18)] their children those foods. A heightened food neophobia between the ages of 3 and 6 years [(14,15)] aids the avoidance mechanism of foods that from an evolutionary perspective may potentially be dangerous, such as vegetables with bitter tasting phytochemicals [(15)], and is likely to add to parental anxiety around their child's refusal to consume vegetables.

It has been well documented that repeated exposure positively affects vegetable acceptance and intake in children at their peak of food neophobia [(19-25)], with several of these studies being parent-led interventions [(19,22,23)]. Mere exposure to vegetables seems to be at least as or more effective than flavour-flavour learning and flavour-nutrient learning [(20,26-29)], and the use of a small reward has been found to increase willingness to try the vegetable [(19,22)].

Repeated exposure studies with children at their peak of food neophobia have all used a single vegetable as target for repeated exposure, and have investigated and found increases in intake related to that particular vegetable only. Ultimately, children with low vegetable intake would benefit from learning to like and consume a broad range of vegetables. Thus, there is a need for simple and effective, easy to implement strategies to increase vegetable consumption in children across a range of vegetables.

Studies seeking to develop best practice for introducing weaning foods to infants have investigated introduction to a single vegetable versus a variety of vegetables [(30,31)]. Offering three different vegetables in an alternating schedule increased intake of a non-tasted vegetable whereas repeated exposure to a single vegetable did not [(30)]. In another study, offering a variety of vegetables including within-meal variation of two vegetables, intake of a target vegetable was greater than when either offering the target vegetable alone or offering between-meal variety only [31]. Infants (typically 4-6 months old) are a very selective group, as their only dietary exposure since birth has been milk. It is unknown whether variety in exposure could have similar positive effects in older children. Older children have a much broader dietary variety, and therefore have had exposure to a much broader range of sensory flavour and texture properties. In addition, older children often are not neutral to vegetables, rather dislike them [32], and have a heightened neophobia [14].

The current pilot study aimed to determine the effectiveness of repeated exposure to either a single or to multiple vegetables as means to increase vegetable acceptance and intake in low vegetable consuming 4-6 year old children, compared with a control group. The intervention was home based and parent-led. It was hypothesized that exposure to multiple target vegetables would increase vegetable intake more than exposure to a single target vegetable.

Methods

Overview of design

This pilot study was a randomised between-group controlled trial with three conditions; 1 = Single vegetable exposure intervention, 2 = Multiple vegetable exposure intervention, 3 = Control.

A pre- and post-test were conducted to determine differences between the three groups in vegetable intake and the associated behavioural factors, vegetable acceptance and exposure, and food neophobia. A three-month follow up using the same outcome measures was conducted to determine whether any effects found were sustainable.

Recruitment and participants

Participants needed to meet the following criteria: child aged between 4 and 6 years; child to have low vegetable intake (< 2 serves/ day); parent would like their child to consume more vegetables. Children with food allergies were excluded from participation. Participants were recruited by public advertisements and flyers in day care centres, preschools, school newsletters, shops, emails to staff in nearby sites, and via social media (Tweets). Interested parents completed an on-line screener questionnaire. Eligible participants were invited to an information session, where study details were provided. Participants providing consent to take part were randomly allocated to a treatment group.

Recruitment was conducted in two cohorts over a 6 month period. Starting with 73 interested participants, baseline data were collected for 34 participants (Fig. 6.1). Two participants dropped out before post-testing, and were excluded from data analysis. Follow up data were available from 28 participants.

The study was approved by the CSIRO Human Research Ethics Committee. Parents provided written informed consent for themselves and their child, and received a $50 gift voucher for participation.

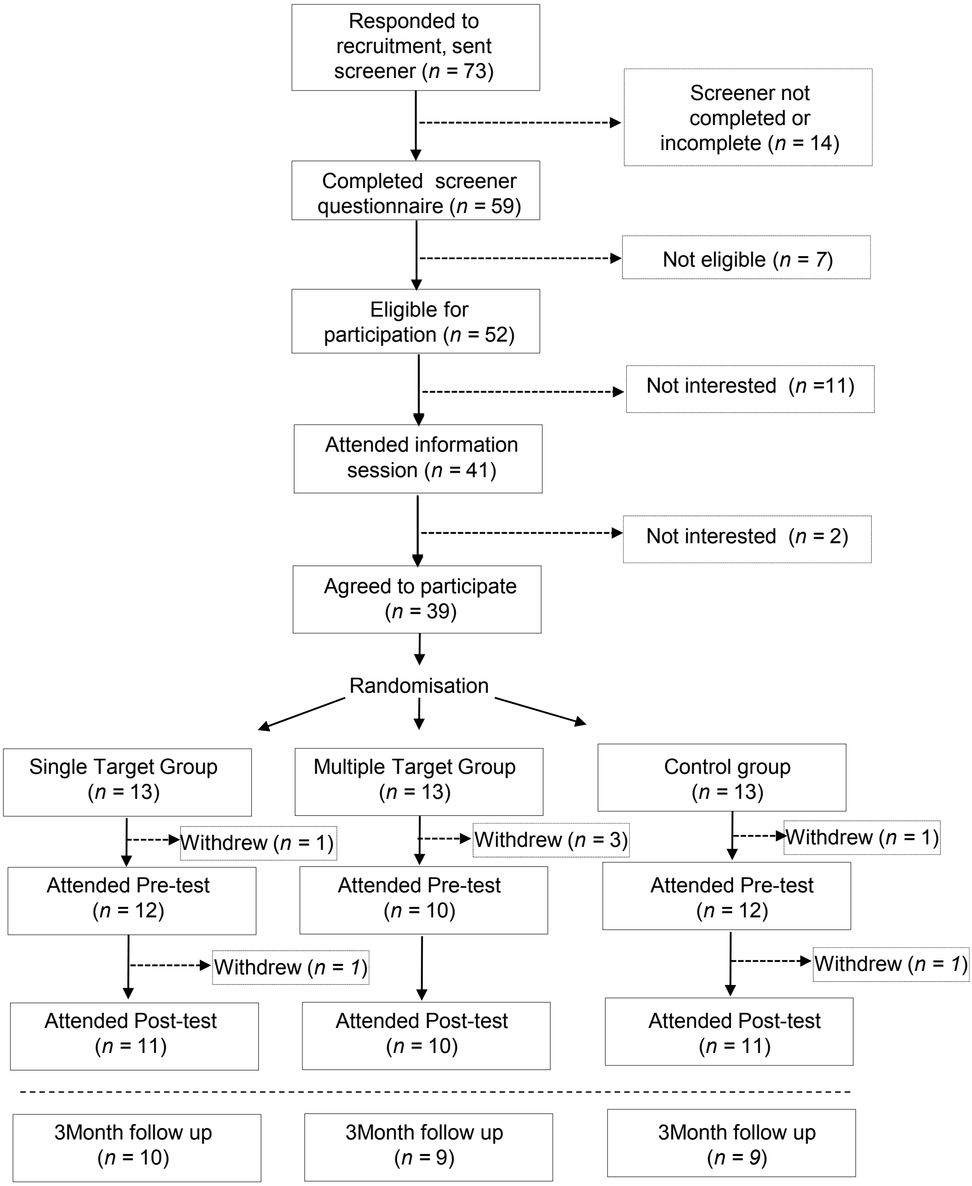

Figure 6.1 Flow diagram describing recruitment, screening and participation of participants.

Intervention

The interventions were parent-led home based interventions, with instructions designed to be easy to follow. In both intervention conditions, children were exposed to a small amount of vegetable three times a week for a total of 5 weeks (so for a total of 15 exposure days). Children in the single target vegetable exposure group were exposed to the same single vegetable on each exposure day during these five weeks (i.e. a total of 15 exposures to the same vegetable). Children in the multiple target vegetable exposure group were exposed to three vegetables, and by rotation two of the three vegetables were offered on each exposure day during these five weeks (i.e. a total of 10 exposures to each vegetable). The vegetables in the study were broccoli for the single target vegetable group, and broccoli, zucchini and peas for the multiple target vegetable group. Vegetables were selected on the basis that they were not highly liked nor highly disliked by children on a group level [(33)], and were vegetables that many parents wished their children to consume more of [(19)].

Parents were informed about the treatment condition they participated in after the pre-test. If they were in an intervention group, they received written and oral instructions to undertake the intervention, and a $20 voucher to buy vegetables. Practical advice was provided on how (small piece (about 1x1x1cm), same preparation type) and when (same time each day, preferably before dinner) to present the target vegetables to their child. Parents also received step-by-step instructions to offer the vegetable to their child, and deal with refusals following the procedure as described by Corsini et al [(19)]. When the child successfully tasted the vegetable, they were given a reward (sticker) to place on a chart. In the multiple target vegetable group, the parents followed the same procedure for both vegetables offered on a given day. In both intervention groups, the parent recorded the outcome of each exposure (whether the child had consumed or refused the vegetable(s)), and how much they thought their child liked the vegetable(s) (using a nine-point hedonic scale). After the last exposure day, the parent reported on perceived ease of implementing the techniques (very easy/quite easy/ a bit difficult/very difficult). Parents were asked not to change the diets of their children other than the intervention during the intervention period, but were encouraged to continue applying the techniques in their daily routines once the intervention had finished. Parents in the control group were instructed to encourage their child to eat vegetables as they normally would, and were provided with the intervention information after the study.

Measures

Pre- and post test measurements were collected whilst participants visited the research facilities, with exception of the weighed diet records, which were completed at home. Three month follow up measures were completed at home. Pre- and post test measurements were scheduled at 5pm and 6pm, with children abstaining from eating and drinking 1 hour before assessments. Children were provided with a meal, whilst parents completed a questionnaire.

Anthropometric information from the child was collected at the first visit. Children were assisted individually by trial staff members, who were not aware of the participants' treatment condition. Measures collected are described in detail below. Unless indicated otherwise, all measures were collected at baseline, immediately post-intervention, and at 3-month follow up. An overview is provided in Table 6.1.

Table 6.1 Overview of data collected at various stages of the study

Pre-test	Intervention (5 week period)	Post-test	Three month Follow up
Meal in lab		Meal in lab	
Food records Questionnaire data		Food records Questionnaire data	Food records Questionnaire data
	Acceptance data for target vegetables (single and multiple target group)		

Vegetable intake: experimental meal

During the pre-and post-intervention visit to the research facilities, children were presented with a meal that consisted of one serve each of three steamed vegetables (75g per vegetable), pan fried chicken breast (80g) and boiled pasta (100g), as well as a glass of water (160ml). Serve sizes were derived from Healthy Eating Guidelines for children in Australia [34]. The three vegetables served as part of the meal were broccoli (target vegetable in both intervention groups), cauliflower, and green beans (not a target vegetable in either of the intervention groups). Each meal was prepared fresh and served in the canteen. Children could eat as much or as little as they wished of all of the food items. Low screens on the table allowed participants to see other participants but not the other participants' meals. However, in most instances only one child at a time participated. Each food component was weighed to the nearest 0.1g before and after the meal.

Vegetable intake: three day weighed food diary

Parents completed 3-day weighed food diaries for their child, in which all food and beverages the child consumed were weighed with a digital kitchen scale and recorded over three times 1 day (24 hours). Weighed food records provide a very precise method to measure food intake [35]. Diaries were completed on 2 representative weekdays and 1 representative weekend day of the parent's choice. Data was entered into Foodworks (Foodworks 7 Professional, Xyris Software, 2012) by research staff and analysed using the AUSNUT 2007 (Food Standards Australia New Zealand, 2007) food composition database. Amount of vegetables consumed (in g) was extracted, and data was averaged across the three days. Variety in number of vegetables consumed across the three days was calculated separately.

Vegetable intake: usual vegetable consumption

The child's usual vegetable consumption was reported by the parent in serves per day. A validated questionnaire to measure usual vegetable intake in Australian adults [36] was modified to measure intake in children through the use of the answer categories 0 serves, ½ serve, 1 serve, 1 ½ serve, 2 serves, 3-4 serves and 5 or more serves (the original scale did not have ½ serves). In addition, pictures portraying ½, 1 and 2 serves of vegetables on a plate were provided. Data were collected at baseline and at three-month follow up.

Vegetable acceptance by the child

Parents recorded the child's vegetable acceptance for a wide range of 38 vegetables that together covered a comprehensive range of vegetable sensory properties using a 9-point hedonic scale [37]. They could also indicate which vegetables their child had never consumed. Parents have been shown to be well capable of reporting their child's food acceptance and preferences [32,38].

Children's exposure to vegetables

Parents reported for each of 22 commonly consumed vegetables [33,39], how many serves per week on average were offered to the child.
Pictures representing ¼, ½ and 1 serve of the vegetable on a plate were provided to allow for accurate understanding of serve sizes. In addition to number of serves per vegetable, the total number of different types of vegetables offered per week to the child was calculated.

Food Attitudinal measures

Parents reported their child's willingness to consume new foods using the 10-item Child Food Neophobia Scale [40,41].

Other measures (collected at baseline)

Children's height (in cm) was measured with a wall-mounted stadiometer, without shoes. Weight (in kg) was measured with participants wearing light clothes and without shoes, using dedicated scales. Parents provided demographic information and information about their own vegetable consumption and food neophobia.

Statistical analysis

Data were analysed using SPSS (IBM SPSS Statistics, v.20.0.0, 2011). A value of $p < 0.05$ was used as criterion for statistical significance. Repeated measures ANOVA was conducted on the outcome measures, with time as repeated factor, and using groups (single target, multiple target, control) as between-subjects variable. Paired t-tests within groups were conducted in case of significant group by time effects. Analyses were conducted separately comparing baseline and post-intervention, and comparing baseline to three-month follow up data, due to lower participant numbers at follow up. Acceptance across vegetables was analysed using univariate ANOVA, with group, vegetable and their interaction as factors, and using a type IV model to account for unbalanced cells (due to the child not consuming this vegetable). Development of acceptance of the target vegetables in the intervention was analysed using univariate ANOVA, using exposure day as factor in the single target group, and exposure day, vegetable and their interaction as factors in the multiple target group. Type IV models were used to account for unbalanced cells (due to parent not offering or child refusing to taste). LSD was used as a post-hoc test in case of significant differences.

Results

Participant characteristics

Participating children (Table 6.2) were 53% boys, with an average age of 5.1 years (SD 0.8, range 4.0 – 6.8 years), a BMI of 15.5 (SD 1.8), and relatively neophobic (48.7 ± 10.2). Participating parents were 71% females, aged 40.8 years (SD 4.9 years), and an average food neophobia score of 26.5 ± 10.8); a majority (91%) was highly educated. Participants randomly allocated to the three groups did not differ significantly in child or parent characteristics with exception of parental vegetable intake. Parents in the control group reported their own vegetable intake to be higher (3.3 ± 1.2 serves) than parents in the single (2.1 ± 1.0) and multiple target (2.3 ± 1.1) intervention group ($F = 3.79$, $p = 0.03$).

Parental compliance with the intervention

Parents that were in one of the two intervention arms of the trial complied well with the procedures, with 55% offering vegetables on all 15 exposure days, 25% missing only one exposure day and none of the parents offering vegetables on ten or less exposures days. When the vegetable was not tasted, in the majority of cases this was because of refusal by the child (and not because of the parent not offering).

Table 6.2 Participant characteristics (n = 34), measured at baseline.

	Single vegetable intervention (n = 12)		Multiple vegetable intervention (n = 10)		Control (n = 12)		p value
	Mean	SD	Mean	SD	Mean	SD	
Gender *(n)*							
boys	6		5		7		0.90
girls	6		5		5		
Age (in years)	5.14	0.80	5.10	0.71	4.98	1.02	0.90
BMI (kg/m2)	15.28	2.54	15.85	1.61	15.31	0.78	0.72
Food neophobia	49.17	8.22	49.40	10.47	47.75	12.46	0.91

Vegetable intake: experimental meal

Vegetable intake in the experimental meal at baseline was 46g (SD 53g) across groups, and significantly decreased with 8g post-intervention across the three groups. This decrease was largely due to a decrease in intake in the control group (Table 6.3), although the group by time effect was not significant. Children in the single and multiple target intervention had been repeatedly exposed to one of the vegetables offered in the meal ('tasted vegetable'), and had not been exposed to the other two vegetables during the intervention ('non-tasted vegetables'). The changes in intake before and after the intervention were not different for tasted and non-tasted vegetables in either intervention group (data not shown).

Table 6.3 Effect of intervention on primary outcome measures of vegetable intake (mean ± SD), comparing baseline, post-test and three-month follow up data.

Measure	Time			p Value *(baseline-post test)*			p Value *(baseline-3 month follow up)*		
	Baseline	Post-test	Three-month follow up	Time	Group x Time	Group	Time	Group x Time	Group
Vegetable intake in meal in experimental setting (g)									
Single target vegetable	55 ± 69	53 ± 73							
Multiple target vegetable	33 ± 31	28 ± 25		0.04	0.26	0.58			
Control	49 ± 52	31 ± 43							
Usual vegetable intake (serves/day)									
Single target vegetable	0.7 ± 0.4		0.8 ± 0.5						
Multiple target vegetable	0.6 ± 0.3		1.2 ± 0.7				0.01	0.04	0.74
Control	0.8 ± 0.4		0.8 ± 0.3						
Vegetable intake from food records (g/day)									
Single target vegetable	55 ± 53	51 ± 48	64 ± 88						
Multiple target vegetable	44 ± 30	74 ± 63	70 ± 53	0.51	0.15	0.94	0.15	0.80	0.98
Control	64 ± 68	56 ± 51	62 ± 56						

Vegetable intake: usual vegetable intake

There was a significant increase (Table 6.3) in usual vegetable intake of the child from before to after the intervention ($F = 7.31$, $p = 0.01$), and the interaction between time and group was also significant ($F = 3.73$, $p = 0.04$). Posthoc tested showed that the multiple target intervention group increased their usual vegetable consumption significantly ($T = -2.91$, $p = 0.02$) from 0.6 to 1.2 serves, whereas no significant change was observed in the single target intervention group or in the control group.

Vegetable intake: three day food diary

Vegetable intake at baseline based on the food record data was 54g (SD 52g) per day across the three groups. Vegetable intake increased in the multiple target intervention group from 44g (SD 30g) pre-test to 74g (SD 63g) post-test, and did not change in the other two groups. Thus, these results were similar to the results observed for usual vegetable intake. However, due to the large variability in intake between individuals, evidenced by the large standard deviation, no statistically significant effects were observed (Table 6.3). Variety in the number of different vegetables consumed across the three days slightly increased in the multiple target intervention group at post-test, and decreased slightly in the other two groups, however the results were not statistically significant (data not shown).

Vegetable acceptance

Children's overall vegetable acceptance significantly increased at post-intervention compared to baseline, and this effect was independent of the treatment group (Table 6.4). A sustained increase in acceptance at three-month follow up was observed for the single target ($F = 20.97$, $p < 0.001$) and multiple target ($F = 4.13$, $p = 0.04$) intervention group, but not for the control group ($F = 0.47$, $p = 0.49$) (results obtained from post hoc testing following a significant time by group effect).

Vegetable exposure

Compared to baseline, there were no significant changes in number of serves or the number of different types of vegetables offered per week by the parent to the child at post-intervention or three-month follow up in any of the groups (Table 6.4).

Food neophobia

There was a small but significant decrease in food neophobia across all groups ($F = 5.41$, $p = 0.03$) at post-test, which just failed to sustain ($F = 3.11$, $p = 0.09$) at three-month follow up (Table 4). The group by time interaction was not significant. These results indicate that children were slightly more willing to taste novel foods after they had completed the two assessments, and regardless of whether participants took part in an intervention or not.

Table 6.4 Effect of intervention on secondary outcome measures acceptance, exposure and food neophobia (mean ± SD), comparing baseline, post-test and three-month follow up data.

Secondary measures	Time			*p* Value *(baseline-post test)*			*p* Value *(baseline-3 month follow up)*		
	Baseline	Post-test	Three-month follow up	Time	Group x Time	Group	Time	Group x Time	Group
Child's overall acceptance of vegetables (range from 1 to 9)									
Single target vegetable	4.4 ± 2.5	5.2 ± 2.3	5.2 ± 2.2						
Multiple target vegetable	4.1 ± 2.6	4.3 ± 2.7	4.6 ± 2.5	<0.0001	0.45	<0.0001	<0.0001	0.03	<0.0001
Control	4.2 ± 2.3	4.7 ± 2.3	4.3 ± 2.4						
Vegetable exposure (number of serves per week offered)									
Single target vegetable	17.9 ± 9.9	20.2 ± 7.7	21.2 ± 5.6						
Multiple target vegetable	19.0 ± 10.5	24.3 ± 12.4	20.9 ± 14.2	0.15	0.47	0.72	0.15	0.97	0.67
Control	22.4 ± 13.1	22.4 ± 12.7	25.1 ± 14.4						
Vegetable exposure (number of vegetables per week offered)									
Single target vegetable	14.7 ± 4.1	14.5 ± 2.8	15.7 ± 2.6						
Multiple target vegetable	12.8 ± 4.9	13.8 ± 5.1	13.7 ± 5.2	0.90	0.38	0.78	0.26	0.97	0.50
Control	14.4 ± 4.9	13.8 ± 4.5	14.3 ± 4.7						
Food Neophobia Score (range from 10-70)									
Single target vegetable	47 ± 7	46 ± 8	44 ± 7						
Multiple target vegetable	49 ± 11	46 ± 10	45 ± 11	0.03	0.93	0.51	0.09	0.47	0.97
Control	45 ± 11	42 ± 11	47 ± 11						

Development of acceptance of target vegetables during the intervention

Acceptance for the target vegetable in the single target intervention group significantly (F = 106.26, $p < 0.001$) increased with exposure. Post hoc testing showed that, compared to the first exposure day, acceptance was significantly higher on most occasions from the ninth exposure onwards (Fig. 6.2). In the multiple target exposure group, acceptance significantly increased with exposure across vegetables ($F = 2.65$, $p = 0.006$), with post hoc testing showing that, compared to the first exposure day, acceptance was consistently significantly higher from the fifth exposure onwards (Fig.6.3).

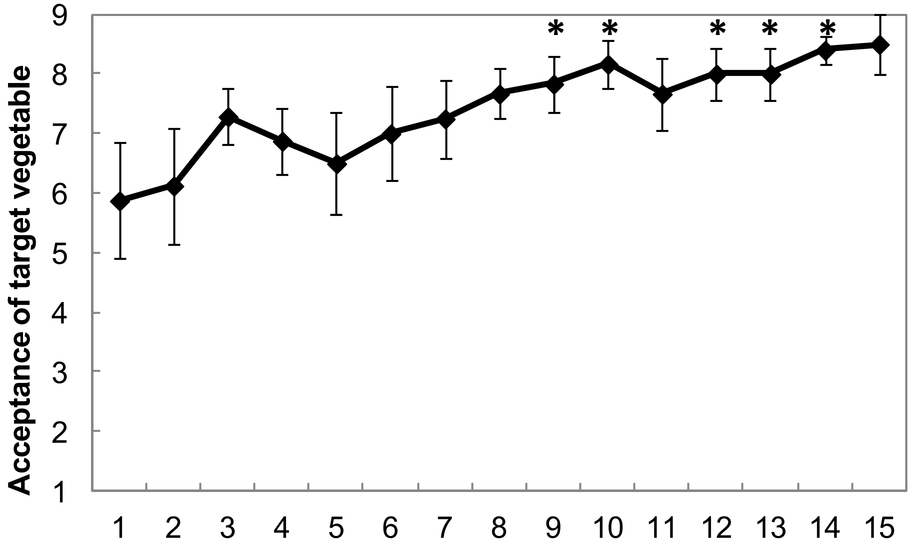

Figure 6.2 Development of mean acceptance of target vegetable of children in the single target intervention group (n = 11) as a function of exposure (an asterisk signifies a significant difference from baseline).

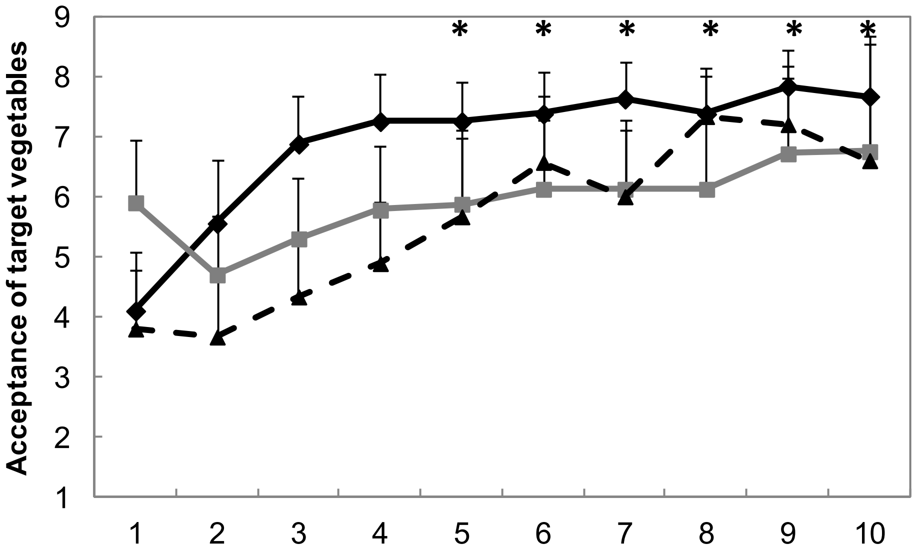

Figure 6.3 Development of mean acceptance of three target vegetables (black line = broccoli, dashed black line = zucchini, grey line = peas) of children in the multiple target intervention group (n = 10) as a function of exposures (an asterisk signifies a significant difference from baseline across vegetables).

Parent feedback on implementing the interventions

Parents found the interventions 'very easy' or 'quite easy' to implement. Only two parents in the single target, and one parent in the multiple target intervention group, found the intervention 'a bit difficult', and none of the parents reported that they found the intervention 'very difficult' to implement.

Discussion

This study compared the effectiveness of repeated exposure to a single target and to multiple target vegetables in a parent-led, home based intervention in increasing vegetable intake in 4-6 year old children. Exposure to multiple target vegetables was found to increase usual vegetable intake of children, whereas exposure to a single target vegetable was not.

Previous research in infants in relation to weaning strategies found positive effects of offering vegetable variety on vegetable intake. Offering variety in vegetables as within-meal variety increased intake more than exposure to a single vegetable (31), and variety increased vegetable intake beyond that of the tasted vegetable (30). Our study was the first to investigate exposure to multiple target vegetables with older children, and provides initial evidence that offering vegetable variety in a repeated exposure paradigm seems to benefit older children also.

The effectiveness of repeated exposure to increase vegetable intake in children at their peak of food neophobia has been well documented. However, so far studies have used a single target vegetables only, and effects on daily vegetable intake were not measured. In our study usual daily vegetable intake doubled from 0.6 to 1.2 serves for children that were repeatedly exposed to multiple target vegetables, whereas no such effects were found for children exposed to a single target vegetable or in the control group. Thus, offering variety as part of an exposure paradigm emerges as a promising strategy for low vegetable consuming children in their peak of food neophobia to contribute to substantial increases in vegetable intake.

The sample size of the current study was low, despite extensive recruitment efforts. Participant feedback showed that participation rates were limited as parents felt procedures were very time demanding. The time and labour intense nature of this study, together with financial constraints, meant that further recruitment was not achievable. Effect sizes for food record data from comparable studies were not available due to the novel nature of this study. Post hoc power calculations showed unfortunately power was compromised for food diary measurements due to large variability encountered in the data. With a significance level of $\alpha = 0.05$, a total of 66 participants would be needed to achieve a power of 0.80 (GPower 3.1.7). Thus, this study should be seen as a pilot, with results warranting validation in a subsequent study.

The mechanisms by which offering variety as part of an exposure strategy is more effective than a single vegetable in older children cannot be fully understood from our study. In infants the varied sensory stimulation from exposure to vegetables that differ in flavour and texture seems to promote acceptance of a wider range of sensory properties in vegetables [30,31]. Our acceptance results support that increased familiarity with wider range of vegetable sensory properties promoting acceptance is likely also affecting intake in our study group. However, other factors may also play a role.

A reduction in food neophobia was observed which contributes to acceptance of vegetables [15,42], although this effect was not specific to the multiple target intervention arm in our study. Our study did not find significant changes in the number of vegetables offered by the parent, and therefore it appears to be increased uptake by the child of what is offered to them, rather than an increased offering.

It is possible that exposure to multiple vegetables better demonstrate the principles of food preference development, and leads to attitudinal changes in the parent and/or the child which in turn affect behaviour [43,44]. With a single vegetable, acceptance may or may not increase; if it increases, it will do so at a certain pace. With multiple vegetables, development of acceptance may occur at different rates for different vegetables, providing both parents and children with more opportunities to experience the child's malleability of food preferences, and the variability therein. Increased awareness or belief in malleability of food preferences may in particular benefit acceptance of vegetables that initially show no or a slower increase in acceptance, as parents typically tend to stop offering foods that children dislike [16]. Our study provides some support for this hypothesis, since a significant increase in acceptance occurred quicker in the multiple than the single target intervention. Insight in changes in attitudes or cognitions related to food preference development will be useful to better understand the mechanisms by which repeated exposure paradigms are effective in older children. Exposure to multiple vegetables may also reduce boredom with the experimental design or the vegetable. Exposure to the same vegetable could become monotonous to the children, thereby having an opposing effect to mere exposure [14].

A transfer effect from tasted to non-tasted vegetables was observed in infants with offering variety [30]. We found a statistically significant increase in the multiple target intervention group in usual vegetable intake only, which does not provide insights in the specific vegetables consumed, and therefore cannot conclusively confirm this is also the case in our study group. However, it is clear from the diet record data that children in the multiple target group consumed a variety of vegetables, and increases in intake could not be ascribed to an exclusive increased intake of vegetables tasted as part of the exposure intervention.

Previous research has found that single target exposure was effective in increasing acceptance and intake of the target vegetable. Children in our single target intervention increased acceptance but not intake. Our measure of vegetable intake differed from those used in other studies, where typically intake was measured in a rather experimental situation. For example, children in Corsini et al's (2013) [19] study ranked 6 vegetables for liking, and ad lib consumption of the fourth ranked vegetable presented in a cup was measured. Our study included more ecologically valid measurements, e.g. actual diet record intake and a meal where vegetables were ‘competing’ with other meal components. As our single target intervention was the same intervention as used by Corsini et al (2013) [19], these results indicate that effects found under more experimental conditions may not necessarily extrapolate to actual behaviour.

We used two measures of vegetable intake related to daily intake: usual vegetable intake and weighed 3-day diet records. Although weighed food record results were not significant, due to large day to day variation as well as variation between individuals, they pointed in the same direction as usual vegetable intake, and thereby strengthen these findings. We did not find an intervention effect in the experimental meal. This meal provided an actual eating occasion without influence from parents. Children were eating by themselves in most cases, accompanied by a staff member, and this setting was unfamiliar to children. This situation may also have led to boredom with the eating event, diminishing their intake at post-test [14]. In future experiments it may be better to investigate a meal situation in which children would typically consume their dinner, by providing instructions to parents to provide a prescribed meal at home.

Several effects were observed across the three groups, i.e. an overall increase in vegetable acceptance as well as an overall decrease in food neophobia. Although the control group was not subjected to an intervention at home, children did take part in the pre- and post-test measurements, as a part of which they were exposed to vegetables in a meal. In addition, taking part in the study may have influenced parental interactions with their child, even in the control group, as their usual strategies to encourage their child to consume vegetables likely became more salient. Therefore, it seems that taking part in the experimental research procedures itself evoked some positive behaviour change. A similar finding has been observed by Reverdy et al (2010) [45], where children in a control group showed the same increase in acceptance of the food they were exposed to in pre- and post-interventions, as children in the intervention arm of the study.

Increased acceptance in the single target vegetable occurred after nine exposures, which is in line the mere exposure theory [46]. In the multiple target intervention, increased acceptance of the target vegetables was observed after five days. These results indicate that fewer exposures may be needed in multiple target interventions to change acceptance. Parents found the multiple target intervention easy to use, and compliance did not differ from the single target intervention. These results provide encouraging support to further develop and investigate this technique for implementation by parents.

A strength of the current study was the robust design, with pre- and post-test measurements as well as a follow up measurement, and the use of a control group. The use of measures of daily vegetable intake, including weighed food record data, was also a strength, but at the same time limited participation. Apart from the previously mentioned small sample size, a limitation in our study was the choice of vegetables. Children in the interventions were all exposed to the same one (single target intervention) or three (multiple target intervention) vegetables, which limits the generalizability of the findings. We had adopted this procedure to be able to investigate the effect on tasted and non-tasted vegetables in an experimental meal, which would have become logistically too difficult if different vegetables were used for each child. However, in future experiments the use of a range of vegetables would be recommended. It would also be relevant to further investigate the most suitable combinations of initial liking to offer the child for repeated exposure to increase acceptance; e.g. all initially neutral or slightly different from each other in initial liking (but not extremely liked or disliked). Lastly, it would be recommended to use a measure of daily vegetable intake with similar robustness and precision as the weighed food records, but which has a lower burden on the participants' time to facilitate recruitment and participation rates.

In conclusion, exposure to a variety in vegetables may offer benefits in increasing acceptance and intake of vegetables over single exposure techniques. Further research is warranted to confirm the effectiveness of offering variety in exposure, and to enhance understanding of the responsible mechanisms.

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Chapter 7

General discussion

This thesis focused on understanding and changing children's sensory acceptance for vegetables. It described how sensory properties of vegetables compared to those of other core food groups in diets of Australian children, how vegetable preparation affects children's acceptance of vegetables, what vegetable preparation practices are used by parents in the home environment, and how repeated exposure to multiple target vegetables compares to exposure to a single target vegetable in increasing acceptance and intake of vegetables. This chapter first presents the main findings of the studies. Subsequently, methodological considerations in relation to study design and execution are discussed. The key research findings are then portrayed in a broader context. In the last section, implications of the research are provided and suggestions for further research are made.

Main findings

The main findings of this study are summarised in Table 7.1.

The sensory properties of vegetables in terms of key flavour and texture attributes differed from those of other core foods (fruit, dairy, meat/fish and grains) typically consumed as part of Australian children's diets. Vegetables were more *bitter,* and amongst the *hardest.* At the same time they were low in *flavour intensity,* in *sweet, salty, sour* and *umami taste,* and in *fatty mouthfeel* (*Chapter 2*). Other core food groups had one or more sensory properties known to be drivers of liking: *sweet* and *sour* for fruit, *sweet, salty, sour* and *fatty* for dairy, *salty, umami* and *fatty* for meat/fish, and *salty* for grains. Vegetable was not high in any known drivers of liking, but was high in a known driver of dislike (*bitter taste*).

Sensory properties of vegetables changed as a result of preparation (*Chapters 3* and *4*) and influenced children's acceptance for vegetables (*Chapters 3, 4* and *5*). Vegetable liking was determined by a combination of vegetable type and preparation, and non-linear combinations of flavour and texture properties determined acceptance. Baking and stir frying led to high *odour intensity* and *browned flavours* compared with boiling, which were unacceptable to children in two of three vegetables tested. They did not impact on acceptance of a third, starchy, vegetable (*Chapter 3*). Steaming led to more intense flavour and taste properties than boiling in Brassica vegetables, but both preparation methods were equally accepted (*Chapter 4*). Cooking time also affected *Brassica* acceptance, and very short cooking times of 2-3 min were disliked (*Chapter 4*).

Table 7.1 Overview of the main findings, presented by chapter.

Ch	Research question	Main findings
2	How do vegetables differ from the other core foods (fruit, dairy, meat/fish and grains) in key flavour and texture properties?	Vegetables as a category were more *bitter* ($p < 0.001$) in *taste* than other core food groups, amongst the *hardest*. They were the lowest or amongst the lowest in *sweet*, *salty, sour* and *umami taste*, in *overall flavour intensity,* and in *fatty mouthfeel* (all $p < 0.001$). Fruit was high in *sweet* and *sour taste*, dairy was high in *sweet, sour* and *salty taste* and *fatty mouthfeel*, meat/fish was high in *salty* and *umami taste* and *fatty mouthfeel,* and grains were high in *salty taste*.
3	What is the effect of an unfamiliar colour on children's expected and actual acceptance of vegetables?	Unfamiliar colour (yellow beans, green cauliflower, white sweet potato) positively affected children expected preference ($p < 0.01$) but not acceptance upon tasting.
3	What is the effect of preparation method on sensory properties and children's acceptance across vegetables from different plant categories?	Preparation affected children's liking for cauliflower ($p < 0.001$) and green beans ($p < 0.003$), but not sweet potato ($p > 0.05$). Baking/stir frying was accepted less than boiling for beans and cauliflower. High *odour intensity* and presence of a *browned flavour* were negatively related to acceptance.
4	What is the effect of cooking method and cooking time on sensory properties and children's acceptance of two Brassica vegetables?	Boiling led to lower flavour and taste intensities than steaming ($p < 0.05$), but did not impact on children's acceptance for broccoli ($p = 0.94$) or cauliflower ($p =0.28$). Very short cooking times (2-3 min) were disliked. Acceptance was driven by a non-linear combination of flavour and texture properties. A medium *firm* and *cohesive* texture and balance of *green* and *cooked flavour* notes was liked the most.
5	What are the vegetable preparation practices used in the home environment of children?	Parents used an average of 6.8 (SD 3.4) preparations for vegetables at home, including in many mixed dishes. Number and type of preparations used was vegetable dependent Flavourings were added to 54% of vegetable dishes.
5	What is children's acceptance for vegetables prepared in different ways, and how is this related to intake?	Preparation was related to acceptance of 2 of 5 vegetables. The most and least liked preparations were vegetable specific. Boiling, steaming and use in mixed dishes were well accepted across all vegetable types. High acceptance was related to high intake across preparations for both low ($\rho = 0.70$, $p < 0.001$) and high ($\rho = 0.58$, $p < 0.001$) vegetable consumers.
6	What is the effect of exposure to multiple target vegetables versus a single target vegetable on children's acceptance and intake of vegetables?	Usual daily vegetable intake of children increased when repeatedly exposed to multiple target vegetables ($p = 0.02$), but not when repeatedly exposed to a single target vegetable. Acceptance of vegetables tasted increased in both the multiple target and the single target intervention group (both $p < 0.01$).

Acceptance in *Brassica* vegetables was related to a medium *firm* and *cohesive* texture, and a mix of *green* and *cooked flavour* notes (*Chapter 4*). Familiarity with the colour of a vegetable influenced children's willingness to try them. Measured by presenting vegetables in a typical and an atypical colour (e.g. green and yellow French beans), we found that children expected to like vegetables in an atypical colour more than typically coloured vegetables, however their acceptance upon tasting was the same (*Chapter 2*).

Parents used a wide range of preparation methods to prepare vegetables for their children in the home environment, and the number and type of preparations used differed between vegetable types (*Chapter 5*). Boiling, steaming and use in mixed dishes were preparation methods commonly used across all vegetables tested. These preparation methods were well accepted by children, with other preferred preparation methods varying per vegetable type (*Chapter 5*). Flavourings were frequently added when parents prepared vegetables as a side-dish in a meal (*Chapter 5*).

A pilot study on repeated exposure to multiple and single target vegetables showed that multiple target vegetable exposed increased children's usual daily intake of vegetables, whereas a single target vegetable did not. Weighed food records showed the same direction. Acceptance for target vegetables increased in both intervention groups (*Chapter 6*).
In conclusion, sensory properties of vegetables differed from those of other core foods, and were not aligned to innate preferences and preferences acquired very early in life. Preparation affected these sensory properties and influenced children's acceptance of vegetables. Very little commonalities across all vegetable types were found. Vegetable acceptance was also increased by repeated exposure to vegetables, and exposure to multiple target vegetables increased usual vegetable intake more than a single target vegetable.

Methodological considerations

The decisions on the design and execution of the study determine to a large degree the internal and external validity of the research results. These factors need to be taken into account when interpreting the results of this thesis. This section discusses what the methodological considerations were in relation to the study population, test environment, methods of data collection, experimental design and samples of the studies, and how these factors influenced results and interpretation of the data.

Study population

Participants

Our study group were children in the upper half of their peak of food neophobia, and included 5-6 (*Chapters 3* and *4*) or 4-6 (*Chapter 6*) year old children. This relatively narrow age range was selected for two reasons: 1) the peak time of neophobia is where refusals of vegetables are common, and parents often struggle to get their child to eat (enough) vegetables. As this induces stress and anxiety in parents, and often creates unpleasant social situations around meal times, there is a societal need to offer support to parents with children in this age group. 2) Peak food neophobia occurs between the ages of 2 and 6, and the upper range of this age group was selected to allow children to take part in the experimental taste tests with cognitive abilities and attention span to perform these tasks [1,2].

The selection of our age group means that our findings are relevant to the particular age group measured. However, the findings in our first study on preparation (*Chapter 3*) closely align to findings from Zeinstra et al (2010) [3] who collected data from 4-12 years. Thus, preparation findings may apply to a larger age range also. Repeated exposure has shown to be effective in infants, toddlers and primary school aged children. The positive effects of multi target compared to single target vegetable exposure were first reported in infants [4,5], and thus it seems likely that these findings are applicable to a large age range within childhood also.

Recruitment

Recruitment of participants was conducted through various sources, primarily advertising in local media distributed for free, schools, day care centres, nearby worksites, and other places in the proximity of the research facilities that parents may attend (shopping mall, sports grounds). This recruitment strategy prevented selection bias that may have occurred if only one source was targeted. However, participation was limited to those parents that live in the vicinity of the research facilities. The research facilities were based in North Ryde, Sydney, Australia. This area is a relatively advantaged area [6], and parents in our study were relatively highly educated. It needs to be investigated whether our results extrapolate to parents that are more disadvantaged and have lower educational levels.

Culture and environment have a large influence of eating behaviours, including the way foods are prepared. Australia shares with other Western countries that vegetable intake of children is well below recommended intakes [7-10]. Moreover, many preparation techniques are common across many cultures, e.g. boiling, steaming, in salads and in mixed dishes. There were also similarity in outcomes of one of our preparation studies with a Dutch cohort [3]. As an immigrant country, Australia as a country is culturally very diverse, and this applies in particular to its cities [11]. Children of different ethnicities and cultural background took part in our study, in particular from European and Asian descent. Familiarity was found to influence acceptance. Thus, findings may have a broader applicability to countries/ cultures that have similar familiarity levels with vegetables and preparations used.

Number of participants

The sample size in the experimental taste tests (*Chapters 3* and *4*) and parental study (*Chapter 5*) was adequate in the context of a consumer panel size, and drop-out was limited to 1-2 children per study due to illness or personal circumstances preventing the parent and child to participate on the scheduled test day.

The sample size in our multiple target intervention study was low despite considerable recruitment effort. Our small sample size was large enough to find statistically significant differences in usual vegetable intake and vegetable acceptance. However, the food record data directionally strongly supported daily usual food intake, but the large variability in these data meant that the study was underpowered to find a statistically significant finding for this outcome measure. Based on the effect size found, which was previously unknown to the novel nature of the study, a power analysis for a repeated measures ANOVA design consisting of 3 groups, and allowing for within-subject (pre/post-test comparisons) and between subject (group) comparisons, a power of 0.80 and alpha of 0.05, shows that a total of 66 participants would be needed (GPower v3.1.7, 2013). Research with a larger number of participants would be recommended to determine whether multiple target repeated exposure increases vegetable intake more than single target repeated exposure.

Test environment

The test environment can influence the outcomes of the study. All measurements were carried out at the research institute, whereas the intervention of the repeated exposure study (*Chapter 6*) took part in the home environment. The research institute was not a familiar environment for the children, such as a classroom or home. However, the sample preparation required tight control, which would not have been possible in the home or school. Several measures were taken to create an environment in which children were as comfortable as possible. Firstly, the parent was present at all times. Secondly, the child was assisted one-on-one by a research staff member who used child-friendly language. Thirdly, drawing and cartoon reading materials were available for children. These measures were effective in creating a comfortable environment, as children were visibly at ease during the procedures and took part in all assessments.

Taste testing took part in small groups. When multiple participants take part in a study, they can potentially influence each other. To minimise influence of peers and parents, children conducted assessments with no more than one other child present in the same room. Children were seated opposite each other, and low screens prevented children seeing each other's samples. Children did not know each other, and no interactions between them occurred during the testing. To avoid unintended bias from the parent, and to ensure consistency and objectivity in test procedures [1,2], children were assisted one-on-one by a staff member. A physical barrier was created from the parent by seating the parent at the other side of the staff member as the child. Parents were completing questionnaires and were instructed not to interact with their child during the assessment.

Time of day influences food acceptability [12]. Vegetables, and in particular cooked vegetables, are mostly consumed around dinner time in Australia [13]. To present an ecologically valid time, all tastings were conducted in the late afternoon (between 4 and 6pm) or actual meal time (between 5-7 pm) [13].

The meal offered as part of the intervention study (*Chapter 6*) was presented in the canteen. Although this environment is a typical meal environment, children were mostly eating alone in the presence of a staff member. We told children they could eat as much or as little as they wanted, as our aim was to measure ad lib consumption of vegetables without interference. We did not find any directional effect of the intervention on vegetable intake as part of the meal, and cannot discard that the different social context influenced the results. Therefore, it may be preferred for future research to use the home environment, and provide parents with specific instructions. The intervention took place in the home, which is a natural environment for children to consume vegetables. The home provides less control than a laboratory setting. To standardise the conditions as much as possible, and to minimise the influence of any bias, parents received detailed instructions on all procedures, including how to deal with refusals, and were asked to keep preparation form and time of day constant. They were also asked to complete the exposure in the absence of other siblings. Parents kept diaries which showed compliance was high. Distraction from siblings could not be checked, however, we assume such effects to be randomly distributed across groups, and therefore not bias results.

Methods of data collection

Different types of methods have been used to collect the perceptual, acceptance and intake data for the research. The question is whether or not the methodology was appropriate and valid, and this is discussed in the next section.

Consumer acceptance measures

Consumer acceptance measures for the child have been collected from either the child or the parent. In the experimental taste tests, data were collected from the 5-6 year old children itself. Facial hedonic scales were used, followed by ranking for preference as described by Birch [15]. There was ample evidence that these scales and tasks could reliably be used by children in this age group [1,2,14], which was confirmed by the findings in our study.

The child's acceptance for vegetables was rated by the parent in two studies. It has been well established that parents are capable of indicating their child's food acceptance [16,17]. Parents rated their child's acceptance using a validated nine-point hedonic scale with all anchors labelled developed by Peryam and Pilgrim (1957) [18]. The choice to collect parent data differed for the two studies. In the study on influence of preparation methods (*Chapter 5*) the size of the survey (14 preparations x 5 vegetables) as well as the task (based upon a verbal description of the sample rather than actual tasting) would go beyond the attention span and cognitive abilities of the child itself. In the multiple target study (*Chapter 6*) development of liking data were collected during the intervention from the parent, as we did not want the child to be consciously thinking about any change in hedonics during the intervention, to avoid any potential influence on the effectiveness the intervention [19]. Thus, the use of acceptance ratings by the parent was well justified.

Vegetable intake measures

Different measures of vegetable intake were used. A relative measure of consumption frequency was used in one preparation study (Chapter 5). This measure allowed the comparison of relative consumption frequencies of preparation methods across vegetables, regardless of absolute intake of the vegetable, which was the main purpose in this study. Direct and actual measures of vegetable intake were collected in the multiple target intervention study (*Chapter 6*). The collection of intake data through the robust method of weighed food record data [20] was a strength in our study. Food record data were recorded by parents for their child. Four-to-six year old children cannot reliably report their own food intake [21], in addition the cognitive effort involved in three days of weighing and recording their foods would be beyond their ability. They are also not used to preparing their own food, and mostly portion sizes are determined by their parent. Therefore, recording of food record data did not interfere with the child's normal routines and behaviour.

Sensory descriptive analysis

Sensory descriptive analysis was conducted to determine the sensory properties of the vegetables. Evaluations were conducted by highly trained assessors, who had been screened for sensory acuity upon employment, and who were all experienced in sensory descriptive analysis. Eight to 10 assessors participated in each profile, which is the number recommended for this type of research [22]. Assessment took part in a designated sensory laboratory that was designed in accordance with International Standards on Sensory Analysis (ISO 6658:1986). Data was determined by descriptive sensory analysis based on Quantitative Descriptive Analysis (*Chapters 3* and *4*) and the Spectrum methodology (*Chapter 2*), and assessors received appropriate training before assessments. Both methods are recognised methods for gathering perceptual data on product properties [23,24]. Data on sample discrimination as well as assessor agreement showed that good quality data were obtained.

The methods used have a high internal and external validity to describe sensory product properties, however the data rely on adult perceptions. Thus, an underlying assumption was made that adult perception of food properties could be used to relate to children's acceptance for food products. There is contradicting evidence about whether children's food perceptions differ from adult perceptions, with some studies finding they differ [25,26], and others finding they don't [27,28]. Since sensory descriptive analysis is a highly complex task that requires a considerable amount of training, such research cannot be conducted with children due their limited cognitive and attention skills [2]. And even if children's perceptions gradually change from childhood to adulthood, there will be considerable individual differences between children of the same age. Although we acknowledge that using adult perceptual data may not fully represent children's perceptions, at current we cannot offer a more suitable methodology that could be used to accurately determine the complex range of sensory properties we were measuring in our studies.

Experimental design

Within-subject designs were used in the experimental taste tests with children and in the parental survey (*Chapters 3*, *4* and *5*). These designs were strong as they control for the considerable inter-individual variation in food acceptance, and thereby are more sensitive than between-subject designs. Testing was carried out in a single session, thereby controlling the effect that confounding variables, such as outside temperatures, the child's previous activities or mood etc. may have on their evaluations.

A between-subject design was used in the intervention study (*Chapter 6*) to compare different intervention strategies and a control group. This design was selected because learning and/or carry over effects would likely have occurred using a within-subject cross-over design, which would have confounded the research outcomes. Moreover, the research procedures already required a high time commitment of the parent, and would impose an unreasonable time demand, limiting participation. Between-subject designs have as disadvantage that larger numbers are needed to attain statistical significance, and that participant characteristics could differ between groups. We assigned participants randomly to groups on the basis of processing consent forms, thus maximisation chances that any difference would be randomly distributed. However, we did find a difference in vegetable intake at baseline, likely because of the small sample size, which resulted in fewer possibilities to 'regress to the mean'. This weakness was lessened as each participant acted as their own control through the use of pre- and post-test measurements. We therefore consider the difference as random and not reducing the validity of our research results.

Samples

Vegetable samples were prepared for tasting in nearly all studies. The use of fresh prepared, hot served samples required careful planning to ensure consistency and uniformity in sample preparation and serving across all participants in the consumer evaluations, as well as to allow comparison between consumer and sensory data. To achieve consistency and uniformity, rigorous protocols for the sourcing, cutting, and cooking of vegetables were used. In particular, timing was critical. 'Reverse engineering' protocols were used, so that all samples served at the same time were ready at the same time. The high level of control and rigour meant that the required preparation conditions were strictly met in all studies.

In several of the experiments other food products were prepared and presented along with the vegetables. These foods were included to enhance the ecological validity of the results. In the experimental taste test that included typical and atypical varieties (*Chapter 3*) pasta provided a context to serve four samples simultaneously on a plate, whereas pasta and meat served together with vegetables meant a full meal was served to the participants (*Chapter 6)*.

The choice of vegetables for each of the studies determines the generalisability of the results. Very little experimental taste test data on children's acceptance of vegetables were available when this thesis was started. It was a strength of our research that we conducted two experiments with similar methods, one focusing on vegetables of very different plant categories (*Chapter 3*), and one focusing on vegetables of the same plant category (*Chapter 4*).

An across vegetable effect was not found for the preparation methods tested (*Chapter 3*) in case of vegetables from different groups. This was confirmed in our parental survey, which included more vegetables and more preparation methods (*Chapter 5*). These results imply that at current no conclusions about preferred preparation techniques across all vegetables can be drawn, rather that an interaction between vegetable type and preparation method determines sensory acceptance. These results suggest a vegetable by vegetable approach should be adopted. More research can elucidate whether there are systematic interactions between categories of vegetable types and preparation methods on sensory acceptance that currently remain hidden due to limited data available.

An experimental taste test specifically on *Brassica* vegetables (*Chapter 3*) showed a similar effect of cooking method (boiling vs steaming) across both vegetables in the study. There, these findings will likely have broader applicability to other *Brassica* vegetables with similar taste properties. They may also have broader applicability to other vegetable categories, since *Brassica* vegetables contain bitter tasting compounds, which are most associated with children's dislike. However, it will need to be investigated whether findings extend to vegetables with much higher bitter intensities than studied, e.g. witlof or Brussels sprouts.

Across vegetable effects were found for the role that atypicality of colour, indicating some generalisability of the findings. A caveat in this atypicality study is that the children were presented with three typically coloured vegetables and one atypically coloured vegetable, thus the atypically coloured vegetable was the “odd one out”. Whereas this choice was justified by the very low consumption of atypically coloured vegetables, we cannot exclude that the unbalanced design for colour typicality influenced the results, and further research using balanced designs would be needed to confirm findings.

A range of vegetables were selected in two studies (*Chapters 2* and *5*). Potato, being a vegetable in Australian nutrition guidelines, was included when the effect of preparation methods on acceptance was studied (*Chapter 5*), as we aimed to investigate the preparation effect on vegetables with different sensory properties to determine cross-vegetable effects. Therefore, inclusion of potato did not bias effects. However, it was excluded when determining the sensory properties of vegetables compared to the overall diet, to increase the representativeness of the results to the wider western population, where mostly potato is not considered a vegetable. The vegetables in the multiple target intervention study were the same for each child in each behavioural intervention group. They were chosen because they were common vegetables that children were neutral in acceptance towards, and were vegetables that parents would like their child to consume more of. This implies that a similar effect would be found in other countries when common vegetables would be used that children are neutral towards, and that parents would like their child to eat more of.

Key findings in a broader context

Sensory properties of vegetables in relation to food preference development

We were the first study to objectively compare the key flavour and texture properties of vegetables to those of a wide range of foods that together comprise the diet of children. Therefore, our data cannot be directly compared to those of others. Previous studies suggested that children’s dislike for vegetables was related to a lack of sweetness, high bitterness and high flavour intensity of vegetables [29-33], however no objective measures were taken to compare these properties in vegetables and other foods. By a formal comparison of a wide range of vegetables to other core food groups representative of children’s diets, we collected objective insights on these properties. Vegetables were indeed low in *sweetness* and higher in *bitterness* than any other core food group. However, we found *flavour intensity* of vegetables to be low, i.e. vegetables were quite bland in their flavour intensity overall.

Vegetable dishes consumed by French adults [34] were classified amongst food groups characterised by high salty, sour and bitter tastes. This study measured dishes as consumed, whereas our study measured separate foods. As we found vegetables to be high in *bitter taste*, but not *sour* or *salty taste*, the results suggest that French adults consumed vegetables mostly with savoury and salty sauces and dressings. This is supported by the fact that despite the different methodologies used, both studies found the predominant tastes in these diets to be the same, i.e. sweet and salty taste [34,35].

We found that vegetables were *harder* compared to the overall diet. There are no other studies to which our results can be compared. Hardness means food requires more mastication before they can be safely swallowed, and mastication effort is related to slower eating rate and lower intake [36-39].

We also found that vegetables were lower in *salty taste* and *fattiness*, for which a preference is acquired very early in life [40,41], and low in *sour* and *umami taste*. Together with the lower *sweetness* and higher *bitterness*, for which humans possess an innate like respectively dislike [42,43], our research objectively demonstrated that vegetables lack the sensory properties that appeal to the palate of young children. These results implicate that children either need to be learned to like vegetables, and/or that vegetable sensory properties need to be modified to create more desirable sensory properties.

Product modification strategies

When this research commenced, studies that investigated children's acceptance of vegetables in relation to preparation were scarce, and in particular experimental taste research was largely lacking.

Previous studies using focus groups and repertory-grid methods with children indicated a preference for raw over cooked vegetables [44-46]. We found that raw vegetables indeed were liked, but this finding related to certain vegetables only, and not across the whole vegetable category. The same conclusion was drawn by Donadini et al (2012) [47] based on an experimental test. Similar generic statements on sensory properties were made, which were not confirmed by actual tasting. These results highlight the need for actual taste tests to determine children's acceptance for sensory properties induced by preparation.

Previously it has been reported that appearance plays a large role in acceptance of fruit and vegetables [29] and other foods [48] amongst young children, and our research supports this finding. We were the first to investigate the role of colour atypicality. Previous research stated that children like brightly coloured vegetables and dislike green (leafy), yellow and purple vegetables [32,46]. Our findings offer a slightly different perspective. Children expected to like vegetables more when they had an unfamiliar colour, and this was independent of the actual colour, e.g. the atypical colour was green in case of cauliflower. Our finding that an atypical, unfamiliar colour increased willingness to try supports the previous reported notion that established flavour/colour associations in vegetables influence children's acceptance for vegetables [44].

Our research showed that preparation affected sensory properties of vegetables. A disliking for browned flavours and colours was found, and this is in agreement with other experimental taste studies [3,47]. Donadini [47] found that liking was positively related to sweetness and negatively to bitterness in vegetables. However, they did not discuss the degree to which this was related to vegetable type or to preparation method. Our research found that small differences in sweetness or bitterness caused by preparation did not impact on children's acceptance, which was in agreement with the study of Zeinstra [3]. Tough [47] and [3] granular texture were negatively related to children's acceptance for vegetables in other studies. We did not find specific disliked texture properties, rather that vegetable acceptance was determined by a non-linear combination of flavour and texture properties.

Our research found that vegetable liking was related to the vegetable type, preparation method and familiarity, which is in agreement with other experimental taste test research in children [3,47]. We found that the most and least liked preparations depended on the vegetable type. Zeinstra et al (2010) [3] did not observe a vegetable-specific effect using two distinct vegetables, however Donadoni's study [47], used six vegetables and agreed with our findings. Thus, vegetable specific effects may only become apparent when a larger number of vegetables are tested simultaneously. Although our research has extended the current body of knowledge, the finding that preparation affects acceptance largely in a vegetable specific way means that this research is far from complete.

We found that boiling, steaming and the use in mixed dishes were generally well accepted preparation methods across vegetables. Zeinstra's study [3] also found that boiling and steaming were well liked by children. The use in mixed dishes has not been systematically investigated using experimental taste test research, however several studies showed flavour masking through the use of salt or dips [49-51] to increase vegetable acceptance in children.
The many idiosyncratic ways in which preparation influences vegetable acceptance and texture and flavour properties demonstrate the potential for further experimental taste research. Further research would be needed to identify if larger trends across vegetable categories on preferred preparation methods can be identified.

Behavioural strategies to increase acceptance and intake

Several studies have investigated the effectiveness of repeated exposure, flavour-flavour learning (FFL) and flavour-nutrient learning (FNL) to increase vegetable intake in children, including through the European Union funded HabEat project. The overall conclusion that emerges from this research is that repeated exposure is effective in increasing intake of vegetables in children, and that FFL and FNL offer no benefits beyond those found through the repeated exposure effect [52-62]. Our study added to this knowledge by comparing two variants of a repeated exposure paradigm for its effectiveness to increase vegetable acceptance and intake. Previous research with infants showed that variety in exposure had benefits over a single target vegetable. In our study, exposure to multiple target vegetables was compared to a single target vegetable, and we found a similar beneficial effect for children in their peak of neophobia, increasing usual daily vegetable intake.

Several exposure studies measured vegetable acceptance [52,63,64] and found an increased acceptance with repeated exposure to a single target vegetable. Our finding is in line with those studies and, similarly, an increase in acceptance after exposure to a multiple target vegetable was found. In contrast, we did not find an effect on vegetable intake with repeated exposure to a single vegetable, whereas others reported positive effects on intake [52,63,64]. Our measures of vegetable intake differed from those studies, as they had measured intake of the vegetable as part of the acceptance rating procedures, whereas we used separate measures of intake of vegetables relating to daily intake and intake in a meal. These results indicate that vegetable intake in a more experimental setting cannot be directly translated to vegetable intake in actual eating situations.

The multiple target vegetable exposure studies in infants found a transfer effect from tasted to non-tasted vegetables [4,5]. Our research was inconclusive on this aspect. Although our food record data indicated that the vegetables consumed by children after the multiple target exposure were not solely the target vegetables, supporting a transfer effect, this measure failed to reach significance and therefore further research would be needed to confirm this hypothesis.

Implications and suggestions for further research

Children's acceptance for vegetables is a key barrier to their intake, which is strongly related to the sensory properties of vegetables [33,65-70]. Strategies are needed to increase children's acceptance and intake of vegetables, since children's intake of vegetables is low, and below recommended intakes for optimal health. These strategies will not only have direct benefits, but also longer terms effects, because sensory acceptance and dietary habits track from childhood into adulthood [71-73]. Two pathways are available to increase sensory acceptance of vegetables. The first strategy is to modify the sensory properties of vegetables to increase acceptance. The second strategy is to address the low vegetable acceptance directly, by the use of sensory learning strategies known to promote food preference development. Repeated exposure emerges as the most effective and simple sensory learning strategy to achieve increased vegetable acceptance and intake. The two different strategies, i.e. product modification and sensory learning strategies, should not be seen as completely independent form each other. Familiarity with preparation methods was found to influence acceptance for them, and this points to a mere exposure effect in itself.

Knowledge on vegetable preparations that are preferred by children can be used to encourage children to try vegetables they dislike. As children's acceptance by vegetables is influenced by preparation, parents can be recommended to try different preparation methods when a child shows clear dislike for the preparation form presented. As it becomes easier to learn to like new foods with increased variety in the diet [74], providing children with vegetables in forms that are most acceptable to them, can be a viable strategy to rapidly broaden the vegetable repertoire amongst children in their peak of food neophobia. Once resistance to eat a particular vegetable diminishes, other vegetable preparations can be offered, which will again broaden the child's dietary repertoire.

Continued experimental taste research using a vegetable by vegetable approach would be recommended. This research could provide insight in commonalities across preparation methods and vegetable categories that exist but have currently remained hidden because of the scarcity in research. Opportunities for cross-vegetable research exist for flavour-masking research and are currently underexplored. Flavour modification preparations that change the vegetable sensory properties, e.g. enhance or create sweetness and reduce or mask bitterness can be effective to overcome barriers based on innate likes and dislikes. The use of mixed dishes to achieve this effect has not yet been experimentally investigated and further research into this area is recommended. Salt and salt-and-fat containing dips have been shown as effective in increasing vegetable acceptance, likely due to their suppression of the bitter taste. The use of other tastants could be further explored. This could include sweetness, umami, but also sourness, as a proportion of children have a preference for intense sour tastes [75]. Further research would in particular be recommended to investigate flavourings of which use is not discouraged in public health messages.

Boiling and steaming were both well accepted by children in *Brassica* vegetables. Since steaming has health benefits over boiling, research to determine whether this finding extends to the wider vegetable category would be recommended, in which case this method could be widely promoted for children in public health messages.

The positive effect of repeated exposure to increase vegetable acceptance and intake in children has been well established. This strategy is simple to adopt by parents and should be further promoted in public health messages and by health professionals that provide individual advice to parents on their children's eating habits. The use of a small non-food reward promotes willingness to try the vegetable [52,76]. Exposure to multiple target vegetables seems a promising strategy to increase vegetable intake more than what can be achieved using single target vegetable exposure, and further research is needed in this area. Experiments should be designed that compare the effect on overall vegetable intake, but also investigate whether a transfer effect from tasted to non-tasted vegetables occurs.

Further research is recommended to determine the role that the initial combination of hedonic values has on the effectiveness of multiple target exposure. For example, would it be better to expose the child to vegetables that differ in initial liking, or would it better to expose them to vegetables they are all neutral towards? Initial hedonics obviously need to be considered within a reasonable range, i.e. it would be pointless to expose the child to only vegetables it already likes, and it may be too difficult to get a child to repeatedly try several vegetables it strongly dislikes. Our research showed that multiple target exposure was perceived as easy by parents to implement as single target exposure, so this strategy does not impose implementation barriers to parents.

It would also be recommended to further investigate the role that appearance and expectations play in children's acceptance for vegetables. Colour, but also other factors such as shape or size of vegetables, create expectations which influence children's willingness to try vegetables. The role of appearance of vegetables and the expectations they raise is largely unanswered territory at the moment. Atypically coloured vegetables offer some unique opportunities. As these vegetables are mostly very similar to their typically coloured counterparts in other appearance and in-mouth sensory properties, they allow understanding the role that expectations other than those created by sensory experiences affect children's acceptance and intake of vegetables.

Lastly, another potential area for research are the individual characteristics of children that determine the effectiveness of sensory learning strategies. Notwithstanding the fact that most of our food preferences are learned, genetic differences play a role in food preferences. A recent study [(77)] using a sample of 2686 young twins, found that genetic effects were more dominant than environmental effects in explaining differences in preferences for vegetables and other nutrient dense foods, such as fruit, meat and fish, whereas the opposite was the case for snacks, dairy and starches. There is some evidence that genetics play a role in vegetable acceptance. Bitter sensitivity, expressed through the gene TAS2R38, was negatively associated with intake of cruciferous vegetables in an adult Italian cohort [(78)], and Fisher et al (2012) [(50)] found that salt affected vegetable intake of a bitter vegetable in bitter sensitive children only. Research that combines (epi) genetic differences between children and the effectiveness of sensory learning strategies to increase vegetable acceptance will allow the development of individualised strategies. It would in particular be useful to determine if particular genetics impede beneficial effects of sensory learning strategies that are observed in general. If this would be the case, product modification strategies such as flavour masking may be more relevant for these children, and/or individualised exposure strategies (e.g. longer duration) may be needed.

The stakeholders to implement research outcomes to increase children's sensory acceptance of vegetables include government, public health organisations and professionals in direct contact with parents about nutritional advice. There may be opportunities for vegetable industry supply chain partners, e.g. in providing recipes for dishes for children. New technologies also allow opportunities to disseminate findings to parents directly, e.g. exposure advice could be brought to parents in the same way as online education courses or weight loss programs are offered.

Main conclusions

- The sensory properties of vegetables differed to those of other foods that comprise children's diets. Notably, they were more *bitter* than other core food groups*, hard*, low in *sweet, sour, salty* and *umami taste,* and low in *fatty mouthfeel*. These sensory properties means that vegetables do not appeal to innate likes and dislikes, or to preferences acquired early in life. In addition, they require considerable mastication effort limiting intake.
- To increase children's acceptance and intake, product modification strategies that change the sensory properties as well as behavioural intervention strategies that target acceptance of sensory properties can be applied.
- Preparation method and cooking time influenced children's acceptance of vegetables. Effects were largely vegetable specific, meaning that a vegetable by vegetable approach needs to be adopted to increase vegetable acceptance. Flavour masking strategies may have potential applicability across a wider range of vegetables. An unfamiliar colour increased willingness to try vegetables
- Parents already use many different preparation techniques to prepare vegetables for children, and these are largely vegetable specific
- Acceptance of sensory properties of vegetables was modified by repeated exposure. Exposure to multiple target vegetables seemed beneficial to repeated exposure to a single target vegetable to increase vegetable intake.

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Summary

Summary

Children's consumption of vegetables is well below recommendations in Australia and most other Western countries. As food choice by children is primarily driven by hedonics, changing children's sensory acceptance for vegetables is a viable way to promote their intake. The present thesis focused on strategies to increase sensory acceptance for vegetables that can be employed by parents in the home environment of the child. Preparation methods and unfamiliar colour (e.g. green cauliflower) were investigated as product modification strategies to change the sensory properties of vegetables to increases children's acceptance for them. In addition, two repeated exposure strategies were compared as a behavioural intervention strategy that aimed to develop children's acceptance for vegetables per se. The focus was on 4-6 year old children. These children are in their peak of food neophobia, and as a consequence refusals of vegetables and other foods are very common in this age group.

Chapter 2 compared the key flavour and texture properties of vegetables with those of other core food groups (fruit, dairy, meat/fish and grains). A trained sensory panel was used to obtain information on flavour intensity, five basic tastes as well as four texture attributes. The foods were part of a dataset of 377 foods that were selected on the basis of their high frequency of consumption using data from the 2007 Australian National Children's Nutrition and Physical Activity Survey, and as such are representative of the diets of Australian children. Vegetables differed from the other core food groups in sensory properties. They were more *bitter* in *taste,* and amongst the *hardest.* At the same time, they were (amongst the) lowest in *sweet, salty taste* and *umami taste,* in *flavour intensity*, and in *fatty mouthfeel*. Whereas the other core food groups had at least one sensory property known to be positive drivers of liking, this was not the case for vegetables, rather they were high in a known driver of dislike. This research demonstrated that sensory properties of vegetables are incompatible to human's innate likes and dislikes and those acquired within the first few months of life, and strategies are needed to increase children's acceptance for vegetables.

Chapters 3, 4 and *5* investigated preparation as factor to influence sensory properties and children's acceptance. *Chapter 3* used three vegetable types of different plant categories. Five-and-six year old children (n = 104) tasted and evaluated cauliflower, French beans and sweet potato prepared using different cooking methods and using typically or an atypically coloured vegetable (e.g. white and green cauliflower). A trained panel established sensory properties of the same samples. Preparation method affected acceptance of cauliflower and French beans, with baked/stir fried samples accepted less than boiled samples. A high *odour intensity* and the presence of a *browned flavour* lowered acceptance. Atypical colour increased willingness to taste vegetables, and did not impact on actual acceptance. In conclusion, preparation affected vegetable acceptance in a vegetable specific way.

The effect of preparation method was investigated in further detail with two vegetable types of the same vegetable category in *Chapter 4*. This study used broccoli and cauliflower as representatives of *Brassica* vegetables, and investigated the effect of two cooking methods and three cooking times. Steaming led to higher flavour and taste intensities than boiling,

including more intense *bitter taste*, but were both equally liked. Very short (<2 min) cooking times were disliked. Acceptance was determined by a non-linear combination of flavour and texture properties, with a *firm* and *cohesive texture* and a mix of *green* and *cooked flavour* notes leading to the highest acceptance. Children with low vegetable consumption had lower overall liking scores than children with high vegetable consumption, but the effect of cooking method and cooking time was the same regardless of the child's vegetable intake. *Chapter 5* then took a much wider angle, and compared children's reported acceptance and intake of five common vegetables in relation to 14 different preparation methods commonly used by parents in preparing vegetables for children. A parental survey (n = 82) was used to collect these data for their 5-6 year old children. This research showed that preparation affected children's acceptance for two of five vegetables measured (carrot and potato), and that most and least liked preparations were vegetable specific. Boiling, steaming as well as mixed dishes were preparation methods well liked by children across all vegetable types. Flavourings were added on average by 54% across vegetable types. Higher vegetable consumption was related to higher liking and exposure to more preparation methods.

The effectiveness of two variants of a sensory learning strategy to increases children's acceptance and intake of vegetables was then studied in *Chapter 6*. A randomised control design with pre-test, post-test and three-month follow up measurements compared: 1) repeated exposure over 15 occasions to a single target vegetable, 2) repeated exposures over the same duration to three target vegetables, and 3) a control group. Vegetable intake was measured in an experimental meal, through weighed food records as well as reported usual vegetable intake, and in addition vegetable acceptance data were collected from 32 4-6 year old children with low vegetable intake. This study showed an increase in vegetable acceptance amongst children in both intervention groups. Usual daily vegetable intake increased from 0.6 to 1.2 serves in the multiple target vegetable exposure group, whereas it did not change in the other two groups. Vegetable intake from food records showed directionally the same trends, but results were not statistically significant. In addition, an overall reduction in food neophobia was found directly after the intervention.

Chapter 7 presented the main findings of the studies, and discussed methodological considerations in relation to study design and execution. The key research findings were then portrayed in a broader context, and implications of the research as well suggestions for further research were provided.

In conclusion, the sensory properties of vegetables do not appeal to innate likes and dislikes, or to preferences acquired early in life. In addition, they require considerable mastication effort limiting intake. In order to increase acceptance, either sensory properties of vegetables need to be changed or children's acceptance for the sensory properties itself needs to be increased. Preparation affects sensory properties and acceptance of vegetables, but in a vegetable specific way, and non-linear combinations of flavour and texture intensities determine acceptance. Atypical colour increases willing to try vegetables. Repeated exposure

to vegetables as a sensory learning strategy increases acceptance, and exposure to multiple target vegetables increases usual daily vegetable intake more than exposure to a single vegetable.

Samenvatting

Samenvatting

Groente-inname van kinderen is lager dan aanbevolen in Australië en in de meeste andere Westerse landen. Omdat voedselkeuze van kinderen met name bepaald wordt door hedonische waardering, is het veranderen van de sensorische waardering voor groente een passende manier om inname te verhogen. Het huidige proefschift richtte zich op strategieën om de sensorische acceptatie van groenten door kinderen te vergroten die kunnen worden toegepast door ouders in de thuisomgeving. Bereidingsmethoden en een ongewone kleur (b.v. groene bloemkool) werden onderzocht als product modificatie strategieën om de sensorische eigenschappen van groenten te veranderen teneinde waardering van kinderen te vergroten. Voorts werden twee herhaalde blootstelling strategieën vergeleken as gedrags-interventie strategieën om de waardering voor groenten als zodanig te verhogen. De focus was op 4-6 jarige kinderen. Deze kinderen bevinden zich in een piek periode van voedselneofobie, en als gevolg hiervan is het weigeren van groenten en andere levensmiddelen zeer gebruikelijk in deze leeftijdsgroep.

Hoofdstuk 2 vergeleek de belangrijkste smaak en textuur eigenschappen van groenten met die van andere basis productgroepen (fruit, zuivel, vlees/vis en graanproducten). Een getraind sensorisch panel werd gebruikt om informatie te verzamelen over de smaak intensiteit, vijf basissmaken en vier textuur eigenschappen. Levensmiddelen waren onderdeel van een dataset van 377 producten geselecteerd op basis van hoge consumptie frequentie door kinderen, gebruikmakend van data van het 2007 Australische Nationale Kinderen Voedsel en Activiteiten Onderzoek, en zijn als zodanig representatief voor het eetpatroon van Australische kinderen.

Groenten verschilde van de andere basis productgroepen in sensorische eigenschappen. Ze waren *bitterder* van *smaak*, en één van de *hardste* productgroepen. Tegelijkertijd waren ze het laagste (of één van de laagste) in *zoete, zoute* en *umami smaak*, in *smaakintensiteit*, en in *vet mondgevoel*. Terwijl de andere basis productgroepen alle tenminste één sensorische eigenschap hadden waarvan bekend is dat ze positief bijdraagt aan waardering, was dit niet het geval voor groenten. Daarentegen waren groenten hoog in een eigenschap waarvan het bekend is dat ze negatief bijdraagt aan waardering. Dit onderzoek toonde aan dat de sensorische eigenschappen van groenten niet in overeenstemming zijn met de aangeboren smaakvoor- en afkeuren van mensen, en met de voorkeuren die aangeleerd worden in de eerste levensmaanden, en dat derhalve strategieën nodig zijn om acceptatie van kinderen voor groente te vergroten.

Hoofstukken 3, 4 en *5* onderzocht bereiding als factor om sensorische eigenschappen en waardering door kinderen te beinvloeden. Drie groenten van verschillende plant categorieën werden gebruikt in *hoofdstuk 3*. Vijf-en-zes jarige kinderen (n = 104) proefden en beoordeelden bloemkool, sperziebonen en zoete aardappel bereid volgens verschillende bereidingsmethoden, en waarbij een typisch en een a-typisch gekleurde variant (b.v. witte en groene bloemkool) werden gebruikt. Een getraind panel bepaalde de sensorische eigenschappen van dezelfde producten. Bereidingsmethode beïnvloedde de acceptatie van bloemkool en sperziebonen, waarbij roerbak/oven bereiding lager werd gewaardeerd dan koken. Een hoge *geurintensiteit* en de aanwezigheid van een *gebruinde smaak* verlaagden waardering. Een a-typische kleur verhoogde bereidheid tot proeven, en had geen invloed op de eigenlijke waardering. In conclusie, bereiding beïnvloedde waardering van groenten op een groente specifieke manier.

Het effect van bereidingsmethode werd in verder detail onderzocht met twee groentesoorten behorend tot dezelfde categorie in *Hoofdstuk 4*. In dit onderzoek werden broccoli en bloemkool as vertegenwoordigers van de *koolfamilie* gebruikt, en werd het effect van twee bereidingsmethoden en drie kooktijden onderzocht. Stomen leidde tot meer intense aroma's en smaken dan koken, waaronder een intensere *bittere smaak*, maar beide bereidingsmethoden werden gelijkelijk gewaardeerd. Zeer korte (<2 min) kooktijden werden niet gewaardeerd. Acceptatie werd bepaald door een non-lineaire combinatie van smaak- en textuureigenschappen, waarbij een *stevige* en *samenhangende* textuur en een combinatie van *groene* en *gekookte aroma's* leidde tot de hoogste waardering. Kinderen met een lage groente-inname gaven lagere acceptatie-scores dan kinderen met een hoge groente-inname, maar de invloed van bereidingwijze en kooktijd op acceptatie was niet gerelateerd aan de groente-inname van het kind.

In *Hoofdstuk 5* werd vervolgens een wijdere invalshoek gekozen, en werd gerapporteerde acceptatie en inname door kinderen van vijf veelgegeten groenten bestudeerd in relatie tot 14 bereidingsmethoden die vaak gebruikt worden door ouders in het bereiden van groente voor kinderen. Een survey onder ouders (n = 82) werd gebruikt om gegevens te verzamelen over hun 5-6 jarig kind. Dit onderzoek liet zien dat bereidingsmethode de waardering van kinderen beïnvloedde voor 2 van de 5 groenten (wortel en aardappel), en dat de meest en de minst gewaardeerde bereidingsmethoden specifiek waren. Koken, stomen en gemengde gerechten waren gewaardeerde bereidingsmethoden over alle groente-varianten heen. In 54% van de gevallen werden smaaktoevoegingen gebruikt. Hogere groente-inname was gerelateerd aan hogere waardering en aan blootstelling aan meer bereidingsmethoden.

De effectiviteit van twee varianten van een sensorische leerstrategie om waardering en inname van groenten door kinderen te vergroten werd vervolgens bestudeerd in *Hoofdstuk 6*. Een gerandomiseerde onderzoeksopzet met voormeting, directe nameting, en nameting na drie maanden werd gebruikt en vergeleek: 1) herhaalde blootstelling over 15 gelegenheden aan één enkele groente, 2) herhaalde blootstelling over 15 gelegenheden aan drie verschillende groenten, en 3) een controle groep. Groente-inname werd gemeten door middel van een experimentele maaltijd, gewogen voedseldagboekjes en gerapporteerde gewoonlijke dagelijkse groente-inname, en eveneens werden waarderings data verzameld van 32 4-6 jarige kinderen met een lage groente-inname. Dit onderzoek liet een stiiging in groentewaardering zien onder kinderen in beide interventiegroepen. Gewoonlijke, dagelijkse groente-inname steeg van 0.6 tot 1.2 porties in de groep blootgesteld aan meerdere groenten, terwijl geen verandering werd gezien in de andere twee groepen. Groente-inname in voedseldagboekjes liet dezelfde trend zien, maar resultaten waren niet statistisch significant. Tevens werd een algehele reductie in voedselneofobie gezien direct na de interventie.

Hoofdstuk 7 presenteerde de belangrijkste onderzoeksresultaten, en bediscussieerde methodologische beschouwingen gerelateerd aan onderzoeksopzet en uitvoering. De belangrijkste onderzoeksresultaten werden vervolgens in een bredere context geplaatst, en onderzoeksimplicaties evenals suggesties voor vervolgonderzoek gepresenteerd.

In conclusie, de sensorische eigenschappen van groenten appeleren niet aan de aangeboren smaak voor- en afkeuren, of aan preferenties die vroeg in het leven worden aangeleerd. Zij vereisen bovendien een behoorlijke kauwinspanning die de inname limiteert. Om acceptatie te vergroten, kunnen ofwel de sensorische eigenschappen van de groenten worden aangepast ofwel de algehele waardering van kinderen voor de sensorische eigenschappen van groenten. Bereiding beinvloedt de sensorische eigenschappen en acceptatie van groenten, maar in een groente-specifieke manier, en non-lineaire combinaties van smaak en textuureigenschappen bepalen acceptatie. Een a-typische kleur verhoogt de bereidheid tot proberen van groenten. Herhaalde blootstelling aan groenten als een sensorische leerstrategie verhoogt de acceptatie, en blootstelling aan meerdere groenten tegelijkertijd vergroot de dagelijkse groente-inname meer dan blootstelling aan één enkele groente.

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About the author

Curriculum Vitae

Astrid Agnes Maria Poelman was born on the 9th of January 1970, in Groningen, The Netherlands. She completed secondary school Atheneum at the RSG Kamerlingh Onnes in 1988. She then started a BSc Human Nutrition and Dietetics, with a specialization in Marketing, at the Hanzehogeschool in Groningen, which she completed in 1991. She continued her education at Wageningen University with the study 'Human Nutrition', specializing in Market Research and Consumer Behaviour, which she completed in 1994. As part of her MSc in Human Nutrition she completed a thesis, under supervision of Gerda Feunekes and Kees de Graaf, on the effect of family and peers on fat intake in adolescents.

Astrid then moved to Cotonou, Benin (West Africa) together with her partner where she worked for two years as an Assistant Project Coordinator for an American NGO, Population Services International. Her main responsibility lay in marketing and consumer research for an HIV/AIDS prevention program. Early 1997 they returned to the Netherlands, where she started working for FrieslandCoberco in Leeuwarden. As an international product manager for the infant milk formula division Friesland Nutrition, she acted as the interface between marketing and R&D.

In 1998 Astrid then took a position as a Consumer and Sensory Scientist at the Agrotechnological Research Institute, where she worked for 8 years in sensory and consumer science, mainly conducting commercial-in-confidence research for the food industry. In 2006 she moved with her family to Sydney, Australia, where she started working as a Sensory and Consumer Scientist at CSIRO (first known as Food Science Australia, later as the Division of Food and Nutrition), mostly leading and managing applied research. In 2011 she started a part time external PhD at Wageningen University. She became the Team Leader of the Sensory, Flavour and Consumer Science team in 2012, which is the role she currently fulfils.

List of publications

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- **Poelman AAM,** Delahunty CM (2010) Increasing children's acceptance for vegetables through modification of sensory properties. 34th Annual Scientific Meeting of Nutrition Society of Australia, 30 Nov - 3 Dec, Perth, Australia (poster presentation).
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- **Poelman AAM,** Delahunty CM, De Graaf, C (2012) Children's acceptance for Brassica vegetables is altered by relatively simple cooking manipulations. 5th European Conference on Sensory and Consumer Research, 9-12 September 2012, Bern, Switzerland (poster presentation).
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- **Poelman AAM**, Delahunty CM, and De Graaf C (2013) Culinary practices and exposure affect 5-6 year old children's vegetable liking and consumption. 7th New Zealand/Australia Sensory and Consumer Science Symposium, 19-20 Feb, Wellington, New Zealand (oral presentation).
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Overview of completed training activities

Description	Organiser and location	Year
Discipline specific activities		
34th Annual Scientific Meeting of Nutrition Society of Australia	Nutrition Society of Australia, Perth (AUS)	2010
Investigating Drivers of liking with Bayesian Networks	Australian Institute of Food Science and Technology, Sydney (AUS)	2012
5th European Conference on Sensory and Consumer Research	Elsevier, Bern (Switzerland)	2012
7th Annual New Zealand / Australia Sensory and Consumer Science Symposium	New Zealand Institute of Food Science & Technology, Wellington (New Zealand)	2013
Front-of-Pack labelling - the Healthstar rating system	Department of Health, Sydney (AUS)	2013
Frontiers in Nutritional Science: The Inaugural Symposium on Nutritional Metabolomics	ILSI and CSIRO, Sydney (AUS)	2013
53rd Meeting of the European Sensory Network	European Sensory Network, Stavanger (Norway)	2014
37th Annual Scientific Meeting of Nutrition Society of Australia	Nutrition Society of Australia, Brisbane (AUS)	2013
Hungry for change: increasing children's vegetable intake	Horticulture Australia Limited and CSIRO, Adelaide (AUS)	2014
39th Annual Meeting of the British Feeding and Drinking Group	Graduate School VLAG, Wageningen (NL)	2015
Understanding Asia for export success	Food Innovation Centre and CSIRO, Melbourne (AUS)	2015
55th Meeting of the European Sensory Network	European Sensory Network, Reykjavik (Iceland)	2015
Beyond nutrition - meal solutions for ageing populations	ILSI and CSIRO, Sydney (AUS)	2015
General courses and workshops		
New People Leader Program	CSIRO, Sydney (AUS)	2011-2012
Publishing with Impact	CSIRO Publishing, Sydney (AUS)	2012
Senior First Aid certification renewal	Red Cross/St Johns, Sydney (AUS)	2012, 2015
Advanced Resuscitation and Defibrillator	Red Cross/St Johns, Sydney (AUS)	2012-2015
Health Safety & Environment Leaders	CSIRO, Sydney (AUS)	2012
Intellectual Property Foundations	CSIRO, Sydney (AUS)	2014
Influencing and Persuasion	CSIRO, Sydney (AUS)	2014
Managing Mental Health at Work	CSIRO, Sydney (AUS)	2014
Writing Winning Scientific Proposals	CSIRO, Sydney (AUS)	2015

Optional courses and activities		
Writing of PhD research proposal	CSIRO, Sydney (AUS)	2011
Co-host/organise visit of PhD study tour to CSIRO Australia	CSIRO, Sydney (AUS)	2013
Biweekly team meetings	CSIRO, Sydney (AUS)	2011-2015
Research presentations	CSIRO, Sydney (AUS)	2011-2015

Colofon

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