Engaging disadvantaged mothers through mHealth to support infant feeding behaviours that promote healthy weight gain

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CERTIFICATE OF AUTHORSHIP/ORIGINALITY

I certify that the work in this thesis has not previously been submitted for a degree nor has it been submitted as part of requirements for a degree except as fully acknowledged within the text.

I also certify that the thesis has been written by me. Any help that I have received in my research work and the preparation of the thesis itself has been acknowledged. In addition, I certify that all information sources and literature used are indicated in the thesis.

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Abstract

Eating behaviours are learned from the beginning of life and it is these habits that are carried throughout the life stages, affecting weight gain. Parental feeding behaviours including early cessation of breast feeding, formula feeding, early introduction to solids and introduction to non-core foods are considered to be correlates of excess weight gain. Further, there are socio-economic disparities which coexist, where families from a lower socio-economic status (SES) are more likely to practise unhealthy feeding behaviours. It is essential to understand how to effectively encourage these parents to make healthier infant feeding decisions.

One emerging approach is to deliver health interventions through digital technologies also known as mobile health (mHealth). Interventions delivered through an mHealth approach have been shown to influence positive behaviour change in the management and prevention of chronic diseases. Yet there are very few studies which have developed mHealth interventions to support infant feeding. The research in which this thesis is embedded was designed to develop and test an mHealth intervention (the Growing healthy program) that delivers expert advice to mothers of young infants about healthy infant feeding behaviours.

This thesis includes a number of studies that were conducted to guide the development of the Growing healthy program and to evaluate the outcomes regarding participant engagement with the program and the uptake of healthy infant feeding behaviours. The Growing healthy program was a non-randomised quasi-experimental study delivered via a smartphone app and website providing advice and suggestions to guide infant feeding decisions for mothers. Firstly, a systematic analysis was conducted to explore the quality of infant feeding websites and apps that were available in 2014. The findings of this study highlighted the overall quality was poor and that apps and websites did not adhere to guidelines. In order for parents to receive trustworthy information, it is important that website and app developers merge user requirements with evidence-based content. The findings from this review of apps highlighted the lack of evidence based mHealth resources for parents and informed the development of the Growing healthy program.

The next study reported in this thesis is a qualitative study that was conducted with socioeconomically disadvantaged mothers of young infants. The purpose of the study was to explore mothers' interest in an mHealth program and features that would engage them to use a program. In addition, determinants associated with mothers' decision on timing of solid food introduction were also explored. The majority of the mothers, particularly primiparous mothers, expressed their interest in an mHealth program to provide infant feeding information. In this study we found that mothers' decisions with regards to solid introduction were mainly driven by their perception of their infants' readiness cues and several reported that they were provided with inconsistent advice on the infant feeding recommendations by health practitioners and from online information. The results informed the delivery and the content of the Growing healthy mHealth intervention.

The third study reported in this thesis describes the participation and engagement of the 225 participants who joined the Growing healthy app program including an analysis of the impact of the intervention on key outcomes; in particular the age at which solids were introduced. Both the participants' engagement level and the intervention's impact on timing of solid introduction were assessed by an Engagement Index which was developed by the candidate to suit the Growing healthy program. Participant engagement was higher amongst those who were primiparous, recruited through a health practitioner and who used both the app and accessed the weekly email. Conversely, participants who joined the program closer to three months of the infants' age, which resulted in less intervention time, were likely to have a lower engagement score. There was no significant association between the participants' engagement and the age they decided to introduce solids to their infant. The majority of the participants introduced solids when their infant was between four to five months of age.

Finally, a qualitative study with a subsample of 18 participants from the Growing healthy app program was conducted to explore their experience and the influence the program had on their decisions about the age of solid introduction. The participants' personal characteristics, the mode of delivery and the quality of the program all contributed to their engagement level. Participants who utilised the push notifications were more likely to access the app frequently and to have a higher engagement level,

while those who experienced technological issues had poor engagement with the app. With regards to the mothers' decisions on solid introduction, consistency in the advice participants were exposed to was the main driver of their decision. This influenced participants regardless of their engagement level with the app.

This thesis provides a unique contribution to the existing literature by reporting the findings of a feasibility study to support mothers with healthy infant feeding behaviours through an mHealth program. As well as being the first infant feeding program delivered through mHealth, it is also the first study to utilise an Engagement Index to measure participant engagement in an mHealth intervention. This work therefore provides valuable information to inform future trials regarding intervention components that enhance engagement among this demographic. The Engagement Index provides an effective method to analyse engagement that can be implemented and adapted to suit any mHealth intervention.

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In Loving Memory

Jeddo Mahmoud Taki

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List of Abbreviations

AAP	American Academy Pediatrics
ABA	Australian Breastfeeding Association
ALLS	Adult and Life Skills Survey
Apps	Applications
BCT	Behaviour Change Technique
BCW	Behaviour Change Wheel
BMI	Body Mass Index
CDC	Centre for Disease Control & Prevention
C_i	Click-Depth Index
CI	Confidence Interval
cm	Centimetre
COM-B	Capability, Opportunity, Motivation-Behaviour
DEECD	Department of Education and Early Childhood Development
EI	Engagement Index
EPOCH	Early Prevention of Obesity in CHildren
FAB	Food, Activity and Breastfeeding
F_i	Feedback Index
F-K	Flesch-Kincaid
HBM	Health Belief Model
HONcode	Health On Net Code of conduct
HRWEF	Health-Related Website Evaluation Form
I_i	Interaction Index
InFANT	Infant Feeding Activity & Nutrition Trial
IQR	Interquartile Range
IT	Information Technology
IOTF	International Obesity Task Force
kg	Kilogram
L_i	Loyalty Index
MARS	Mobile Application Rating Scale
MCH	Maternal and Child Health
mHealth	Mobile Health

m^2	Metre square
MRC	Medical Research Council
NHMRC	National Health Medical Research Council
NSW	New South Wales
OR	Odds Ratio
PHC	Primary Health Care
PIFI	Parent Infant Feeding Initiative
PN	Practice Nurses
QCSS	Quality Component Scoring System
R_i	Recency Index
RWG	Rapid Weight Gain
SAM	Suitability of Assessment Material
SEIFA	Socio-Economic Indexes for Areas
SCT	Social Cognitive Theory
SES	Socioeconomic Status
SD	Standard Deviation
SMOG	Simple Measure of Gobbledygook
SMS	Short Message Services
SPSS	Statistical Package for Social Sciences
TAFE	Technical and Further Education
TDF	Theoretical Domain Framework
TPB	Theory of Planned Behaviour
WHO	World Health Organization
WIC	Women, Infants, and Children

Chapter 1: Introduction

1.1 Introduction

Dietary intake is considered as one of the most important direct determinants of overweight and obesity (Crino et al. 2015; World Health Organization 2016). A growing body of evidence suggests that dietary intake is influenced by eating habits that are learned from the beginning of life and are carried on to adolescence and adulthood (Birch & Doub 2014; Paul et al. 2011). Specifically, infant feeding behaviours including early cessation of breastfeeding (Clayton et al. 2013), formula feeding (Gibbs & Forste 2014), early solid introduction (Huh et al. 2011; Wang et al. 2016) and consumption of non-core foods (Pearce & Langley-Evans 2013) have been associated with excess weight gain. However, there is still little research on understanding how to effectively promote the uptake of healthy infant feeding behaviours.

Infant feeding behaviours are driven by various factors including social and physical influences, knowledge and skills, and parents' beliefs about the infant's health consequences associated with those behaviours (Russell, Taki, Azadi, et al. 2016). However, intervention trials have rarely analysed and targeted these antecedents. In addition, very few studies have targeted infant feeding behaviours through using mobile health (mHealth) interventions. This thesis aims to address these research gaps, specifically focusing on the timing of solid introduction to infants.

1.2 Candidate contribution

Given this thesis is only focused on one intervention outcome (timing of solid introduction), other feeding behaviours will not be further described. Further, the thesis is nested in a larger intervention, the Growing healthy study. The candidate's contribution to the larger intervention is outlined in Table 1.1. The studies which make up chapters of this thesis are represented in italicised text.

Table 1.1 Candidate contribution and role in Growing healthy study and the relationship with thesis content.

Intervention development	• co-led a formative systematic review including screening and analysis of articles, writing up and editing parts of the publication (Russell, Taki, Laws, et al. 2016) (Appendix 2C); • led a systematic analysis on the quality and comprehensibility of infant feeding websites and apps (Taki et al. 2015) *(Chapter Three)* (Appendix 3B)*;* • co-led the preparation of a pre-intervention qualitative study with mothers including: developing the interview schedule and recruitment material; screening eligible participants; conducting 20 of the 30 interviews; coding and analysing the transcriptions; and contributing to writing the publication (Russell, Taki, Azadi, et al. 2016) *(Chapter Four)* (Appendix 4A)*;* • had primary responsibility for preparing focus groups with mothers including: developing interview schedule; conducting two of three focus groups; and analysing the findings which contributed to finalising the development of the app (Appendix 5C);
Intervention conduct	• contributed to the recruitment of participants, attended three clinics within NSW to send out letters for recruitment; • participated in general project administration over three years including undertaking tasks related to recruitment, developing recruitment material, liaising with external services, organizing team agenda and minutes, developing project materials, entering data and maintaining database; • managed the Growing healthy Facebook group which included developing the Facebook group protocol plan, posting and responding to the group which was co-supervised with other researchers; • participated in identification of technical issues and solutions related to the app during the course of the intervention;
Intervention analysis	• held primary responsibility for all aspects of the post-intervention qualitative study including conceptualization, ethics application, recruitment, development of interview schedule, conduct of all interviews, coding and analysis of interviews *(Chapters Four and Seven);* • participated in the development of quantitative surveys to measure participants' satisfaction with the mHealth program; • managed app data including programming, cleaning and analysis; and • developed an Engagement Index to measure participants' use of the app (Taki et al. 2017) *(Chapter Six)* (Appendix 6A).

The current literature on infant feeding behaviours is reviewed in Chapter Two, and shows that specifically with solid introduction, a majority of mothers in Australia introduce solids to their infants before the recommended age of around six months. Further, it reviews previous interventions, with a particular focus on mHealth interventions to improve infant feeding behaviours and parental correlates. Finally, factors associated with enhancing and measuring participant engagement in mHealth interventions are also reviewed.

Chapter Three describes an analysis of the quality and comprehensibility of infant feeding websites and apps. Details of the method and tools used to analyse the websites and apps are presented. Chapter Four then describes a qualitative study exploring the interest of mothers (of low educational attainment) in an mHealth intervention and also their behaviours associated with the timing of solid introduction.

Chapter Five describes a summary of the methodology of an intervention conducted in Australia, within which this thesis was nested. The Growing healthy app program was an mHealth intervention aiming to improve the uptake of healthy infant feeding behaviours that promote healthy weight gain. A summary of the studies conducted to aid with the development of the intervention, the content, recruitment process and data analysed are presented. In addition, a summary of the candidate's contribution in the Growing healthy app program is provided in section 5.3.

Chapter 6 presents an assessment of participant engagement with the Growing healthy app program and the intervention effect on the primary outcome, age of solid introduction. Participant engagement with the program is assessed using an Engagement Index tool, developed as part of this PhD research analysing participant behaviour with the app and their satisfaction with the program. It then analyses participant Engagement Index score in relation to the outcome timing of solid introduction to explore the association between the two behaviours. In addition, covariates measured in the intervention are also included in the analysis for the two behaviours.

The findings of a qualitative study, conducted to explore participants' experiences using the Growing healthy app program, are described in Chapter Seven. This study fills an existing gap in understanding the factors that impact on participant engagement such as app quality, mode of delivery and content. Further it identifies participant

characteristics that are associated with various levels of engagement. It further explores the impact that the program had on the mothers behaviour regarding the age at which they introduced solids to their infant. Finally, Chapter Eight provides an overview of those findings including the strengths and limitations of this thesis, the relevance and public health implications of the findings, and recommended directions for future research.

Chapter 2: Literature Review

2.1 Introduction

This chapter provides an overview of current knowledge of infant feeding behaviours associated with the development of obesity in young children and interventions targeting these behaviours that use an mHealth approach. The literature review includes:

I. Obesity in young children
II. Current infant feeding guidelines
III. Interventions targeting healthy infant feeding behaviours
IV. mHealth interventions
V. Strategies used to enhance participant engagement in mHealth interventions

This chapter closes with a description of a conceptual framework that has been developed for this thesis. It highlights the factors that have been found to influence participant engagement in mHealth interventions, which aimed to enhance the uptake of healthy behaviours (delaying solid introduction). Further, a summary on the implications of this literature (Section 2.8) and the objectives of this thesis (Section 2.9) are also described.

2.2 PART I - Obesity in young children

2.2.1 Prevalence of childhood obesity in Australia

Child overweight and obesity are a public health priority as the prevalence has steadily increased over the past three decades (Askie et al. 2010; National Health and Medical Research Council 2014). In Australia, a national survey conducted in 2011 to 2012 identified that 23% of children aged two to four were overweight or obese. When children of all ages were included (2-17 years) 18% were overweight with seven percent categorised as obese (Australian Bureau of Statistics 2013b). The high prevalence of overweight is concerning as excess weight tends to persist into adulthood (Baird et al. 2005; Durmuş et al. 2010) and excess weight negatively impacts on health and wellbeing throughout childhood (Lynch & Smith 2005; Wake et al. 2013).

Defining overweight and obesity in children

Overweight and obesity have been measured differently in various studies (De Onis & Lobstein 2010; De Onis 2006), and this has caused limitations with comparing studies. The two commonly used cut-offs are from The World Health Organization (WHO) and the Centre for Disease Control and Prevention (CDC). The WHO defined cut-off points for overweight and obesity in children as weight-for-height >2 and >3 Standard Deviations (SD) above the WHO growth standard median (De Onis 2006; World Health Organization 2017). For CDC children and adolescents with Body Mass Index (BMI) values ≥85th and <95th percentile of the growth chart are overweight and ≥95th percentile are categorised as obese (Fryar, Carroll & Ogden 2014).

Socioeconomic status & cultural differences

There are various demographic indicators that have been used in studies to define low socioeconomic status (SES) populations, including geographical area of socioeconomic disadvantage (Spargo & Mellis 2013), low parental education (Van Den Berg et al. 2013; Zarnowiecki et al. 2014), or low family income (Balistreri & Van Hook 2011). In Australia, infants from a low SES background and from Indigenous families have a higher prevalence of overweight and obesity (Hardy et al. 2011). One study found approximately one quarter (27%) of infants from a low SES background were overweight or obese in comparison to less than one fifth (19%) of infants from a high SES family (Department of Health Victoria 2014). Minority cultural groups including Middle Eastern and Asian cultures within the low SES Australian population are at greater risk of overweight and obesity (Hardy et al. 2013). Furthermore, a recent study of urban Indigenous infants found more than a third (36.9%) were overweight or obese at two years of age (Webster et al. 2013). It is therefore necessary to explore the reasons why children from disadvantaged backgrounds are at greater risk of becoming overweight.

2.2.2 Consequences of childhood overweight and obesity

Childhood overweight and obesity have short-term and long-term consequences associated with significant psychological, medical and social factors (Williams et al. 2013). Short-term consequences include impaired cardio-respiratory fitness, mobility

problems, pre-diabetes, obstructive sleep apnoea, high blood pressure and high cholesterol increasing the risk of cardiovascular disease and also psychological issues such as low self-esteem, discrimination and depression (Dixon 2010; Lobstein, Baur & Uauy 2004; Tsiros et al. 2011).

Long-term consequences include the increased likelihood of remaining overweight or obese throughout adolescent and adulthood (Kelsey et al. 2014; Lee 2009). An American longitudinal study with a sample of 1042 children identified that children who were overweight at 24, 36 or 54 months were more than five times as likely to be overweight at 12 years than those who were below the 85th percentile in early childhood (Nader et al. 2006). Further, a meta-analysis which included 15 large prospective cohort studies measured the association between obesity in childhood or adolescence and obesity in adulthood. Overall, 200,777 participants were followed up and identified that obese children and adolescents were approximately five times more likely to be obese in adulthood than those who were not obese (Simmonds et al. 2016). The severity of childhood obesity is also associated with consequences in adulthood including cardiovascular disease, type 2 diabetes and types of cancer (Baker, Olsen & Sørensen 2007; Kelsey et al. 2014; Maffeis et al. 2002). Due to the increased risk of consequences associated with childhood obesity, it is important to prevent the onset of obesity from early childhood.

2.2.3 Early life determinants of childhood obesity

The causes of childhood overweight and obesity are complex and multifaceted. They include the interaction of multiple social, biological, behavioural and environmental factors that adversely impact on energy imbalance (Katzmarzyk et al. 2013; Lytle 2009).

Rapid weight gain

One key risk factor associated with obesity in childhood and later in life is excess weight gain in the first year of life (or rapid weight gain: RWG) (Baird et al. 2005; Monteiro & Victora 2005; Ong & Loos 2006). Excess weight gain is defined as an abnormal acceleration of growth in early life (Goodell, Wakefield & Ferris 2009; Ong & Loos 2006; Webster et al. 2013). Clinical measurements to define RWG have varied

between an increase of >0.67 (Ong & Loos 2006) or ≥1 standard deviation (SD) (Stettler et al., 2003) in weight-for-age Z-score from birth to the age of four months using a statistical method (LMS; L= skewness; M= median; S= coefficient). In clinical practice, the LMS method is used to obtain normalised growth centile standards. The prevention of excess weight gain has been declared as a universal priority by the WHO and the International Obesity Taskforce (IOTF) (Kremers et al. 2008).

From the beginning of life, infants are highly dependent on their parents or caregivers, who have a major influence on a child's dietary and physical activity behaviours (De Lauzon-Guillain et al. 2012). Feeding during the first year of life involves a number of major dietary transitions commencing with exclusive milk feeding through introduction of solids and transition to family meals. The timing and success of these transitions impacts on physical development and long term eating habits (Birch & Doub 2014). Parental feeding practices, such as breastfeeding (Van Rossem et al. 2009), formula feeding (Kramer et al. 2004), timing and type of solid foods introduced (Huh et al. 2011; Wijlaars et al. 2011) or parental feeding attitudes such as parental pressure to eat, restrictive or coercive feeding have been linked with excessive weight gain in children (Burdette et al. 2006; Faith et al. 2004).

Modifiable parental feeding practices associated with rapid weight gain

Breastfeeding

In Australia, the rate of breastfeeding initiation is high (96%), although many mothers also cease breastfeeding their infants early with only 39% and 15% continuing to exclusively breastfeed for four and six months, respectively (Australian Institute of Health and Welfare 2010). Socioeconomic disparities with the initiation and continuation of breastfeeding have been identified, with women from lower SES backgrounds less likely to breastfeed (Silva et al. 2012).

Breastfeeding duration is linked with weight status among infants (Van Den Berg et al. 2013). In particular, excess weight gain in the first year of life is related to breastfeeding cessation, including infants who were not breastfed or were only breastfed for a short time (Baird et al. 2008; Griffiths et al. 2009; Van Den Berg et al. 2013). On the other hand, breastfeeding infants for a longer duration has been inversely associated with the reduction of excess weight gain by 20% to 50% (Owen et al. 2005; Wen et al. 2014).

Factors associated with early cessation of breastfeeding includes breastmilk supply, infant-related reasons, pain and discomfort felt by the mother and emotional reasons (Hauck et al. 2011). These factors commonly arise due to the lack of support for breastfeeding from healthcare professionals as well as family and friends (Hauck et al. 2011). Providing mothers with peer support up to at least four months to establish breastfeeding is important as it can contribute to the continuation of breastfeeding (McLeod, Campbell & Hesketh 2011).

Due to the nature of breastfeeding, mothers are unable to monitor the volume of milk consumed and are reliant upon their infants' hunger and satiety cues to determine whether their baby has 'had enough' (Brown & Lee 2012). This process encourages the infant to develop the skill to self-regulate intake (Bartok & Ventura 2009). Self-regulation is the infant's ability to identify hunger and satiety cues and eating according to their nutrient energy requirements (Li, Fein & Grummer-Strawn 2010).

Formula Feeding

In Australia, 40% of infants aged one month are receiving infant formula with the rate increasing to 55% at six months and about 80% at 12 months (Australian Institute of Health and Welfare 2010). Formula feeding is associated with excess weight gain in infants (Arenz et al. 2004; Owen et al. 2005). An Australian randomised controlled trial (RCT), NOURISH, targeted the promotion of positive early feeding practices and reported that formula feeding had a significant direct association with RWG compared with breastfeeding (OR= 1.72 [95% CI: 1.01–2.94], p= 0.047) (Mihrshahi et al. 2011). A Canadian cross-sectional study among 5,560 participants explored the relationship between breastfeeding duration, mixed feeding, and overweight and obesity in school children (Rossiter et al. 2015). The findings illustrated that children who were only formula fed or mixed fed for less than six months were more likely to be overweight or obese compared to their breastfed counterparts (OR 1.29, 95 % CI: 1.04–1.60 and OR 1.35, 95 % CI: 1.09–1.69, respectively) (Rossiter et al. 2015). Possible mechanisms related to increased obesity rates in formula-fed babies include disturbed energy self-regulation (Li, Fein & Grummer-Strawn 2010), higher protein content in formula (Koletzko et al. 2009), consuming bottle beyond weaning age (Bonuck, Huang & Fletcher 2010; Ciampa et al. 2010) and bottle consumption associated with bedtime (Gibbs & Forste 2014).

Further, formula feeding is also indirectly associated with early introduction of solids and poor quality of food such as commercial infant drinks and lower consumption of fruit and vegetables compared to breastfed infants (Hohman et al. 2017; Noble & Emmett 2006). A study conducted in the United States reported that infants who were formula-fed and introduced to solids before four months were six times more likely to be obese at three years of age than the infants who were introduced to solids after four months (Huh et al. 2011).

Mothers choose to formula feed for a number of reasons such as knowledge, attitudes or biological factors (Australian Institute of Health and Welfare 2010; Brown, Raynor & Lee 2011). A common belief is that formula milk contains the same nutritional benefits as breastmilk (Australian Institute of Health and Welfare 2010). Other common reasons are associated with breastfeeding problems such as sore nipples, engorgement, mastitis (Thulier & Mercer 2009), belief that they have insufficient breastmilk supply or that infant formula helps their baby sleep longer (Li, Fein & Grummer-Strawn 2008). In addition, formula feeding is often thought to be more convenient for mothers than to breastfeed, more conducive to others helping to feed the infant, and more convenient for the mother to return to work and routine (Brown, Raynor & Lee 2011).

Formula feeding practices are implicated in unhealthy weight gain; however, obesity risk may be avoided by increasing adherence to guidelines to promote feeding infants in response to hunger and satiety cues, as well as delayed introduction of solids.

Introduction of solids

The age of solid introduction is another modifiable behaviour that is associated with RWG in infants (Kim & Peterson 2008). In Australia, 35% of infants were introduced to solid foods by four months of age and the majority (92%) by the recommended age of six months (Australian Institute of Health and Welfare 2010). There is mixed evidence with regards to the association between timing of solid introduction and excess weight gain. A common finding among many studies is that solid introduction before four months of age increases the risk of being overweight as a child (Daniels, Mallan, Nicholson, et al. 2015; Pearce, Taylor & Langley-Evans 2013; Wang et al. 2016). The literature on timing of solid introduction and association with childhood obesity is further explored in Section 2.3.

Various factors associated with early solid introduction have been identified in a number of studies (Brown & Rowan 2016; Hamilton et al. 2012; Hamilton et al. 2011; Horodynski et al. 2007). An Australian study assessed the reasons associated with the decisions on the age of solid introduction among 375 first-time mothers (Hamilton et al. 2012). The factors which contributed to the prediction of introducing solids at six months included 'decreased risk of my baby developing a food allergy' (β= 0.16, p= 0.016), support from 'partner/spouse' (β= 0.25, p= 0.04), 'doctor' (β= 0.46, p= 0.005) and also the availability of commercial foods (β= -0.21, p= 0.004) aimed at infants younger than six months (Hamilton et al. 2012). Another quantitative study conducted in the United Kingdom among 756 mothers, identified common reasons associated with early solid introduction (<16 weeks) included perceptions that their infants needed more than milk can offer and that their infants showed signs of readiness (Brown & Rowan 2016).

Parental feeding associated with excess weight gain

Parental feeding behaviours are major influencers in shaping infants' health and eating habits from a young age (Stifter et al. 2011) including parental feeding styles (Wardle et al. 2002), parental beliefs (Stifter et al. 2011) and parental knowledge (McLeod, Campbell & Hesketh 2011).

Feeding styles

Parental control (restrictions, monitoring and pressure to eat) (Askie et al. 2010; Brown & Lee 2011) hinders infants' ability to self-regulate fullness and hunger cues (DiSantis, Hodges & Fisher 2013). For instance, a prospective cohort study, Project Viva, measured maternal restriction of their child's food intake and pressuring their child to eat more (Taveras et al. 2004). Mothers who breastfed for longer or those who exclusively breastfed compared to those who exclusively formula fed at six months were less likely to restrict their children's food intake at one year of age (Odds Ratio: OR= 0.27; [95% CI: 0.10–0.72]) (Taveras et al. 2004).

In contrast, studies have illustrated that mothers who bottle feed their infant are more likely to develop a "controlling" parenting style (DiSantis et al. 2011; Li, Fein & Grummer-Strawn 2010). Authors suggest this is because parents who bottle feed constantly monitor the amount of infant formula consumed and encourage their infant to

finish their bottle, impacting on self-regulation (Li, Fein & Grummer-Strawn 2008). Similarly, indulgent parenting involves high responsiveness and less demand on the infant which has also been associated with the consumption of less nutrient dense food and a higher BMI in infants (Hoerr et al. 2009; Hughes et al. 2005; Hughes et al. 2008).

The authoritative parental style is a balanced approach in terms of responsiveness to infants' cues and is related to healthier eating habits and lower BMI in infants and older children (Hughes et al. 2005; Rhee et al. 2006). The Healthy Beginnings Trial, an Australian cross-sectional study with first-time mothers, assessed maternal responsiveness with infants two years of age and the type of food consumed (fruits, vegetables, soft drinks and snacks) (Xu et al. 2013). Children were reported to consume two serves of vegetables per day with mothers of higher levels of global parental self-efficacy and self-efficacy for an infant with OR 2.40 (95% Confidence Interval (CI): 1.35–4.27, p= 0.003) and OR 1.88 (95% CI: 1.06–3.36, p= 0.03), respectively. Similarly, mothers that had higher parental warmth were also more likely to report their children consuming two serves of vegetables per day with OR 1.85 (95% CI: 1.06–3.25, p= 0.03) (Xu et al. 2013).

Parental beliefs

Parental perception and belief about their infants' weight status, growth and feeding patterns are major contributors to unhealthy weight gain (Redsell et al. 2010). One study identified that parents share similar beliefs regarding infant weight and perceptions on milk feeding practices (Redsell et al. 2010). For instance, some perceptions include supplementing infants' diet with formula milk due to parental belief of inadequate breastmilk supply or in order to encourage longer sleep duration. Further, many of the unhealthy behaviours are driven by anxiety around adequacy of growth and perceptions that heavier children were healthier (Redsell et al. 2010).

Parental knowledge

Knowledge is a predictor of infant feeding practices, including breastfeeding as well as the timing and type of solid food introduced, and may therefore be a potential target for enhancing healthy weight-related behaviours (Dungy et al. 2008; Newby et al. 2014; Redsell et al. 2010). An Australian study, the Melbourne Infant Feeding Activity and Nutrition Trial (InFANT), found that, post intervention, mothers who reported higher

feeding knowledge and lower use of foods as a reward received a positive intervention effect on the quality of the child's diet (Spence et al. 2014). Another study measured the impact that exposure to breastfeeding information and maternal knowledge has on breastfeeding outcomes in early infancy (Kornides & Kitsantas 2013). The authors identified that mothers with greater knowledge about breastfeeding benefits were 11.2 (95% CI: 6.87–18.45) times more likely to initiate breastfeeding and 5.62 (95% CI: 4.19–7.54) times more likely to continue breastfeeding at two months than those with lower levels of knowledge (Kornides & Kitsantas 2013). Further, a study assessed parents' understanding of the Infant Feeding Guidelines in the United Kingdom and their decision about the age of solid introduction (Moore, Milligan & Goff 2014). Greater parental knowledge of the guidelines was directly associated with later introduction of solids ($p < 0.001$), although 80% of mothers introduced before 24 weeks and 65% introduced before 17 weeks rather than the recommended 26 weeks despite their knowledge (Moore, Milligan & Goff 2014).

2.3 PART II – Current infant feeding guidelines

2.3.1 Infant feeding guidelines

The WHO (World Health Organization 2011) and the Australian Infant Feeding Guidelines (National Health and Medical Research Council 2012) recommend exclusive breastfeeding until around six months of age and then the introduction of solids, with breastfeeding (or formula feeding) continuing up to 12 months or beyond. These recommendations are evidence based and aim to provide infants with optimal nutrition and health, with many health benefits to the mother (National Health and Medical Research Council 2012). Exclusive breastfeeding reduces the risk of several conditions including respiratory illnesses (Ip Chung et al. 2007), bowel disease (Akobeng et al. 2006; Barclay et al. 2009), diabetes (American Diabetes Association 2002; Eriksson et al. 2003; Knip et al. 2010), allergies and asthma (Australian Institute of Health and Welfare 2002; Prescott & Tang 2005), leukaemia (Ip Chung et al. 2007) and childhood obesity (Horta et al. 2010; Monasta et al. 2010). For mothers, it reduces the risk of postpartum haemorrhage (Chan et al. 2001; Hiller, Griffith & Jenner 2002; Sobhy & Mohamed 2003), breast and ovarian cancer (Ip Chung et al. 2007).

It is broadly agreed that the composition of breastmilk or infant formula can provide all the nutrition a baby needs for the first six months of life (Kramer & Kakuma 2001; National Health and Medical Research Council 2012). Breastmilk provides the newborn infant with sufficient energy and nutrients for growth and development and to help mature their cognitive (Kramer et al. 2008) and psychomotor (Horta et al. 2010) development and physiological systems including digestive, neural, renal, vascular, hepatic and immune systems (Lawrence & Lawrence 2010). However, by around six months of age breastmilk (or infant formula) becomes insufficient as the sole nutritional source to fulfil the infants' energy needs for growth and development, although it should still remain as the major source between six and 12 months (National Health and Medical Research Council 2012). Hence, the introduction of solid foods is necessary to meet the infants' increasing nutritional requirements (National Health and Medical Research Council 2012).

Introduction to solids

While there have been many studies and reviews regarding factors that influence mothers' decisions about exclusive and complementary breastfeeding, exploration of that literature is beyond the scope of this review. This thesis focuses on factors associated with mothers' decisions on the age they introduce solids to their infant and explores how to encourage mothers to delay solid introduction. There has been increasing interest in the transition from milk feeding to solid feeding as an intervention point to encourage appropriate feeding practices that promote healthy rather than excess weight gain.

The process of introduction of solids has also been referred to as weaning or complementary feeding. The WHO has defined complementary feeding as 'The period during which other foods or liquids are provided along with breastmilk…any other nutrient-containing foods or liquids other than breastmilk given to young children during the period of complementary feeding are defined as complementary foods' (Organization 1998). In this thesis, the term solid introduction will be used to provide more clarity as the introduction to solid foods is the main focus rather than introduction to other liquids such as formula milk.

2.3.2 The importance of the timing of solids introduction to infants' health

The age at which solids are introduced to infants is an important milestone and a sensitive period influencing infants' health (Qasem, Fenton & Friel 2015). For instance, introducing solids to the infant too early may lead to increased risk of chronic disease such as islet autoimmunity (the preclinical condition leading to type 1 diabetes), obesity, celiac disease and eczema (Filipiak et al. 2007; Nwaru & Virtanen 2017). In addition, early solid introduction may also lead to nutrient deficiencies. For instance, one nutrient that is commonly raised as a concern is sufficient consumption of iron. Until around four to six months of age, sufficient iron stores are obtained from either breast or formula milk (Lozoff et al. 2006; Qasem, Fenton & Friel 2015). After this age, it is recommended that infants are fed iron-rich solid food to sustain their stores as it becomes depleted due to their rapid growth (National Health and Medical Research Council 2012, 2016).

However, introducing solids too late has been associated with increased risk of feeding difficulties (Hollis et al. 2016), food allergies (Du Toit et al. 2008; Ierodiakonou et al. 2016) and nutrient deficiencies such as iron, zinc, protein and vitamins B and D which might lead to faltering growth (Butte, Lopez-Alarcon & Garza 2002; Qasem, Fenton & Friel 2015). The introduction of solids to the infant is therefore deemed successful if their nutritional requirements for optimal growth are met (Lanigan et al. 2001).

Recommendations for the timing of solid introduction

The recommendation for introducing solid foods to infants has changed since the 20th century and still generates debate amongst health professionals (Kleinman & Coletta 2016; Party 2016). Research as early as the 1900s identified that solid foods were seldom offered before one year of age as it was believed this practice would harm the child (Fomon 2001). A number of studies were conducted describing the importance of infant nutrient intake; longitudinal studies conducted at the University of Iowa focused on infant nutrition and metabolism (University of Iowa Carver College of Medicine). It was not until 1958, however, that the first report on recommendation for solid introduction was released by the American Academy of Pediatrics (AAP) Committee on Nutrition (American Academy of Pediatrics 1958). The report stated that an indication to determine readiness of solid introduction was based on infant developmental maturity

of the gut and neuromuscular system, growth rate and activity level. To date the seven editions of the AAP Nutrition Handbook have consistently utilised an evidence-based model concerning age of solid introduction which still refers to these readiness principles (American Academy of Pediatrics Committee on Nutrition 1979, 1985, 1993, 1998, 2004, 2009, 2014; Barness et al. 1980; Hill et al. 1958).

Similar to the AAP, the WHO and the National Health and Medical Research Council (NHMRC) of Australia emphasise the importance of identifying an infant's developmental behaviours of readiness as indicators to commence feeding solids (National Health and Medical Research Council 2012; World Health Organization 2011). Infant developmental behaviours include: has good neck control and can sit upright with support, shows an interest in food, reaches out for food and opens their mouth when food is offered to them on a spoon (Anderson, Malley & Snell 2009; Fewtrell et al. 2017; National Health and Medical Research Council 2012). However, there is some evidence that behaviours such as the baby watching their parents eat and not sleeping through the night are often misinterpreted as readiness to commence solids (Australian Institute of Health and Welfare 2010; Pearce, Taylor & Langley-Evans 2013).

In recent years both the WHO and NHMRC have changed their recommendations for solid introduction. The latest changes occurred in May 2016, and involved agreement amongst government and industry bodies within Australia to change the NHMRC recommendations on the age of solid introduction in the Australian Infant Feeding guidelines. The latest recommendations include the following: 'when your infant is ready, at around six months, but not before four months, start to introduce a variety of solid foods, starting with iron rich foods, while continuing breastfeeding' (Australasian Society of Clinical Immunology and Allergy 2016). Further changes were also made regarding the type of first foods that should be introduced including 'all infants should be given allergenic solid foods including peanut butter, cooked egg, dairy and wheat products in the first year of life. This includes infants at high risk of allergy. The emerging evidence (Australasian Society of Clinical Immunology and Allergy 2016; Du Toit et al. 2008; Ierodiakonou et al. 2016; Koplin et al. 2010; Prescott et al. 2008) identified that there is benefit in introducing solids after 17 weeks but before 26 weeks and introducing high allergenic foods to potentially reduce the risk of developing early

onset allergic diseases such as some food allergies and eczema. Majority of these studies however, included infants at high risk of allergy. Despite the ongoing debate on age of solid introduction, it has been argued that the growth of every individual varies considerably, even within specific groups. This emphasises that the appropriate point of solid introduction for any one infant may be inappropriate for another (Lanigan, 2001).

2.3.3 The current statistics on the age of solids introduction

A national study, the 2010 Australian National Infant Feeding Survey, showed that less than 1% of parents reported introducing solid foods to infants aged one month (4.3 weeks), while 35% of infants received solids aged four months (17.3 weeks) and 92% of infants aged six months (26 weeks). The median age was 4.7 months (Australian Institute of Health and Welfare 2010). Several maternal characteristics were associated with the timing of solids. For instance, mothers who were younger (<24 years), were of lower educated background and those who were obese introduced solids earlier than their counterparts (Australian Institute of Health and Welfare 2010). A more recent study among 1470 mother-infant dyads between 2008 and 2009 identified similar findings (Magarey et al. 2016). Self-reported questionnaires at birth, four, seven and 13 months of age reported that by four months 33.3% of infants received solids. This was particularly found among infants of younger and/or less educated women (Magarey et al. 2016).

Conversely, an Australian longitudinal study, the VicGeneration study (De Silva-Sanigorski et al. 2010), involved 464 mother-infant dyads recruited from disadvantaged communities and identified different findings (Amezdroz et al. 2015). The mean age of solid introduction was 5.2 months (22.5 weeks); almost 20% started solids before 16 weeks and 10% did not commence until after 32 weeks. Although participants were recruited from disadvantaged communities, there was no reported analysis on the socio-demographic variation between groups in the age of solid introduction. Previous studies (Australian Institute of Health and Welfare 2010; Magarey et al. 2016) have identified that variations exist across socio-demographic groups which suggests earlier introduction of solids is more likely among less educated parents.

2.3.4 Timing of solid introduction and association with obesity [1]

In recent years, the body of literature on predictors of obesity in early childhood has increased considerably. Specifically, the association between the age at which solids are introduced and child weight has been the subject of several reviews (Barrera et al. 2016; Daniels, Mallan, Fildes, et al. 2015; Moorcroft, Marshall & McCormick 2011; Pearce, Taylor & Langley-Evans 2013; Poskitt & Cole 1978; Sun et al. 2016; Wang et al. 2016)

Although several reviews have explored the association between timing of solid introduction and child weight, there were slight variations in the aims and selection criteria. Characteristics of these reviews are summarised in Table 2.1. One recent review (Daniels, Mallan, Fildes, et al. 2015) specifically focused on the timing of solid introduction and obesity risk in children >12 months in developed countries, which is consistent with the focus of this thesis. An update of this review was conducted by the candidate utilising the same search terms, databases and exclusion criteria as the original review (see Appendix 2D). Six eligible studies (Barrera et al. 2016; Giles et al. 2015; Klag et al. 2015; Moss & Yeaton 2014; Sun et al. 2016; Wen et al. 2014) were retrieved that had been published from 2013 to 2016. Results are presented in Table 2.2.

Summary and limitations of reviews

Overall 61 separate studies were included in the four comprehensive reviews (Daniels, Mallan, Fildes, et al. 2015; Moorcroft, Marshall & McCormick 2011; Pearce, Taylor & Langley-Evans 2013; Wang et al. 2016) presented in Table 2.1 and the update of the Daniels review (Daniels, Mallan, Fildes, et al. 2015) in Table 2.2. Of these, 57 used a cohort study design. In total, 31 studies found an association between timing of solid introduction and some measure of child weight (BMI z-score, skinfold or weight status). Findings regarding the relationship between solids and child weight are mixed and the studies summarised by reviews demonstrated several limitations.

Each of the reviews had different inclusion criteria which impacted on the heterogeneity of the findings in each review and resulted in limitations in conclusions about the association between the two variables, timing of solids and child weight status. For instance, one review (Pearce & Langley-Evans 2013) included studies from both

[1] Parts of this section have been published in BioMed Central Public Health 2016, 16:151 (Appendix 2C)

developing and developed countries. The other reviews included studies that varied in design, categories used for timing of solid introduction, the age at which participants were followed up and outcome measurements for child weight status (Daniels, Mallan, Fildes, et al. 2015; Moorcroft, Marshall & McCormick 2011; Pearce & Langley-Evans 2013). Measuring the causes of obesity is complex as it involves genetic, environmental and social factors. Therefore the inconsistency in the variables measured across each study contributes to the challenges in drawing clear conclusions.

The Moorcroft et al. review (Moorcroft, Marshall & McCormick 2011) concluded that there was no clear association between timing of solid introduction and obesity. They also reported variations in cut-off ages used to define early introduction of solid foods in each study which ranged from two to six months. As this review included studies that were published as early as 1978 (Poskitt & Cole 1978) and as recently as 2010 (Griffiths et al. 2009; Schack-Nielsen et al. 2010) it is likely that the recommendations for solid introduction would have changed throughout the years. Similarly, the 2013 review (Pearce & Langley-Evans 2013) also concluded that there was no strong association between age of solids introduction and overweight or obesity in childhood, although some evidence suggested that very early introduction, at or before four months of age rather than at four to six months or greater than six months, may increase the risk of being overweight as a child. The Daniels et al. review (Daniels, Mallan, Fildes, et al. 2015) also reported that introduction to solids prior four months is indirectly associated with increased risk of childhood obesity, although there is little evidence of adverse weight outcomes with introducing solids at four to six months rather than at six months (Daniels, Mallan, Fildes, et al. 2015). The latest review (Wang et al. 2016) which analysed the risk of overweight and obesity with solid introduction before four months in cohort studies also reported increased risk from introduction at or before four months compared to at four to six months.

Similarly, the six studies published more recently (Table 2.2) did not consistently demonstrate an association between timing of solids introduction and weight status. Two studies did not find any relationship (Giles et al. 2015; Klag et al. 2015). Out of the four studies that did (Barrera et al. 2016; Moss & Yeaton 2014; Sun et al. 2016; Wen et al. 2014), one (Barrera et al. 2016) found that the association was no longer statistically significant after adjusting for covariates. The majority of the studies reviewed measured

timing of solids using similar categories, namely less than four, four to six and greater than six months.

Another recent review also focused on relationships related to child eating and child weight in very early childhood (0-5 years) (Russell, Taki, Laws, et al. 2016). Only studies which focused on introduction to solid foods were considered. Of the 32 articles which met the inclusion criteria, very few (n= 4) investigated age of introduction to solid foods as a predictor of infant adiposity (Gibbs & Forste 2014; Jimenez-Cruz et al. 2010; Layte et al. 2014; Worobey, Lopez & Hoffman 2009). Only one study (Gibbs & Forste 2014) included reported statistically significant indirect associations between these variables.

Although these reviews reported mixed findings regarding the association between timing of solid introduction and risk of childhood overweight and obesity, some studies also identified other factors which may have also contributed to the child's weight status. For instance, as breastfeeding has been identified as reducing the risk of obesity (Wen et al. 2014; Yan et al. 2014), earlier introduction of solid foods has increased the likelihood of earlier breastfeeding cessation (Holmes, Auinger & Howard 2011). Further, formula feeding has also been associated with earlier introduction to solids, up to the age of four months. Project Viva, a birth cohort study which included 847 children, explored the timing of solid introduction as a precursor of obesity at three years of age and the milk feeding practices from birth to four months (Huh et al. 2011). There was a sixfold increase in odds of obesity at three years of age among formula-fed infants who were introduced to solids before four months. However, this was not the case with breastfed infants who were introduced to solids before four months. Earlier introduction to solids is also associated with other behaviours linked to obesity including poor diet quality such as high fatty foods and sweetened beverages (Abraham et al. 2012; Jimenez-Cruz et al. 2010).

Overall, the majority of the studies reported a consistent finding that there is a lack of strong evidence to conclude that obesity is associated with solid introduction at four to six months or older. The factors contributing to this limited evidence may be due to the lack of consistency in how timing of solids is measured and categorised regarding early or late introduction. In order to definitively conclude whether the timing of solids

predicts child weight status, more longitudinal studies should be conducted. Despite this, the most consistent finding is that the introduction of solids before four months is associated with increased risk of overweight or obesity. Coupled with this finding, the number of benefits associated with delaying solids such as development of digestive tract and attainment of nutritional requirements from breastmilk (Klagsbrun 1978; Underwood & Hofvander 1982) indicate that these messages should be emphasised in interventions.

Table 2.1 Key characteristics of four reviews on association between timing of solid introduction and child weight

	(Moorcroft, Marshall & McCormick 2011)	**(Pearce, Taylor & Langley-Evans 2013)**	**(Daniels, Mallan, Fildes, et al. 2015)**	**(Wang et al. 2016)**
Main aim	To determine whether the timing of introducing solid foods is associated with obesity in infancy and childhood	To update the evidence presented by Moorcroft et al., using different inclusion criteria including data from comparable populations in developing countries	To update and extend the Moorcroft et al. review through more detailed consideration of the impact on outcomes of variation in exposure comparator groups (e.g. introduction of solids at <4 versus 4–6 or around 6 months) and treatment of indicators of obesity risk and covariates	To evaluate association between the age of solid introduction and risk of overweight and obesity in prospective cohort studies published in developing and developed countries.
Years covered	Up to July 2010	Up to September 2012	1990 to March 2013	Up to March 2015
No. of studies	24	23	26	13
Overlap	-	7 in common with Moorcroft et al.	20 in common with Moorcroft & Pearce	4 in common with Moorcroft, Pearce & Daniels
Study design	2 RCTs	- 16 unique studies 14 cohort	- 6 unique studies 2 RCTs	- 9 unique studies 13 cohort

	19 cohort 1 case-control	8 cross-sectional 1 case-control	22 cohort 2 case control	
Age range at which outcomes were measured	Range: 8 weeks to 18 years; 1 to 5 years= 14 *(11/14 measured at ≤12 months)* >5 years= 10	Range: 2 to 11 years 1 to 5 years= 10 >5 years= 13	Range: 12 months to 42 years 1 to 5 years= 19 >5 years= 7	Range: 3 to 11 years 1 to 5 years= 9 >5 years= 4
Summary	11/24 studies identified significant association between the timing of solid introduction and risk of obesity, 6 of which were identified at ≤12 months of age	4/23 studies identified significant associations between early introduction of solids (<3 months) and weight gain, 3 of which was identified at >5 years of age	8/26 studies identified significant associations between early solid introduction and weight gain particularly among parents who introduced at ≤4 months or who formula fed	5/13 studies illustrated significant effect on the risk of becoming obese following early introduction to solids at <4 months compared to 4 to 6 months
Limitations	Studies included in this review used different outcome measures to determine overweight and obesity, which limits the comparison between included studies Some of the included studies had a small sample size which could therefore lack sufficient	Pre-defined methodologies such as age at follow up or defining overweight or obese resulted in excluding some studies producing varying results to other reviews Some of the included studies had a small sample size which could therefore lack sufficient	No limitations were specified in this study	Some studies were omitted from analyses based on inclusion/exclusion criteria A dose-response or trend analysis was not performed to provide further evidence for limited eligible studies

	power to detect a meaningful associations	power to detect a meaningful associations

Table 2.2 Update of the 2015 Daniels review – Six studies examining associations between timing of solid introduction and child weight

Study, country, design	**Sample characteristics**	**Measure of solids introduction and child weight**	**Results**	**Co-variates**	**Limitations**
(Giles et al. 2015) Australia, Cohort	n= 557 Age= birth to 9 years Gender= 49.3% male Ethnicity= Caucasian Mothers	Timing of introduction of solids: <12 weeks, 12 to <16 weeks, 16 to <20 weeks and ≥20 weeks Body size: weight (kg), height (cm) and BMI measured at birth, 6, 9 and 12 months, and 2, 3½ and 9 years	Neither duration of breastfeeding nor the timing of introduction of solids have a role in distinguishing between growth trajectory groups.	Maternal characteristics: gestational age, BMI, smoking status, parity and maternal educational attainment by late pregnancy	Some relevant covariates associated with child BMI were not collected i.e. paternal BMI during the gestational period Possibility that particular associations observed in this study are due to unmeasured variables
(Barrera et al. 2016) United States, Longitudinal	n= 1181 Age= 6 years Gender= 50.1% female	Timing of introduction of solids: <4, 4–<6, and ≥6 months Body size: BMI (≥95th percentile) at 6 years	Obesity was higher among infants introduced to solids <4 months compared to those introduced at 4-<6 months (OR= 1.66; [95%	Maternal characteristics: age, gestational age, race/ethnicity, education, poverty-income, BMI, marital	The study sample was not nationally represented Child BMI at six

	Ethnicity= 88.3% non-Hispanic white Mothers	of age	CI: 1.15, 2.40]) in unadjusted analysis. Not significant after adjustment for covariates.	status and parity Child characteristics: sex and birth weight	years was based on height and weight measurements reported by the mother
(Wen et al. 2014) Australia, Longitudinal (structured short telephone interview)	n= 242 Age= 2 years Gender= 54% female Ethnicity= 65% born in Australia Mothers	Timing of introduction to solids: ≤2, 3-5, ≥6 months Body size: weight/length (kg/m^2) at 2 years of age	Mean (SD) BMI of children at age 2 years was 16.87 kg/m^2 (1.62), with 14% classified as overweight/obese. Earlier introduction of solids was a predictor for children's overweight/obesity status.	Maternal characteristics: pre-pregnant weight, age, employment status, education level, marital status, country of birth, household income, and smoking status Child characteristics: birth weight, duration of breastfeeding and timing of introduction of solids	Generalisation of the findings due to recruitment within one district area Selection bias of participants from more high income families included in the analysis due to differential loss to follow up The small study sample size limited the number of variables that can be included in the logistic regression model

					for BMI
(Moss & Yeaton 2014) United States, Longitudinal	n= 7,200 at 2 years; 6,950 at 4 years Age= 2 and 4 years Gender= Not reported Ethnicity= Not reported	Timing of introduction to solids: 4 months, 4-5 months, and 6 months Body size: weight (kg) and height (cm) at 2 and 4 years	At 2 years, the proportion of healthy weight status increased with the delay of solid introduction, for both breastfed (from 61.9% for <4 months to 70.3% for ≤6 months, p= <0.01 and never breastfed children (from 55.8 % for <4 months to 62.4 % for ≥6 months, p= 0.07).	Maternal characteristics: education, family poverty status, age and race. Child characteristics: gender and birth weight	The duration of breastfeeding was not collected in this study and results were dichotomised as 'breastfed' or 'not'. The analysis on breastfeeding and status may therefore be underestimated
(Klag et al. 2015) United States, Cohort	n= 438 Age= 12 months Gender= 52.2% male Ethnicity= 80.1% non-Hispanic white Mothers	Timing of introduction to solids: <6 months, ≥6 months Body size: weight (kg) at birth and 12 months	For each additional month of breastmilk feeding, solid food introduction was delayed by 1.32 days (95% CI: 0.11-2.53) and average weight gain per month decreased by 5.05g (95% CI: 7.39-2.17). No associations were observed between age at solid foods introduction and growth.	Maternal characteristics: ethnicity, smoking status, marital status, education level, employment or school enrolment and gestational age at birth Child characteristics: sex, weight, infant feeding practices and demographics	Possibility of recall bias as mothers were asked about feeding practice decisions that may have been made 6 months prior to completing the survey

(Sun et al. 2016) Australia, Cross-sectional	n= 3153 Age= 1 year Gender= 50% male Ethnicity= 90.1% Not Asian Mothers	Timing of introduction to solids: <4, 4, 5, 6, and ≥7 months of age Body size: above normal BMI (*z* score >2, equivalent to >97.7th percentile)	Both early and delayed introduction were associated with increased odds of above normal BMI at ≤4 months, OR= 1.75 (95% CI: 1.10-2.80) and at ≥7 months, OR= 2.64 (95% CI: 1.26-5.54) compared with introduction at 6 months.	Maternal characteristics: mother's country of birth, age at childbirth, smoking status, gestational age, mode of birth, birth weight, siblings	The associations identified in this cross-sectional study are limited to infant BMI at one year. This limits its generalisability to longer term outcomes

2.4 PART III – Interventions targeting infant feeding

2.4.1 Previous interventions targeting healthy infant feeding behaviours for the prevention of childhood obesity

The previous sections highlighted the importance of nutrition, particularly during infancy which has an impact on both short and long term health of the child. Those sections have described modifiable factors associated with RWG in infants, recommendations associated with solid introduction and the association between the age solids are introduced, and childhood overweight and obesity. Although the evidence with regards to the association of childhood obesity and the age of solid introduction between four to six months was not strong, the majority of studies illustrated that introducing before four months was associated with increased risk of unhealthy weight gain. Those sections have emphasised the importance of conducting interventions that target parents during early childhood as they play a critical role in the child's growth and behavioural habits.

In recent years, the body of literature on obesity prevention studies in early life has increased considerably and has been the subject of a number of systematic reviews (Blake-Lamb et al. 2016; Hesketh & Campbell 2010; Knowlden & Sharma 2012; Laws et al. 2014; Redsell et al. 2016; Skouteris et al. 2011; Skouteris et al. 2012; Waters et al. 2011). This section, however, provides a description of studies included in the Early Prevention of Obesity in CHildren (EPOCH) Collaboration which describes four Australian RCTs (Askie et al. 2010) that informed the larger study in which this thesis is embedded. Further, a review conducted by the candidate on mHealth interventions targeted at prevention of childhood obesity is also described (Section 2.4.4).

Summary of the EPOCH studies

Healthy Beginnings

The Healthy Beginnings Trial was one of the first RCTs conducted which aimed to deliver an obesity prevention intervention through home visits to reduce obesity among children at two and five years of age (Wen et al. 2007). The intervention targeted mothers from their third trimester and was delivered over the first two years of life to influence healthy infant feeding practices, encourage physical activity and enhance

parent-child interaction. The study was conducted in South West Sydney Australia, a socioeconomically disadvantaged area, and included a sample of 667 first-time mothers. The intervention group received eight home visits by specially trained community nurses over two years and telephone support between the visits. The control group received usual childhood nursing services from the Area Health Service and written resources on home safety/tobacco. Overall the study provided evidence that BMI can be reduced by 0.04kg/m^2 if breastfeeding was continued longer than six months (Wen et al. 2014).

NOURISH

The NOURISH trial promoted healthy infant feeding practices to encourage healthy food preferences and intake as well as the capacity for infants to self-regulate food intake for prevention of obesity at age two (Daniels et al. 2009). A sample of 698 first-time mothers of infants aged three months was recruited from major maternity hospitals in Brisbane and Adelaide in Australia. The study continued until 18 months of age. The intervention group received six, fortnightly parent education and peer support group sessions delivered by dietitians and psychologists. The control group received usual child health services. Overall, participants in the intervention group reported using more frequent responsive (warmth) feeding ($p \leq 0.03$) and less controlling feeding practices ($p < 0.001$) (Daniels et al. 2013). However, no statistically significant differences were identified in BMI z-score ($p = 0.23$) nor in prevalence of overweight or obesity at 18 months (control 17.9% vs intervention 13.8%; $p = 0.23$) (Daniels et al. 2013).

The Melbourne InFANT Program

The Melbourne InFANT Program promoted healthy infant feeding practices including the encouragement of responsiveness to infant hunger and satiety cues, healthy food intake, reduced TV viewing, management of child feeding behaviours (i.e. fussiness) and promotion of active play (Campbell et al. 2008). A sample of 542 parents were recruited from first-time parent groups at Maternal and Child Health Centres from local government areas in Victoria, Australia. First-time parent groups within selected local government areas were randomly allocated to either the intervention or the control group and the study was conducted until 18 months of age. The intervention group received six sessions delivered by a dietitian at three-month intervals during regular

meeting times of the first-time parents' group. The sessions included group discussions and peer support, exploration of perceived barriers to practise healthy feeding behaviour using visual written messages, follow-up delivery of messages by text-messages and mail-outs. The control group received usual care from the Maternal and Child Health nurses and were sent general health newsletters (e.g. dental health, sun protective behaviours, general safety). Overall the findings of the study indicated that, compared to the control group, the intervention group consumed fewer grams of non-core drinks (mean difference= -4.45; 95% confidence interval [CI]: –7.92 to –0.99; p= 0.01), fewer grams of sweet snacks (mean difference= -3.69; 95% CI: -6.41 to -0.96; p= 0.008) and viewed fewer daily minutes of television (mean difference= -15.97; 95% CI: -25.97 to -5.96; p= 0.002) (Campbell et al. 2013). There were no significant differences between groups for consumption of foods such as fruit, vegetable, savoury snacks, water consumption or in BMI z-scores or physical activity (Campbell et al. 2013).

Prevention of Overweight in Infancy (POInz)

The POInz study was a four-arm RCT that promoted sustaining breastfeeding, delaying solid introduction, responding to infant hunger and satiety cues, promoting healthy child food intake, reducing TV viewing and promoting active play (Taylor et al. 2011). A sample of 802 families was recruited from a maternity unit in Dunedin, New Zealand. Participants were randomly allocated into either the intervention or control group during their pregnancy and the study was conducted over the child's first two years. The control group received usual care, which included seven contacts with a provider of government-funded 'Well Child' care. In addition to the 'Well Child' care, the three intervention groups included the Food, Activity and Breastfeeding (FAB) group which received eight parent contacts in the first two years; the Sleep group which received at least three parent contacts over the first six months of life with a focus on prevention of sleep problems (including active intervention if there was a sleep problem from six months to two years); or the Combination group which received all contacts from the 'Well Child' care, FAB and Sleep groups. Overall, the study illustrated that at two years there was no significant difference in food intake or eating behaviour between the Sleep and control group (Fangupo et al. 2015). There was very little significant difference in parental feeding practices in the groups that received the FAB intervention (including Combination group) with greater child control over eating (mean difference: 0.14; 95%

CI: 0.02, 0.26) and less pressure to eat (mean difference: 0.18; 95% CI: 0.04, 0.32) at 18 months, as well as greater encouragement of nutrient-dense foods at 24 months (mean difference: 0.16; 95% CI: 0.03, 0.30). Further, the study reported no significant differences were observed between the groups who received the Sleep intervention (including Combination group) and the FAB group.

Summary of follow up outcomes from studies included in EPOCH

Each of the research groups included in EPOCH have published either protocols (Hesketh et al. 2013; Taylor et al. 2016) or outcomes (Daniels, Mallan, Nicholson, et al. 2015; Wen 2015) of follow-up studies to explore the effect these interventions had on child weight and related correlates at up to five years of age.

These studies reported modest effects on early childhood weight (Wen et al. 2011), diet (Campbell et al. 2013; Daniels et al. 2013; Wen et al. 2011) and sedentary behaviours (Campbell et al. 2013), which support the importance for interventions to target early life. However, the analysis of the follow-up studies including NOURISH and the Healthy Beginnings Trial, found that the effect on child BMI was not sustained at age five years and no statistical effect was identified for anthropometric outcomes (BMI Z-score: p= 0.06 and p= 0.03, respectively) (Daniels, Mallan, Nicholson, et al. 2015; Wen et al. 2015). The InFANT program has not yet published follow-up results, although another article described the InFANT Extend program protocol, and mentioned that similar outcomes were attained (Campbell et al. 2016). Despite these findings, small intervention effects on other correlates were found at five years of age. For example, in the NOURISH study the intervention group had higher fruit and vegetable intake (15.3 vs. 14.5, target ≥18, p= 0.03), infants were less responsive to food cues such as emotional eating (2.3 vs. 2.4, of maximum 5, p= 0.04), and more responsive to satiety cues (3.1 vs. 3.0, of maximum 5, p= 0.04) (Daniels, Mallan, Nicholson, et al. 2015). The outcomes of these studies illustrate that unique barriers are associated with every stage of growth and various strategies need to be considered to address and target these barriers. For example, some of these antecedents include child's personality, changes in food preferences and further environmental influences that may directly impact both the child and the parents.

2.5 PART IV – mHealth interventions

2.5.1 An mHealth approach for behavioural interventions

Over the past decade there has been a proliferation in the advancement and ownership of mobile and wireless technologies (Australian Communication and Media Authority 2015a; Turner et al. 2015). Digital devices have become an integral part of society across all demographics and age groups (Evans et al. 2014). In Australia, mobile phone use increased from 2.2 million in 2010 to 5.2 million in 2014 with a substantial proportion of the population (21%) relying on their mobile for internet access (Australian Communication and Media Authority 2015a). Further, access to research and information was one of the top three reasons consumers used their mobile phone (Australian Communication and Media Authority 2015a). The practicality of mobile phones offer a novel opportunity to deliver health services and engage a larger proportion of populations to target public health priorities such as obesity (Tate et al. 2013; Turner et al. 2015).

Researchers in the field of health promotion have capitalised on the exponential growth of digital technology use over the past decade. As well as its practicality, digital technology has the potential to target hard-to-reach populations and decrease health care costs, which have been limiting factors with traditional face-to-face interventions (Jacobs & Graham 2016; Redfern et al. 2014; Tate et al. 2013). Mobile health (mHealth), has been defined as 'emerging mobile communications and network technologies for healthcare systems' (Istepanian, Pattichis & Laxminarayan 2006). It harnesses the potential of the ubiquity of wireless mobile devices including mobile phones, tablets/ iPad and monitoring devices (Danaher et al. 2015; Hurley, Cross & Hughes 2011). mHealth services are therefore practised in many forms including communication via Short Message Services (SMS), smartphone applications (apps), videos and phone call services provided by health professionals (Baltierra et al. 2016; Webb et al. 2010). The mode of delivery chosen is dependent on the aim of the intervention and that which appeals most to the target demographic.

An array of mHealth services has been developed and conducted to address various public health problems including treatment and management of chronic diseases, health

monitoring (Hurley, Cross & Hughes 2011) to encourage healthy behaviours for prevention (Li et al. 2013), health education and awareness, and provision of other medical services (Mitchell et al. 2013). Specifically, mHealth has been found to positively impact on many public health problems such as smoking cessation (Knip et al. 2010), weight management (Fjeldsoe, Marshall & Miller 2009), diabetes management (Zhang et al. 2013) and depression treatment (Burns et al. 2011). However, more research needs to be conducted to understand how mHealth interacts with desired behavioural outcomes and its overall impact on the prevalence of chronic diseases (Li et al. 2013).

2.5.2 The potential to utilise an mHealth approach to support infant feeding behaviours

The research on preventing childhood obesity through the encouragement of healthy infant feeding practices has become a focus for public health researchers over the past few decades (Askie et al. 2010). Mothers obtain information about infant feeding in multiple forms including books, the internet, friends and family, and from health practitioners (Shirima et al. 2007). In particular with the rapid growth of technology, childbearing women are increasingly seeking information about pregnancy, birth and infant care through technology-based media (Romano 2007). Specifically, mothers who own a smartphone are more likely to access social networking platforms and apps like Facebook®, Twitter® and internet forums compared to the general population (Jang & Dworkin 2014). These platforms are beneficial in providing social support to this demographic where they may be socially isolated, time poor and reliant on reassurance in caring for their infant (Hearn, Miller & Fletcher 2013; Jang & Dworkin 2014; McDaniel, Coyne & Holmes 2012).

Further, an American study which included a sample of 2,400 women who completed the Listening to Mothers III survey, identified that a large proportion of the sample believed that technological-based sources that provided medical or health-related information were ‘very valuable’ (Declercq et al. 2013). Similarly, the Special Supplemental Nutrition Program for Women, Infants, and Children (WIC) examined the use of technology among socioeconomically disadvantaged mothers (Bensley et al. 2014). They identified that the majority of clients use the internet accessed from a

computer or mobile phone, e-mail, text messaging and Facebook® as a source of communication. These studies illustrate the potential for the development of nutrition education programs using technology among this demographic (Bensley et al. 2014; Demirci et al. 2016).

2.5.3 Review of mHealth interventions targeting healthy infant feeding behaviours to prevent childhood obesity

Previous reviews have explored the use of electronic media (web-based programs) (An et al. 2009; Nguyen, Kornman & Baur 2011) and mHealth programs (Turner et al. 2015) targeted at prevention of childhood obesity and treatment interventions. These reviews, however, did not include mHealth studies targeted at infant feeding behaviours. This section of the literature review includes an analysis of published studies that have utilised this novel approach.

There is a dearth of studies reporting the use of mHealth to prevent unhealthy weight gain in infants. A total of nine studies (Campbell et al. 2016; Geoghegan-Morphet et al. 2014; Horodynski et al. 2015; Jiang et al. 2014; Jordan et al. 2011; Uesugi et al. 2016; Wen 2015; Wen et al. 2017; White et al. 2016) were identified which used an mHealth approach to encourage the uptake of healthy infant feeding behaviours. However, of the nine studies, only one study (Jiang et al. 2014) has published outcomes while the remainder were protocols.

The one publication which met the inclusion criteria is a quasi-experimental study conducted in China (Jiang et al. 2014). The aim was to explore the effect of weekly SMSs sent to first-time mothers from the third trimester up to 12 months of age to prolong exclusive breastfeeding. Rates of exclusive breastfeeding up to six month were higher in the intervention group (median 11.41 weeks (95% CI: 10.25-12.57)) compared to the control group (median 8.87 weeks (95% CI: 7.84-9.89)). The effect size, however, was small with only approximately 2.5 days difference between both groups. In addition, small differences were identified with the age at which solids was introduced between the intervention group (1.5% before four months and 67.5% before six months) compared with the control group (3.8% before four months and 61.3% before six months). A number of limitations with this study were highlighted. For

instance, a variation in the demographic of the study sample was identified where the intervention group had younger mothers from a lower SES background. Another limitation included the variation in usual care services offered at the clinics which were used to recruit participants for the intervention group compared to those in the control group.

Update of interventions encouraging healthy infant feeding behaviours through mHealth

Three of the published protocols (Campbell et al. 2016; Wen 2015; Wen et al. 2017) are iterations of the RCTs involved in the EPOCH study. The Melbourne InFANT Extend program has been adjusted in that it now provides support until 33 instead of 15 months of age and incorporates an mHealth component including use of web-based materials and Facebook® engagement. The Healthy Beginnings Trial has published two protocols, one of which briefly reported the development of an app version of the Healthy Beginnings program to support parents with infant feeding behaviours. The second protocol describes a three-arm RCT delivered in NSW Australia. The two interventions will be delivered through telephone consultations or text messages and six intervention packages will be mailed at specific times from the third trimester of pregnancy until 12 months post birth. Another Australian study entitled Milk Man incorporated an app designed to socially connect information and support resources for men particularly focused on breastfeeding and infant feeding as well as being a supportive partner (White et al. 2016). This study is currently being trialled as part of the Parent Infant Feeding Initiative (PIFI) (Maycock et al. 2015).

One of the two studies based in the United States focused on providing support to teenage mothers with infant feeding through social media during their infants' first four months (Horodynski et al. 2015). The second study is a more comprehensive intervention supporting mothers with infant feeding behaviours (Uesugi et al. 2016). This intervention is a digital-based nutrition guidance system targeted to first-time mothers to prevent obesity during the first two years. The system consists of content informed by the WHO's health education theoretical concepts and strategies in early childhood (World Health Organization 2012). In addition, it included articles, e-mails, videos, quizzes, infographics, printable and interactive trackers and a goal setting tool to help initiate and maintain the behaviours advocated. Lastly, the program provides

telephone-based professional support delivered via the internet, e-mail, and text messages, focusing on educational modules addressing the modifiable factors associated with childhood obesity. Further the Canadian study included the development of an online breastfeeding support resource which aimed to support with breastfeeding up to six months (Geoghegan-Morphet et al. 2014).

Overall, findings from the literature indicated that although there is a growing interest in conducting mHealth interventions, little is known about the feasibility of this novel approach to influence the uptake of healthy infant feeding behaviours. To the candidate's knowledge, no studies have yet been published in Australia and minimal research around the world reporting outcomes on the impact that these mHealth interventions had on infant feeding behaviours to promote healthy weight gain.

2.6 PART V – Strategies used to enhance participant engagement in mHealth interventions

The first part of this literature review focused on factors related to childhood overweight and obesity as well as interventions that have been implemented to encourage healthy infant feeding behaviours for the prevention of childhood obesity. This section of the literature review will focus on strategies implemented to enhance participant engagement in mHealth interventions. An exploration on measuring engagement in mHealth interventions is also described.

Despite the limited findings of mHealth interventions implemented to prevent unhealthy weight gain in childhood, this method of delivery holds potential advantages. In addition to the increased likelihood of reaching participants of various demographic backgrounds, they enable researchers to collect real-time data and have the ability to deliver personalised, interactive and adaptive interventions to suit the target demographic (Li et al. 2013; Turner et al. 2015). Further, compared to traditional face-to-face interventions, they require less time, energy and effort for participation. Using this mode to deliver health interventions provides the opportunity to encourage healthy behaviours in participants' natural environment. This is specifically known as ecological momentary intervention (Heron & Smyth 2010), which includes interventions embedded into participants' life without impeding their daily routine (Turner et al. 2015; White et al. 2016).

Engagement with health interventions is a prerequisite for effective programs (Sawyer et al. 2016; Spoth & Redmond 2000; Yardley et al. 2016). Particularly with mHealth behaviour change interventions, maintaining high levels of participant engagement has been deemed as difficult and poor engagement has often resulted in high attrition rates among participants (Brouwer et al. 2011; Waller & Gilbody 2009). The challenges in sustaining engagement in these interventions arise from limited or no face-to-face human interaction which is usually provided in traditional interventions (Eysenbach 2005; Kohl, Crutzen & de Vries 2013; Yardley et al. 2016). It is therefore necessary to not only consider specific digital engagement strategies but also to involve the target audience in the intervention development phase. As technology is continuously growing and people are increasingly becoming technologically literate expectations also grow

(Dennison et al. 2013). Thus to reach the expected numbers of the target demographic, it is essential that researchers meet their expectations through exploring and understanding their needs and interests.

2.6.1 Defining engagement in mHealth interventions

The term engagement has been used in various fields including user experience with digital technologies, in education and health behaviour interventions. The variation in definitions has made it challenging for researchers to systematically analyse and compare engagement in mHealth interventions (Kelders et al. 2012; Weston et al. 2015). Previous definitions of engagement includes the level of the participants' emotional (feel), cognitive (think) and behavioural (act) participation with a service for the management of health (Graffigna et al. 2013). Another definition includes using attributes which assess the quality of the user's experience when using technology (O'Brien & Toms 2008). Recently, engagement has been described as 'stickiness' which includes exploring participants' retention rate (Weston et al. 2015).

The variation in definitions for the term engagement particularly in the mHealth field is potentially due to its multidisciplinary approach. Although the main focus of these interventions is to target health, other disciplines are also involved including Information Technology (IT) and marketing. For instance, viewing engagement from the health perspective is similar to traditional face-to-face interventions whereby it draws on the process of achieving and effectively influencing the uptake of desired health behaviours (Graffigna et al. 2013; Yardley et al. 2016). From the marketing perspective, it includes selecting the appropriate modes to deliver the intervention based on what appeals to the target audience (Baltierra et al. 2016). Finally, from the IT perspective, this focuses on participant engagement with the digital technology, and includes novelty, aesthetics, usability and usage, and factors which influence how they use the intervention such as the modes in which the intervention is delivered (O'Brien & Toms 2008; Sawyer et al. 2016; Yardley et al. 2016). Engagement and strategies need to be considered from each discipline.

2.6.2 Developing engaging mHealth interventions

Mode of delivery

The mode selected to deliver an mHealth intervention is an important component to enhance participant engagement (Baltierra et al. 2016; Webb et al. 2010). Digital technology provides the opportunity to deliver information in several modes, including smartphone apps, text notifications, videos, games, quizzes, message boards, tools or surveys (Uesugi et al. 2016; Webb et al. 2010). The level of interactivity in each of these modes will vary according to the interests from both a demographic and an individual level. Selecting and prioritising the most appopriate modes to deliver an intervention that will encourge engagement and the uptake of the desired health behaviours is the challenge (Baltierra et al. 2016).

Smartphone applications

Smartphone apps are software programs that can be downloaded and installed onto phones from specific operating platforms (Jaakkola et al. 2015). With the emergence of smartphone ownership, apps are increasingly being used as a convenient mode to access internet services through mobile devices (Dube & Kandampully 2014; Jaakkola et al. 2015). In Australia, it has been estimated that in 2015 74% (13 million) of adults used smartphones compared to 67% (12 million) in 2014 (Australian Communication and Media Authority 2015b). Further, in 2013, approximately 75% (nine million) of Australian smartphone users had downloaded an app to their phone within a six-month period (Australian Communication and Media Authority 2014)

Due to the increase in technology demands, particularly the usage of smartphones (International Data Corporation 2015), a number of mobile platforms are available (Dalmasso et al. 2013). Apps are developed for either one (*native)* or more than one operating system *(hybrid apps/cross platform approach)* such as iOS, Android, Blackberry, Bada and Symbian. Native apps are commonly-used platforms for operating systems; they run locally on the specific smartphones to utilise the existing hardware available such as the camera, geographical-positioning or call logs. Hybrid apps are a combination of both mobile-web and native apps, they are installed from an app store e.g. Google Play store (Android) or app store (iOS) and are embedded into the smartphone similar to the native app (Dalmasso et al. 2013; Serrano, Hernantes &

Gallardo 2013). When designing apps, deciding on what type of app is appropriate for the mHealth intervention is dependent upon a number of factors, including the resources available to develop the app, the service needed for the intervention, the need to access data and ease of distributing the app (Danaher et al. 2015).

As discussed in section 2.5 the literature contains very few mHealth interventions to encourage healthy infant feeding behaviours delivered through an app (Wen 2015; White et al. 2016), although a number of studies from other health fields have utilised this mode of delivery. For instance, a recently-published systematic review examined the effectiveness of smartphone apps and their influence on the targeted health behaviour (Zhao, Freeman & Li 2016). A total of 23 studies met the inclusion criteria and health behaviours ranged from mental health, weight management, medication management to lifestyle and management of chronic diseases. Of these studies, 17 reported finding statistically significant uptake of the desired behaviour. Factors which were likely to impact on the effect of the intervention and retention rate included utilising a theoretical model and implementing appropriate Behaviour Change Techniques (BCT), tailoring content to suit the demographic, personalising weekly text notifications and goals, and using simple interface designs to reduce the time required for participation (Zhao, Freeman & Li 2016).

Text notifications

Text notifications can come in the form of an SMS, email or push notification delivered via mobile apps. Using text notifications has a number of advantages, including that they are asynchronous and can be accessed at the individual's convenience. In addition, these messages can be tailored and personalised to individuals, which has been illustrated to be an important strategy to enhance participant engagement and to be more effective than un-tailored messages (Dijkstra & De Vries 1999; Fjeldsoe, Marshall & Miller 2009; Trevena et al. 2006). Text notifications have been used as a form of data collection (Li et al. 2013), to reinforce knowledge or prompt use of behaviour change strategies (including goal setting, seeking further support or overcoming barriers) (Armanasco et al. 2017; Fjeldsoe, Marshall & Miller 2009; Zhao, Freeman & Li 2016). They are also a form of nudging, which is defined as 'any aspect of the choice architecture that alters people's behaviour in a predictable way without forbidding any options or significantly changing their economic incentive' (Thaler & Sunstein 2008).

Nudging is therefore used as a trigger to encourage the uptake of particular behaviours and is uniquely shaped around participants' daily routine (Heron & Smyth 2010; M'hamdi et al. 2017). Due to the flexibility of text notifications they have been shown to be effective in both long and short term behaviour change outcomes than just using static information (Chou et al. 2013; Heron & Smyth 2010).

SMSs allow instantaneous delivery of short messages (1 SMS is 160 characters) directly to individuals at any time, place or setting and the recipient does not require internet data to receive them. SMSs can also be used for bi-directional communication between the participant and researchers implementing the intervention. This can be particularly beneficial in monitoring participant engagement and can be compared to exposure (Atun & Sittampalam 2006; Sherry, Colloridi & Warnke 2002).

Push notifications are a means by which messages can be sent through mobile apps (Mohr et al. 2014; Warren et al. 2014). Notifications are programmed into the system and can be scheduled to be delivered at specific times (Mohr et al. 2014). Compared to other forms of messages such as email or SMS, push notifications can take the user to the appropriate section in the app to more information referenced in the message through tapping or swiping. However, unlike SMSs, push notifications rely on internet data to send messages.

Email is another mode which is used as a form of text notifications (Mohr et al. 2014). Similar to SMSs and push notifications, they can proactively push content to participants in mHealth interventions. However, emails are less salient or visible as they require participants to seek the messages at their own initiative. That being said, automated emails have been frequently used in eHealth interventions as an engagement strategy (Civljak et al. 2013).

Social connectivity

The proliferation of technology use worldwide has changed and influenced the way in which people are interacting; many rely heavily on social media platforms to keep socially connected (Chou et al. 2013; Lim et al. 2017). Sensis, a large Australian marketing service, recently conducted telephone surveys with 800 randomly-selected Australians over 18 years of age from various sociodemographic areas to explore social

media use (Sensis 2016). The majority of online Australians aged 18 and over (69%) have at least one social media profile (e.g. Facebook®, Twitter®) and 50% were using it on a daily basis. Facebook® was the most commonly-used platform (95%), which was accessed on average 32 times per week (Sensis 2016).

The concept of utilising peer support has been a valued method and been shown as effective in attaining positive health outcomes across various behavioural science and health disciplines (Cohen, Underwood & Gottlieb 2000; Dennis 2003). Using social relationships from resources that are considered as supportive has been highlighted by the WHO and the Ottawa Charter as a health promotion strategy (Epp 1987; World Health Organization 1998). Coupled with this finding, more researchers are leveraging from the penetration of social media sites used as an engagement strategy in mHealth interventions (Lim et al. 2017). This mode of delivery has now been used across various health areas including weight management (Fukuoka et al. 2011), sexual health management (Yager & O'Keefe 2012) and smoking cessation (Phua 2013).

Particularly during the childbearing years, mothers often receive informal social support from friends and family to provide advice with infant feeding behaviours (Bridges 2016; Chezem, Friesen & Clark 2001). More recently, the internet has become a common means for enabling mothers to connect with others for emotional support and a platform to exchange advice and infant feeding experiences (Appleton, Fowler & Brown 2014; Jang & Dworkin 2014). A recently-published qualitative study explored the use of social media among 14 first-time African American mothers during the antenatal and postnatal periods (Asiodu et al. 2015). The findings illustrated that participants frequently used social media through various technological devices for social support as well as information about perinatal and parenting advice including infant feeding and infant development (Asiodu et al. 2015). Further an Australian qualitative study explored experiences of 23 mothers using a closed Facebook® group part of the Australian Breastfeeding Association (ABA) (Bridges 2016). As well as a Facebook® group, ABA also offers information and support via Breastfeeding Helpline, email, counselling, online forums and face-to-face group meetings (Australian Breastfeeding Association). The majority of the mothers in the study felt the Facebook® group was a useful complementary resource that provided them with immediate information and a trusted sense of community to meet like-minded people.

Both studies illustrate that using social networking sites may enhance participant engagement and uptake of desired behaviours.

Quality

Due to the proliferation of technology use, health information has also become readily accessible on the internet for the public (Eysenbach et al. 2002). Although the internet is convenient and can be an interactive resource to access health information, it is also unregulated and there is the potential for the public to access poor quality information. Various studies that analysed the quality of health and medical information identified a large number of internet sources which are of poor to medium quality (Fahy et al. 2014; Nasser, Mullan & Bajorek 2012; Schubart et al. 2011). While it has been recognised that the internet has become a crucial source to disseminate health information, it has been recommended that quality indicators to measure health information on the internet are utilised (Eysenbach et al. 2002). Further, as highlighted in Section 2.6.1, one of the factors which contributes to user engagement is the quality of their experience using the technology (O'Brien & Toms 2010). Although a number of quality tools currently exist, it has been found that developers rarely use them (Reichow, Shefcyk & Bruder 2013).

Quality of user experience with technology is a multidimensional construct. One study which developed an engagement satisfaction survey identified factors such as Focused Attention, Perceived Usability, Endurability, Novelty, Aesthetics, and Felt Involvement which are associated with quality of user engagement (O'Brien & Toms 2010). Another tool which has been developed to measure quality includes the Health On Net Code of conduct (HONcode) developed by the HON Foundation, a non-government organisation (Health On Net Foundation 2010). This tool guides website managers in developing good quality websites which provide health or medical information. The elements considered in this quality tool include the authorship, publisher, credentials, accuracy, currency and readability level of information as well as the design (aesthetics) and functionality. Lastly, a recently-developed quality tool for apps, the Mobile Application Rating Scale (MARS) aims to classify and assess the quality of mHealth apps (Stoyanov et al. 2015). The quality elements considered in this tool includes engagement, functionality, aesthetics, information quality and a subjective quality rating. In order to enhance participant engagement, developers should utilise these tools to address each element involved in providing a good quality website or app.

Theoretical models

The Medical Research Council (MRC) framework developed in 2000 characterised the process to develop and implement effective complex interventions (Craig et al. 2008). It emphasised that developing interventions in a systematic approach using a theoretical model and pilot testing the intervention to address uncertainties is best practice. Similar recommendations have also been suggested when developing mHealth interventions to guide the process of selecting modes to deliver the intervention and adapting and tailoring the content to suit the needs of the target demographic (Danaher et al. 2015; Riley et al. 2011; Yardley et al. 2016; Zhao, Freeman & Li 2016). The utilisation of theories in interventions has enabled researchers to appropriately evaluate and make adaptations to enhance intervention fidelity and uptake of desired behaviours (Hawe, Shiell & Riley 2004; Moore et al. 2015).

Theories are commonly used in health-related interventions to understand the underpinnings including antecedents and barriers to take up desired health behaviours (Baranowski, Cerin & Baranowski 2009; Yardley et al. 2016). Then, specific behavioural techniques are applied to modify or mediate factors that influence the adoption of the target behaviour (Abraham & Michie 2008; Michie et al. 2009). Theories used in nutrition-based interventions include ecological, social and psychological theories (Yardley et al. 2016; Zhao, Freeman & Li 2016). Specifically, Social Cognitive Theory (SCT), Theory of Planned Behaviour (TPB), Health Belief Model (HBM) and Intervention Mapping have been successfully implemented in intervention trials aimed at encouraging healthy infant feeding behaviours for prevention of childhood obesity (Campbell et al. 2013; Daniels et al. 2013; Evans, Wallace & Snider 2012; Taylor et al. 2013) and in proposed interventions with similar aims (Uesugi et al. 2016; White et al. 2016).

Although these interventions targeted similar outcomes for the prevention of childhood obesity using various theories, the effectiveness of the intervention on the outcomes varied. For example, interventions which utilised SCT found it to be predictive of breastfeeding intention and duration (Gregory et al. 2008), increased positive responsive feeding practices (Daniels et al. 2013), decreased consumption of sweet snacks, and lowered daily television viewing time (Campbell et al. 2013). The TPB influenced constructs such as perceived behavioural control, moral norms and subjective norms

associated with breastfeeding (Ahmed 2008; McMillan et al. 2009) as well as introduction to nutritious food (Heinig et al. 2006). Despite the variety of theories available and the impact they had on intervention outcomes, the SCT (Bandura 1986), TPB (Ajzen 2011) and HBM (Becker 1974) do not thoroughly address all possible theoretical domains, including impulsivity, habit, self-control, associative learning and emotional processing (West 2006).

A recently-developed theoretical model which is increasingly used in health interventions is the Behaviour Change Wheel (Michie, van Stralen & West 2011). This model is made up of tools which are interlinked to guide researchers to comprehensively design and evaluate behaviour change interventions. As this model includes the exploration of theoretical domains that are not addressed in other theories, this model was selected. A detailed description of this model has therefore been described.

Behaviour Change Wheel (BCW)

This model is a synthesis of 19 frameworks of behaviour change interventions and has been designed to comprehensively cover a range of intervention elements and build on the frameworks utilised (Michie, van Stralen & West 2011). For instance, Intervention Mapping (Bartholomew & Dolan Mullen 2011) is a six-step protocol for designing, implementing and evaluating behaviour change interventions in an iterative approach using a theory. The BCW model builds on this framework by providing methods to link theory with BCTs without using formal theories of behaviour change. Another framework utilised was MINDSPACE, which focuses on the application of behaviour science to the policy-making process (Dolan et al. 2010). The BCW builds on this framework by providing a model to comprehensively design interventions by linking behaviour analysis to intervention functions, policy categories and BCT.

The BCW includes a behaviour system at the centre, involving three components, Capability, Opportunity, Motivation – behaviour (COM-B system). This system is positioned around nine intervention functions (i.e. Restriction, Education, Persuasion, Incentivisation, Coercion, Training, Enablement, Modelling and Environmental restructuring) which are used to address the deficits identified within one or more of the COM-B components. Lastly, around this are seven categories of policy (i.e.

Environmental/Social Planning, Communication/Marketing, Legislation, Service Provision, Regulation, Fiscal Measures, and Guidelines) that may potentially enable those interventions to occur. Overall, the implementation of the BCW involves eight steps embedded in three phases which include to understand the behaviour, identify intervention components and to identify the delivery options (Michie, van Stralen & West 2011).

- **Capability, Opportunity & Motivation - Behaviour (COM-B) model:**

The COM-B model is part of the BCW and specifies three components, namely Capability, Opportunity and Motivation, which interact to generate behaviour (Figure 2.1). This is a theoretical model used to understand behaviour and the barriers and antecedents associated with desired behaviours. The behavioural components are defined as the following:

- **Capability** refers to the individual's psychological (e.g. comprehension, knowledge) and physical (strength, skill, stamina) capacity to engage in a particular activity;
- **Opportunity** includes factors external to the individual that enable or prompt a behaviour to occur such as the physical opportunity (e.g. the environment) and social opportunity (e.g. cultural milieu) which influence thought processes; and
- **Motivation** includes the brain processes that direct the behaviour such as personal goals and decision making such as reflective processes (e.g. evaluations and plans) and automatic processes (e.g. emotions and impulses from associative learning).

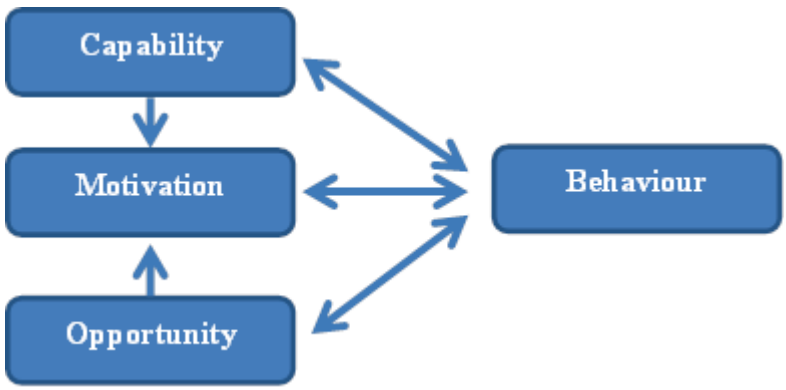

Figure 2.1 COM-B Model (Michie, van Stralen & West 2011)

- **Theoretical Domains Framework (TDF)**

The TDF is an elaboration of the COM-B model, with 14 domains of theoretical constructs allowing for a more detailed understanding of behaviour (Michie, van Stralen & West 2011). This framework is used to understand behaviour theoretically and identify factors that need to change to achieve the desired behaviour. Behaviour is explored by using 14 domains that cover main factors which influence behaviour change including knowledge; skills; social/professional role and identity; beliefs about capabilities; beliefs about consequences; motivation and goals; memory, attention and decision processes; environmental context and resources; social influences; emotion; behavioural regulation; and nature of the behaviours (French et al. 2012) (See Appendix 2E). Exploring which TDFs need to be addressed is one of the first steps involved in developing a behaviour change intervention.

- **Behaviour Change Techniques (BCT) Taxonomy**

Behaviour Change Techniques have been developed to constitute the active content of interventions aimed to target the barriers associated with the uptake of desired behaviours identified from the theory. Coupled with the BCW, the BCT Taxonomy list provides a systematic approach to comprehensively select a range of intervention functions, BCTs and policy categories to design and deliver interventions based on the target behaviour (See Appendix 2E).

Very few studies have utilised this model in interventions targeted at prevention of childhood obesity (Curtis, Lahiri & Brown 2015; Handley et al. 2016). However, it has been applied in other contexts such as increasing physical activity in school children (Norris et al. 2016), smoking cessation (Free et al. 2011) and medication adherence (Jackson et al. 2014).

Further, as mHealth interventions targeting infant feeding behaviours are still in their infancy, there is very little knowledge on what strategies are most effective in this field to enhance engagement. It is therefore necessary to implement theoretical models which underpin digital behaviour change interventions (DBCI), such as Behavioural Intervention Technology (BIT) Model which combines behavioural principles (such as BCW) with technological features (Mohr et al. 2014). It is suggested that a BIT model

needs to consider both conceptually and technically, why (target behaviours), what (mode of delivery), how (behaviour change strategies) and when.
Overall to address the elements that are involved in a DBCI it is necessary to explore parents' preferences for strategies they feel are appropriate to enhance their engagement and to measure the impact that these strategies had on their engagement level.

2.6.3 Evaluating engagement in mHealth interventions

There is increased interest in the evaluation of participant engagement with mHealth interventions. Participant engagement needs to occur throughout each stage of the intervention including formative, pre-testing, implementation and evaluation (Yardley et al. 2016). Engagement during each stage can be evaluated using various research methods (see Table 2.3) (Whittaker et al. 2012; Yardley et al. 2016). The methods used to evaluate mHealth interventions are unique and differ to those from traditional face-to-face interventions, (as discussed in section 2.6) this approach includes dimensions such as user experience elicited by qualitative methods such as telephone interviews, focus groups or think-aloud walkthrough and quantitative satisfaction surveys (Avis et al. 2015; O'Brien & Toms 2010; Yardley et al. 2016). Another dimension is technology usage which can be measured through app data metrics (Chaffey & Patron 2012; Sawyer et al. 2016). Lastly, participants' behaviour and reaction to the intervention can be elicited through qualitative and quantitative methods and also through app data if appropriate measurement tools were embedded in the app (Baltierra et al. 2016; Moore et al. 2015).

Table 2.3 Summary of methods to consider during the development and evaluation of mHealth interventions

Stage	Description of method	Purpose

Formative research	• Qualitative study
	  ○ Focus groups
	  ○ Semi-structured interviews
	• Online surveys
		• To inform the development of the intervention content and mode of delivery

Pre-testing	• Focus groups • Think-aloud walkthrough • Quality tools • Alpha & Beta testing	• To determine the acceptability of the proposed intervention to target demographic • To explore the user-friendliness, aesthetics and ease of navigation of the developed app • To refine the intervention based on the feedback
RCT/Feasibility study	• Pragmatic community-based RCT/Feasibility study	• To test the effect and acceptability of the intervention in comparison with a control group

Evaluation	• Qualitative study
	  ○ Focus groups
	  ○ Semi-structured interviews
	• Online surveys
	• App analytics
	• Engagement Index
		• To collect feedback to improve the intervention further
		• To explore participant satisfaction with the intervention
		• To explore usability of the intervention
		• To determine implementation issues and methods
		• To explore the intervention impact on the uptake of the desired behaviours
		• To determine the scalability of the intervention

Formative research

Formative research is conducted to understand the target behaviour and the appropriate mode to deliver the intervention for optimum engagement. Section 2.6 of this thesis describes engagement strategies that have previously been utilised in mHealth interventions. In order to select the most appropriate mode of delivery for an intervention, it is necessary to involve the target demographic during the development stage (White et al. 2016; Whittaker et al. 2012). This is because of the high dependence

on participant engagement for the intervention to be effective (Eysenbach 2005; Kohl, Crutzen & de Vries 2013).

Qualitative methods have been used to understand the barriers and facilitators associated with the uptake of desired behaviours, which is commonly explored using a theoretical model (Moore et al. 2015; Yardley et al. 2016). For example, the Healthy and Active Parenting Programme for Early Years study (HAPPY), used Intervention Mapping to elicit information regarding barriers associated with the uptake of healthy infant feeding behaviours through qualitative methods. Qualitative interviews (n= 12), three focus groups (n= 29) and surveys with parents and grandparents (n= 1242) and with health professionals (n= 20) were conducted and the outcomes were used to determine the content and BCT that needed to be targeted in the intervention (Taylor et al. 2013). Another study utilised the TDF and COM-B model to determine the barriers and enablers to deliver the Healthy Kids Check (HKC) program (Alexander, Brijnath & Mazza 2014). Overall six focus groups were conducted with health professionals and thematically analysed to inform the design of an intervention promoting provision of HKC services in Australian practice.

Another part of the formative stage includes exploring interest among the target demographic in an mHealth intervention and modes of delivery. Studies have explored this using a combination of quantitative and qualitative methods to inform their intervention. A study conducted focus groups involving 27 high school children to explore how they use their mobile phone and their perceptions on receiving health support through that mode. Further, they used quantitative surveys (n= 153) to obtain wider perspectives and inquire about students' preferences about frequency of text messages within the health program (Whittaker et al. 2012). Other studies with similar aims utilised either quantitative or qualitative methods. For example, the Special Supplemental Nutrition Program for Women, Infants, and Children (WIC) conducted surveys with 8144 participants to determine preferences in technology use for communication with the WIC program (Bensley et al. 2014). To inform the design and development of Milk Man app, focus groups with new and expectant fathers (n= 18) as well as health professionals (n= 16) were conducted.

Pre-testing

The pre-testing phase of mHealth interventions can include assessing the acceptability of the mode of delivery and content of the intervention, user testing and beta testing. As with the formative phase, previous studies have used either one or a mixture of methods during the pretesting phase. For instance, a study targeted at supporting men in the transition to fatherhood through text messages pre-tested the content and frequency of the messages in three phases (Fletcher et al. 2016). Phase one involved health professionals (n= 15) to rate the texts based on their benefit, clarity and usefulness. The second phase involved fathers (n= 46) and mothers (n= 56) who were invited to rate ten messages based on their clarity, usefulness and relevance using a 3-point scale. The final phase included pilot testing the SMS software with fathers (n= 21) receiving 12 messages over various time-points and weekdays over a three-week period. The researchers then contacted participants to conduct in-depth telephone interviews to discuss their preferences on the timing of the SMS and their relevance (Fletcher et al. 2016). Other forms of pre-testing include alpha and beta testing which is usually conducted on website or apps to identify any technological or design problems and attain user feedback for final adjustments of the app (Ybarra et al. 2016). For instance, in the Milk Man app study, the researchers conducted beta testing and user testing (White et al. 2016). Beta testing was conducted during the early development phase of the app to explore technological issues including bugs, broken links, navigational issues or errors which were then addressed by the developers. The second pre-testing phase involved recruiting a sample from the target demographic to obtain feedback on the app's functionality, design and useability.

Other forms of pretesting include qualitative methods such as focus groups, interviews or think-aloud walkthroughs (Avis et al. 2015; Nielsen 1994). These methods are traditionally used in marketing and advertising to elicit consumer feedback to enhance products before releasing them publicly (Merton 1987). Although focus groups are commonly used to evaluate traditional interventions, they are also useful to help refine digital interventions prior to use with the demographic. This method has helped identify participant perceptions about changes to the structure, content and utility of digital interventions (Fukuoka et al. 2011). For example, during the formative phase of the Horizon mHealth weight management program delivered via text messages, 3 focus

groups (n= 20), one-on-one interviews (n= 5) and quantitative online surveys (n= 120) were conducted to test the appropriateness of the program (Waterlander et al. 2014). The participants provided feedback on the concept of the program, expressed preferences for the program to be personalised, prompt and practical; they also expressed their thoughts on the appropriateness of the messages and preferred frequency they would like them sent.

Further, think-aloud walkthrough is another method utilised by industry for software development and is commonly used to test health apps (Balaam et al. 2015; Nikolaus et al. 2014; White et al. 2016). FeedFinder, an app to support breastfeeding women find, review and share public breastfeeding places with other breastfeeding women (Balaam et al. 2015) utilised this method during the formative phase to enhance the engagement of participants. Six women were invited to use the app and to complete the three target activities that is, finding, viewing and reviewing places. The women were then encouraged to voice their experiences and discuss issues they experienced for suggestions to improve the aesthetics of the app.

Evaluation

The evaluation of mHealth interventions can involve a number of methods to explore users' experience, behaviour and reaction to the intervention. One of the advantages of mHealth interventions, specifically apps and websites, is the collection of real-time data (Donkin et al. 2011; Yardley et al. 2016). Delivering an intervention through a smartphone app allows researchers to collect participant usage data for the program through app analytics or metrics (Jacobs & Graham 2016). The use of analytics dates as early as 1990s when systems were developed to improve online marketing (Chaffey & Patron 2012). Metrics are data about dimensions that can be measured, such as how many times participants visits a page on the app (Google 2016b). A list of commonly used metrics that can be collected is summarised in Table 2.4, although this is not an exhaustive list (Localytics 2016).

Although metrics provide valuable insights into participants' use of mHealth interventions, they can be complex data sets and challenging to interpret (Yardley et al. 2016). It is therefore common for researchers with limited knowledge on information technology to rely on Google analytics which only has the capacity to provide a

summary of the total population's use of the app rather than individualised information (Google 2016b). Doing this, however, is limiting as digital interventions can provide data sets sufficient to develop models to analyse the effectiveness of intervention components (Murray et al. 2016). Further, usage metrics can also be used alongside behavioural outcomes collected by the app or through quantitative surveys (Mohr et al. 2015; Yardley et al. 2016). This data can be used to explore the rate of attrition and the effectiveness of specific intervention components and analyse this with the uptake of desired behaviours (Sawyer et al. 2016).

Previously-published reviews exploring the effectiveness of mHealth interventions have reported that effectiveness is commonly measured using the number of log-ins as the sole measure of engagement and to explore its association with behavioural outcomes (Donkin et al. 2011; Hebden et al. 2014; Kelders et al. 2012). A review of 69 studies of interventions delivered through mHealth identified that less than 50% examined the association between adherence and behavioural outcomes (Donkin et al. 2011). Further, the number of log-ins was the most commonly used metric to measure adherence. This method, however, has been deemed insufficient as, with the enhancements of technology, other data capturing participant engagement including time spent, content visited and push notifications access can also illustrate participants' engagement and uptake of behaviours (Kelders et al. 2012). To determine optimal delivery and dosage for mHealth interventions delivered via the internet, new ways to understand and evaluate user engagement are needed.

Table 2.4 A summary of common activity metrics and elements defining the level of engagement

Metric name	**Definition**
Basic app metrics	
Session duration	Amount of time a participant spends browsing the web site or on an App page
Page views per session	The number of page views for each unique participant
Number of sessions	A count of the total number of times a participant has accessed the app/site
Conversion rate	How many times a participant completes an action e.g. opening a push notification, downloading a document or making a purchase
Satisfaction	Responses to subjective questions asked about the participant's experience with the app/website

Although digital technologies provide valuable information on participants' use of the intervention through metrics, this data can also be misguiding and should not be used alone for evaluation. People's interaction with digital technologies, including their psychological and social response, will be heterogeneous (Kelly 2016). To explore characteristics and themes that emanate from participants' use of mHealth interventions, conducting qualitative methods are necessary.

Qualitative studies can be used to explore user experience and to capture critical information such as understanding perceptions and experience with the intervention elements including the mode of delivery, content or quality (Anderson, Burford & Emmerton 2016). Although data analytics are useful in measuring participants' use of an app, they provide limited understanding of why they interact in particular ways (Yardley et al. 2016). Using qualitative methods can help explore these patterns in the use of the app program and generate more reliable hypotheses on factors which enhance participant engagement. Patterns which describe participants' use of the app may also be found in themes within the qualitative data (Braun & Clarke 2006; Meyrick 2006). These themes might help identify variations in participant engagement based on specific characteristics, such as demographics or knowledge on the targeted health behaviour (Morgan et al. 2016). These findings can aid researchers to enhance interventions.

In addition to qualitative methods, quantitative surveys are also commonly used to measure further dimensions of engagement. For instance, satisfaction or quality surveys can provide subjective understanding of user experiences with the mHealth program (O'Brien & Toms 2010; Wiebe et al. 2014; Yardley et al. 2016).

2.7 The conceptual framework of the study

Based on the literature, a proposed BIT conceptual framework (Figure 2.2) has been developed to address the objectives of this thesis. As illustrated in Section 2.6.1, engagement in the context of mHealth interventions has various definitions due to its multidisciplinary approach. These definitions highlight that engagement can be related to the uptake of health behaviours (health), user experience (marketing) or app usage (IT). It is hypothesised that researchers who adapt the intervention components including mode of delivery, content and quality by i) utilising a theoretical model and

ii) matching the unique attributes and preferences of the target demographic, will experience greater intervention engagement and improved outcomes.

Limited literature is available on mHealth interventions targeting infant feeding behaviours. To address this gap, the framework utilises the BCW model to explore how to enhance participants' engagement in using the mHealth intervention through content, mode of delivery and quality to enhance the uptake of the targeted behaviour. This thesis focuses on the targeted health behaviour of participants: delaying the age at which they introduce solids, following the Infant Feeding Guidelines (National Health and Medical Research Council 2012).

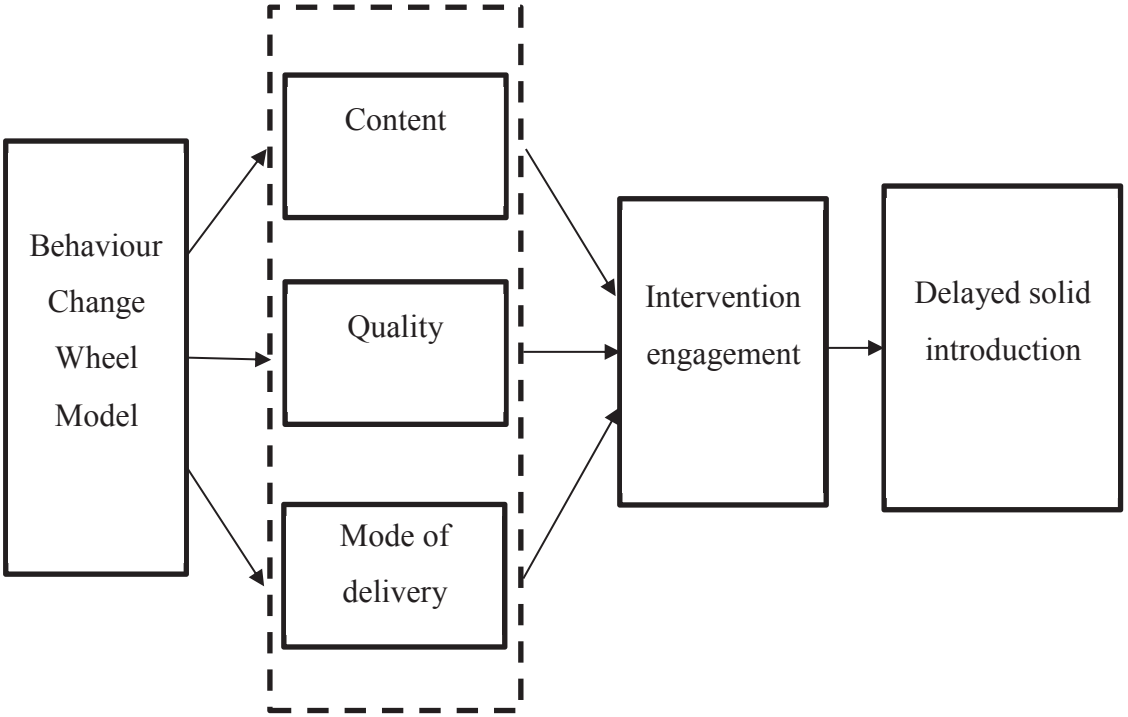

Figure 2.2 The conceptual framework utilised in this thesis

2.8 Summary and implications

Nutrition during early childhood is an important component of infants' life as it not only impacts on their growth and development, but also because lifetime eating habits and preferences are learned from a young age. The existing literature suggests that early cessation of breastfeeding, incorrect formula feeding practices and early introduction to solids increase the risk of RWG, overweight and obesity in children. Further, there are SES disparities which coexist, where those from a lower SES are more likely to practise unhealthy feeding practices. The parents' feeding behaviours play a major role in the infant's dietary intake particularly within the first few years of life. Understanding the determinants associated with infant feeding behaviours is essential to determine how to encourage parents to make healthier infant feeding decisions.

Digital technologies have become a novel approach to deliver health interventions also known as mobile health (mHealth). Firstly, this review has highlighted that there is limited research on using mHealth to support parents with infant feeding behaviours. Secondly, there is a need to explore whether conducting mHealth interventions among parents from a lower SES background in Australia is feasible. Thirdly, very little is understood about which features are most effective in engaging participants to use these interventions, specifically among parents. Finally, although mHealth interventions have been shown to influence positive behaviour change in the management and prevention of chronic diseases, there are few studies which rigorously measure participant engagement with mHealth interventions. This thesis will present further studies to address some of these research gaps.

2.9 Research Questions

To address some of these research gaps, this thesis will present studies that were implemented to develop the intervention, and to evaluate an mHealth intervention (the 'Growing healthy' app) that delivers expert advice to parents of infants about infant feeding. Specifically, this thesis aims to:

1. Critically evaluate the quality of information provided on infant feeding websites and apps;

2. Assess parents' current behaviours with infant feeding and identify determinants that would promote healthy behaviours, specifically on the timing of solid introduction;
3. Explore what app features will engage mothers to use an mHealth infant feeding intervention that will encourage delaying solid introduction;
4. Use an Engagement Index to assess whether participants' engagement level with the app was associated with delaying solid introduction; and
5. Explore perceptions of users of different engagement levels on the usefulness of the features included in the app through a qualitative study.

Chapter 3: Infant Feeding Websites and Apps: A Systematic Assessment of Quality and Content

3.1 Introduction

The previous chapter described the evidence base regarding the importance of targeting infant feeding practices to reduce the rates of childhood obesity. In considering opportunities for prevention, it highlighted the limited research about the use of mHealth to support parents achieve best practice in infant feeding behaviours. This chapter will describe a systematic analysis that sought to explore the quality and content of infant feeding websites and apps. This chapter has been published in the *Interactive Journal of Medical Research*[2] (this publication can be found in Appendix 3B).

3.1.1 Prevalence of technology use

The internet has become a popular medium for consumers seeking health-related information (Eysenbach et al. 2002) . The proportion of the population accessing the internet regularly is large and growing: 83% of Australians used the internet in 2012 and 2013 compared to 76% in 2010 (Australian Bureau of Statistics 2014). In 2014 the majority of Australians predominantly accessed the internet via desktops (80%) compared with around 19% who used mobile phones (MarginMedia 2014) . However, in Australia, mobile phone access to the internet is growing rapidly with a 33% increase from 2012 to 2013 (Australian Communication and Media Authority 2013).

Recent data suggest that searching for health and medical information was one of the top 15 reasons for accessing the internet among Australians over 14 years of age (Australian Communication Media Authority 2011). In addition to websites, smartphone applications (apps) represent another increasingly popular source of health information (West et al. 2012). The number of smartphone apps downloaded globally was around 2.5 billion in 2009 and is expected to reach approximately 268 billion in 2017 (Statista 2016). In Australia, 68 per cent of the surveyed population with a smartphone (8.9 million) with internet access downloaded a mobile app in 2013

[2] (Taki et al. 2015)

(Australian Communication and Media Authority 2013). It is estimated that presently there are more than 165,000 mHealth apps available in the Apple iTunes® and Android™ app stores, and with the growth of smartphone ownership in both the United States and Australia, the utilisation of health apps is likely to continue to rise (Aitken & Gauntlett 2013; Misra 2015).

3.1.2 The quality of website and smartphone applications on infant feeding

Increasingly, parents are turning to the internet for information and support about how and what to feed infants and toddlers (Buultjens, Robinson & Milgrom 2012), including infant feeding issues such as breastfeeding, formula feeding, introducing solids and also the type of food to introduce (Bernhardt & Felter 2004). A Google Consumers Survey found that expecting parents conduct internet searches twice as frequently as non-parents (Rost, Johnsmeyer & Mooney 2014). However, there are concerns regarding the quality of information provided on websites and apps about infant feeding as this may lead to the adoption of inappropriate practices (Rosser & Eccleston 2011).

There is evidence that many eating habits and preferences are formed in infancy and childhood and are then carried through to adulthood (Baird et al. 2005; Skinner et al. 2002). As poor eating habits, such as eating too many energy-dense foods or eating too few fruits and vegetables, begin in early life, there is a key opportunity to support parents to establish healthy eating in early life (Spence et al. 2013; Starling Washington et al. 2010). Given this, it is important that the information provided to parents is continuously updated and consistent with the latest evidence-based Infant Feeding Guidelines, such as those available in Australia (National Health and Medical Research Council 2012). This will ensure that parents have access to credible and good quality sources of information.

Presently there is little information on the quality of websites and apps regarding infant feeding practices accessible in Australia. Despite this, various tools are available for evaluating the quality of web-based health information. The evaluation of quality includes assessing the website and app content, its credibility, currency, accuracy, reliability, readability and design (Ghezzi, Chumber & Brabazon 2014; Pealer & Dorman 1997). However, there is evidence that website developers rarely use these tools (Reichow, Shefcyk & Bruder 2013). Several studies have evaluated the content of

websites and apps focused on health issues such as asthma, pain self-management and warfarin intake. These studies suggest that the quality of the information provided and the user-friendliness of these resources varied substantially (Huckvale et al. 2012; Nasser, Mullan & Bajorek 2012; Reynoldson et al. 2014).

The assessment of the suitability of health information focuses on factors which affect readability and how well information can be understood by the general public. The Suitability of Assessment Material is a tool used to systematically assess the appropriateness of information in terms of content and literacy demands, and to measure graphics and layout, learning motivation and cultural specificity (Doak, Doak & Root 1996). While health information is widely available on the internet through websites and apps, we cannot assume it is usable if it is not clearly understood by the consumer. Indeed many individuals, particularly adults with poor health and low literacy, who are most in need of this information, may not find this information usable (Birru et al. 2004). An overestimation of consumers' ability to comprehend the information provided on the internet may ultimately increase the risk of adopting inappropriate behaviours (Walsh & Volsko 2008).

This chapter examines the quality element that is included in the conceptual framework developed for this thesis (Figure 3.1). This will include exploring factors that contribute to developing good quality websites and apps which in turn impact on participant engagement in mHealth interventions.

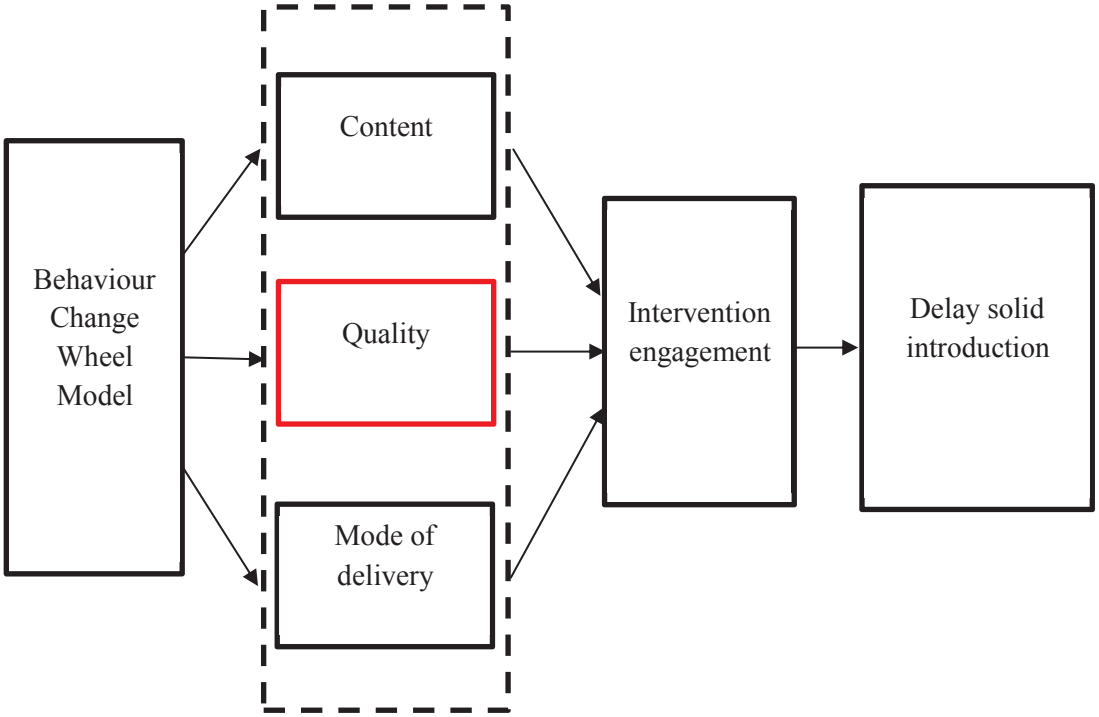

Figure 3.1 The element explored in the conceptual framework addressed in this chapter is highlighted in red

3.2 Aims

This systematic analysis aimed to critically evaluate information provided on infant feeding websites and apps. It addressed the quality of content, credibility, currency, accuracy, reliability, readability and design; the comprehensibility, including the accuracy and coverage of the content; and the suitability, including literacy level, cultural appropriateness, content and layout, of information available.

3.3 Methods

A systematic analysis was conducted between December 2013 and December 2014. It used various tools to evaluate the quality, comprehensibility, suitability and readability level of health information on infant feeding practices from websites and smartphone apps.

The first stage of the systematic analysis involved the selection and evaluation of infant feeding websites and apps. The second stage entailed critically evaluating the selected websites and apps.

3.3.1 Stage 1: Website and app selection

Websites

Infant feeding websites were identified using Internet Explorer and specifically Google and Bing to conduct searches. The selection of the internet browser and search engines was based on the most commonly used in Australia (MarginMedia 2013; StatCounter 2015). The key search terms used for website identification included 'infant feeding', 'baby feeding', 'breast feeding', 'infant feeding schedule', 'infant formula', 'formula feeding', 'introducing solids', 'introducing baby solids', 'solids and fussy babies' and 'introducing solids schedule'. These key terms were identified on Google trends as the terms in relation to infant feeding practices most frequently used by consumers (Google 2015). Evidence suggests that consumers seldom search beyond the first page on search engines such as Google for online health information (Morahan-Martin 2004). To ensure comprehensive sampling, the first 30 websites for each search term in both search engines were screened (that is, the first three search pages containing 10 entries per page). Another researcher (LW) on the research team screened the websites using predefined inclusion and exclusion criteria (Figure 3.2). If they met these criteria, the websites were then reviewed using the tools described in Table 3.1 (in Section 3.4.1). All websites were cross-checked by the candidate. Any disagreements regarding which websites should be included in the study were discussed until consensus was reached.

Inclusion criteria

- websites or apps that include information on infants and children 0-1 years
- available in Australia
- written in English
- information last updated between 2003-2014
- **websites and apps that address at least one of the following:**
    - ***healthy milk feeding behaviours:*** breast, formula, bottle, expressed breast milk, frequency, timing, correct preparation, feeding on demand, non-nutritive feeding
    - ***healthy solid food feeding behaviours:*** age of introduction, types of foods introduced, repeated exposure, varied exposure, reducing exposure to unhealthy food/beverages

Exclusion criteria

- electronic books, videos, YouTube clips, audio, news, magazines, podcasts, blogs, pdf and word documents
- developed in countries other than Australia (exclusion for websites only)
- content last updated prior to 2003
- content only on feeding for children older than 1 years of age
- website or smartphone apps that could not be accessed due to a broken/dead link or app
- apps that are not free to consumers

Figure 3.2 Inclusion and exclusion criteria for selection of website and smartphone apps

Apps

Infant feeding apps were identified on the two of the largest smartphone operating systems: iOS® (developed by Apple Inc., Cupertino, CA, USA) and Android™ (a Linux-based system currently owned by Google, Mountain View, CA, USA). The iOS® apps were searched using iTunes® (Apple Inc.), and Android™ apps were searched on Google Play™, a digital application distribution platform, using the same search terms utilised in the website search. However, as few apps were found using this search strategy, a broader search strategy was adopted. The following terms 'infant feeding schedule', 'infant formula', 'introducing solids', 'introducing baby solids', 'solids and fussy babies' and 'introducing solids schedule' were revised to 'bottle feeding', 'baby solids', 'baby food' and 'baby weaning' instead. All the apps identified using the key terms were screened for eligibility as both iTunes® and Google Play™ do

not sort by the most commonly-used apps as Google does when searching for websites. The researcher (LW) involved in this study screened the iOS® apps and the candidate screened the Android™ apps using predefined inclusion and exclusion criteria. The apps were then reviewed in stage two if they met the criteria. All apps were cross-checked by the candidate. Any disagreements regarding the inclusion of apps in the study were discussed until consensus was reached.

Inclusion criteria for selecting websites and apps for this study are show in Figure 3.2. Websites were restricted to those which originated in Australia to identify whether the information provided is consistent with the Australian Infant Feeding Guidelines (National Health and Medical Research Council 2012). However, this requirement did not apply to apps as app stores cannot restrict products by country of origin. Although to be included they needed to provide at least information on the Australian Infant Feeding Guidelines. The websites and apps needed to have included information on at least one of the following topics around healthy milk feeding behaviours (breast, expressed breast milk, formula feeding, frequency, timing, correct preparation, feeding on demand, non-nutritive feeding, repeated exposure, varied exposure and reducing exposure to unhealthy food/beverages) or healthy solid food feeding behaviours (age of solid introduction, types of food introduced, repeated exposure, reducing exposure to unhealthy food/beverages). Additionally, websites and apps that could not be accessed due to broken/dead links, electronic books, videos, YouTube, audio, news, podcasts, blogs, PDF and Word® documents were excluded. In addition only free apps were included.

3.3.2 Stage 2: Assessment of infant feeding information on the websites and smartphone apps

A variety of tools was used to assess the quality, suitability and readability of infant feeding websites and apps (described in Table 3.1). This was to ensure the websites and apps were comprehensively assessed and for reliability purposes.

Table 3.1 Summary of the scoring criteria for evaluation tools and items measured

Evaluation tools/items	No. of items	Scoring system	Final composite score
Quality of information			
Health-Related Website Evaluation Form (HRWEF)[a]	29	0= Not applicable 1= Disagree 2= Agree	>90%= Excellent 75-89%= Adequate <75%= Poor
Quality Assessment Tool for Smartphone Apps[b]	31	**Items judged yes/no were scored:** 1 point= Yes the application meets the criterion 0 points= No, the application does not meet the criterion **Items marked with an asterisk (*) were scored as:** 3= 100% of the application meets the criterion 2= 50% or more of the application meets the criterion 1= Less than 50% meets the criterion 0= The application does not meet the criterion at all	>90%= Excellent 75-89%= Adequate <75%= Poor
Quality Component Scoring System (QCSS)[c]	20	0= No information 1= Partial information 2= Complete information	>80%= Excellent 70-79%= Very good 60-69%= Good 50-59%= Fair <50%= Poor
Suitability of information			
Suitability of Assessment Material[d]	40	0= Not suitable 1= Adequate 2= Superior	70-100%= Superior 40-69%= Adequate 0-39%= Not suitable
Items measured in the website and app quality tools			
Information content (Coverage)[e]	19	2= Complete 1= Partially complete	3= 100% of the application meets the criterion 2= 50% or more of the application meets the criterion

			1= Less than 50% meets the criterion
Information content (Accuracy)	19	+1= Correct advice -1= Incorrect advice 0= Not addressed	
Reading Level[f]		2= Agree if reading level was <8th grade 1= Disagree is reading grade level was >8th grade	

[a] Health-Related Website Evaluation Form (Health On Net Foundation 2010)

[b] Quality Assessment Tool (Appendix 3C)

[c] (Ghezzi, Chumber & Brabazon 2014)

[d] Suitability of Assessment Material (Doak, Doak & Root 1996)

[e] The Infant Feeding Guidelines was used to analyse information content (National Health and Medical Research Council 2012) (Appendix 3D)

[f] Readability tools: Simple Measure of Gobbledygook (SMOG) (McLaughlin 1969) & Flesch-Kincaid (F-K) (Si & Callan 2001)

Quality assessment of infant feeding websites and apps

Websites

Website quality was assessed using two validated tools: the Health Related Website Evaluation Form (HRWEF) (Pealer & Dorman 1997) and the Quality Component Scoring System (QCSS) (Ghezzi, Chumber & Brabazon 2014; Martins & Morse 2005). Combining these tools facilitated a deeper comprehension of the quality of the websites, as they contain different criteria.

The HRWEF tool is currently used by a non-government organisation, the Health On the Net Foundation Code of Conduct (HON code) (Health On Net Foundation 2010), to certify the quality of an array of health-based websites. It assesses the quality of websites in terms of the content, credibility, currency, accuracy, reliability, readability and design of web-based health information. The QCSS tool was previously utilised for medical website evaluations (Martins & Morse 2005; Peterlin et al. 2008). The assessment criteria in this tool include: purpose of the content; disclosure of authors/sponsors; currency of information; accuracy and reliability of information; accessibility and interactivity; readability of information; and graphics/layout of information (Harland & Bath 2007; Van der Marel et al. 2009). The HRWEF scores each criteria as 0= not applicable, 1= disagree or 2= agree; the QCSS uses 0= no information, 1= partial information or 2= complete information. A final score assessing each item on both of the tools were calculated. Using the HRWEF tool websites were rated as either excellent (>90%), adequate (75-89%) or poor (<75%). Using the QCSS tool, websites were rated as excellent (>80%), very good (70-79%), good (60-69%), fair (50-59%) and poor (<50%).

Apps

At the time of conducting the study (December 2013), there were no published, validated tools available to evaluate the quality of apps. Given this, the candidate developed a Quality Assessment Tool (Appendix 3C). Tools previously developed in other studies (Huckvale et al. 2012; Reynoldson et al. 2014) did not comprehensively address the quality of apps. For example, one study only focused on comprehensively analysing the content of apps that provided information on asthma management

(Huckvale et al. 2012). The second study analysed the quality of apps for pain self-management, measuring five components including: product description (app specifications), development team (information about the developers and their qualifications), content (detailed information on pain self-management), interface design (design, layout and ease of reading) and ease of use (navigation content security and interactivity) (Reynoldson et al. 2014).

The tool developed for this study was therefore based on items from the HRWEF tool used for websites (Pealer & Dorman 1997) as well as the tools used in previous studies (Huckvale et al. 2012; Reynoldson et al. 2014). It incorporated the scoring system used in one of the previous studies (Reynoldson et al. 2014). The scoring system included 29 items which either agreed= 1 or disagreed= 0 that the app met the criteria, while the remaining 12 items were scored as 3= 100% of the application met the criteria, 2= ≥50% of the application met the criteria, 1= <50% of the application met the criteria or 0= the application did not meet the criteria at all. The final scoring system used in the current study was similar to that of the HRWEF tool (Pealer & Dorman 1997), where a final score rated each app as excellent (>90%), adequate (75-89%) or poor (<75%) (Table 3.1). The QCSS tool was also used to measure the quality of the apps.

Comprehensiveness of infant feeding information on websites and apps

Comprehensiveness was items measured in the quality tools utilised. They assessed the accuracy and coverage of the content available on websites and apps. In addition, the candidate developed an infant feeding guide sheet with eight topics and 22 subtopics based on the Australian Infant Feeding Guidelines (National Health and Medical Research Council 2012) to identify if the information provided on these resources was consistent with best practice (Appendix 3C). For each topic on infant feeding, the guide sheet measured accuracy, defined as the reliability and consistency of information with the guidelines (National Health and Medical Research Council 2012), rated as either correct (+1), incorrect (-1) or absent (0). Completeness, defined as the breadth of information provided on each topic, was measured as 2= complete, or 1= partially complete. The total score was then summed and averaged against the 19 items to calculate a final score for the utilised quality tools which included, 3= 100% of

information was covered/accurate, 2= ≥50% of information was covered/accurate or 1= ≤50% of information was covered/accurate.

Suitability of infant feeding information on websites and apps

The Suitability Assessment of Material (SAM) tool (Doak, Doak & Root 1996) is a validated instrument used to evaluate the appropriateness of information for the target audience relating to literacy level, cultural appropriateness, content and layout. Information on the websites and apps was scored as 0= not suitable, 1= adequate, 2= superior. Each website and app was given a final rating of superior (70-100%), adequate (40-69%) or not suitable (0-39%).

Readability of infant feeding information on websites and apps

The term *readability* refers to the grade level of written text. Readability was measured on the HRWEF, the Quality Assessment Tool for apps and the SAM instrument discussed above. Two readability tools were used to measure the content of websites and apps: the Flesch-Kincaid (F-K) (Si & Callan 2001) and Simple Measure of Gobbledygook (SMOG) (McLaughlin 1969). The F-K score was calculated by placing a block of writing from each website or app on a blank Microsoft Word® document (Professional Edition 2010) to record the reading ease and grade level. The same block of writing was pasted onto an online SMOG calculator that automatically calculated a SMOG score as well as the F-K reading grade level.

As the tools used to measure readability are American, the reading level of information provided could not be compared against the average reading level of Australians. The average level of reading of North American adults is between 7th and 8th grade level (National Center for Education Statistics 2005; Statistics 2003). In Australia, literacy competence is measured using the Adult and Life Skills Survey (ALLS) which uses a ranking scale from level one (lowest) to level five (highest) (Australian Bureau of Statistics 2008).The average literacy level for almost half of all Australians aged 15-74 years had literacy levels below level 3 (Australian Bureau of Statistics 2008, 2013a) Both the website and app quality tools use a scoring system of 2= agree if the reading level was ≤8th grade or 1= disagree if the reading level was >8th grade. The SAM

instrument rated readability as Superior= ≤5th grade, Adequate= 6th to 8th grade or Not suitable= ≥9th grade.

3.4 Results

3.4.1 Stage 1: Website and app selection

The systematic analysis was conducted between December 2013 and December 2014. Using the search terms generated 600 websites from Google and Bing and 2,884 apps from the app stores for Android™ and iOS® (Figure 3.3). The websites and apps were then screened, based on the inclusion criteria (Figure 3.2). A total of 44 websites and 46 apps were evaluated for the quality, comprehensibility, suitability and readability of the information. Of the 44 websites, eight were published by Australian governments, ten were sponsored by commercial organisations and the remaining 26 websites were non-commercial sites such as education/non-profit organisations or hospitals. Of the 46 apps, one was a commercial product, two had endorsement from a university and the Australian Breastfeeding Association, and the remaining 43 apps were non-commercial. A list of websites and apps included in the current study can be found in Appendix 3E.

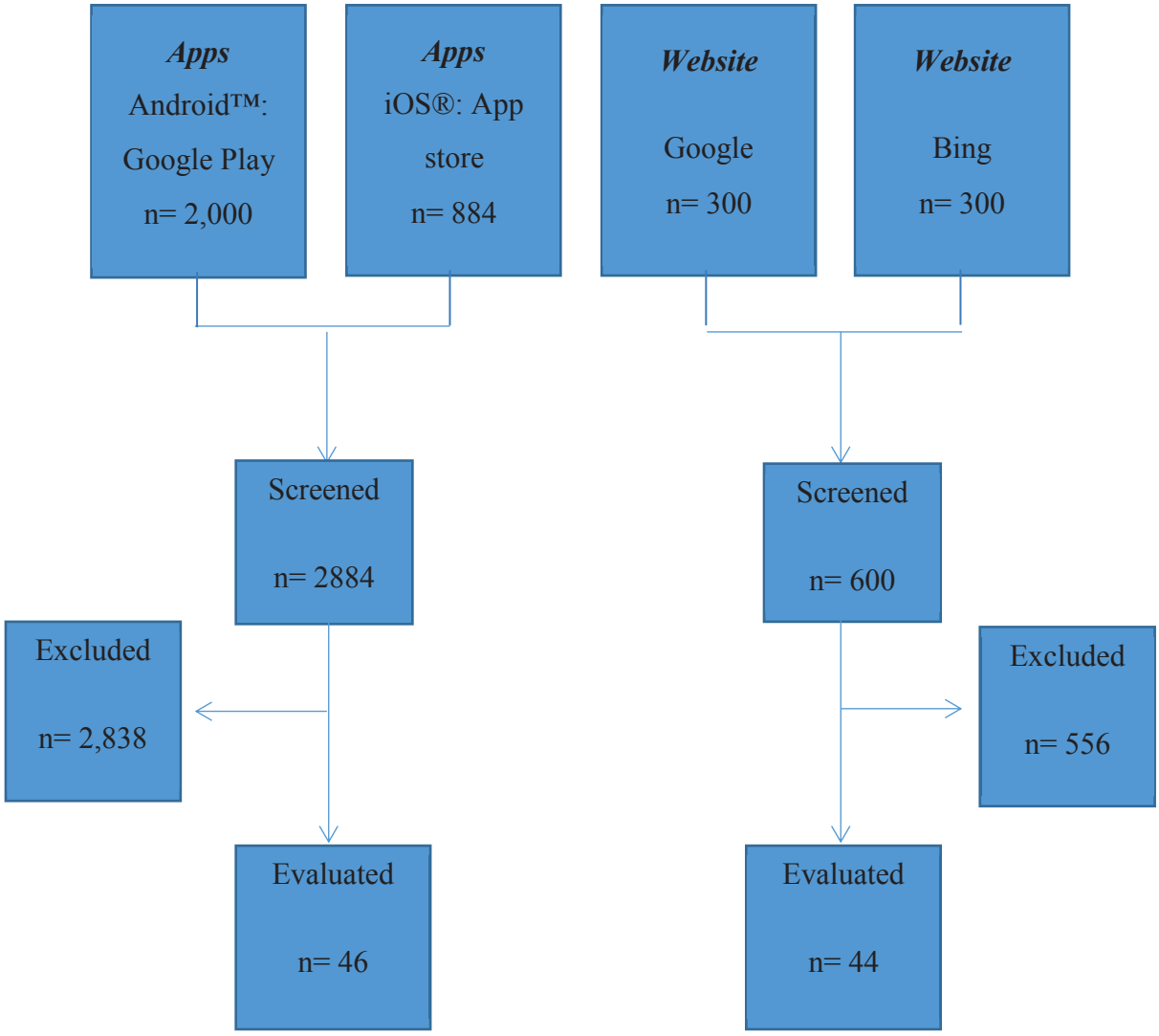

Figure 3.3 Flow chart of the number of websites and apps which were identified, screened and evaluated

Quality assessment

Figure 3.4 shows a box and whisker plot for each tool used to measure the quality of the websites and apps. The majority of the websites and apps were rated as poor quality. Of the websites, 61% (n= 27) were assessed as 'poor' using the HRWEF tool, and 45% (n= 20) were rated as 'poor' using the QCSS. Of the apps, 78% (n= 36) were assessed as 'poor' using the Quality Assessment Tool and 65% (n= 30) using the QCSS.

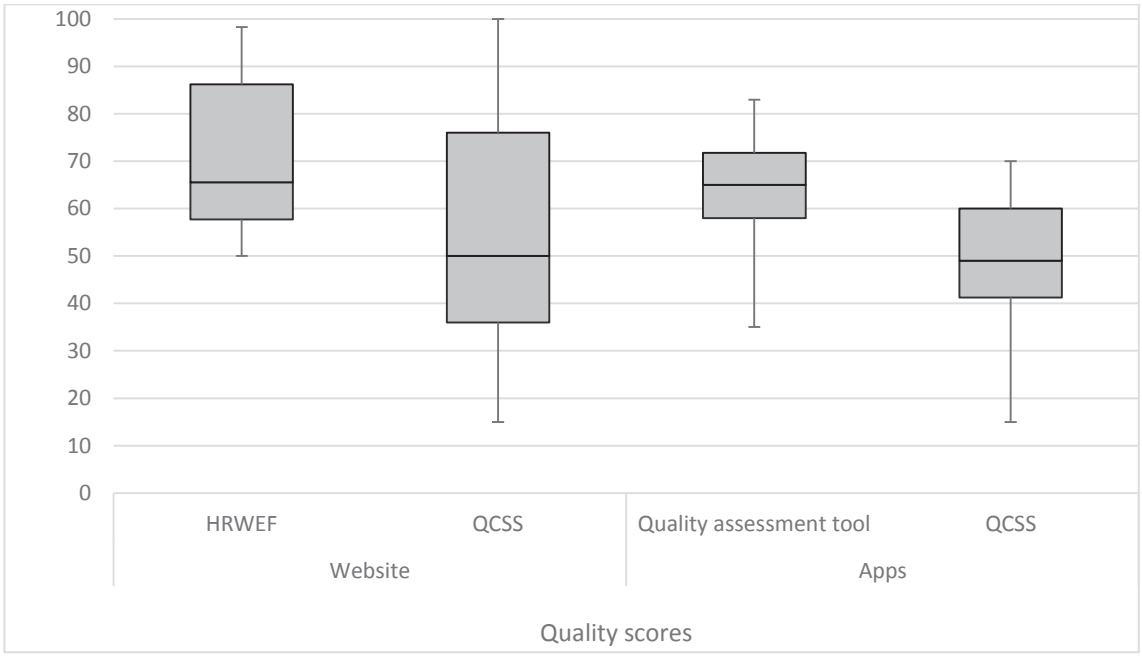

Figure 3.4 Box and whisker diagram of the range of scores for the quality of the websites and apps analysed

Websites

Using the HRWEF tool, the median score was 65% and the interquartile range (IQR) 57% to 86%. Eight of the 44 websites scored an 'excellent' (>90%) rating for quality with the top three websites being websites number 11, 24 and 43 (Appendix 3E). Whilst nine websites achieved 'adequate' scores, the remaining 27 websites attained 'poor' scores with the lowest three being websites number 26, 29 and 35. Four websites (numbers 11, 24, 36 and 40) subscribed to and attained the recommendations of HON code principles, a certification used to identify good quality websites from a non-government organisation.

Using the Quality Component Scoring System (QCSS) the median score for the included websites was 50% (IQR 36% to 76%). Seven of the 44 websites scored an

‘excellent’ (>80) rating. Similar to HRWEF findings, websites number 24 and 43 were found to provide information of ‘excellent’ quality. While seven websites were rated as ‘very good’, five were ‘good’, four were ‘fair’ and the majority (n= 20) were rated as ‘poor’.

Of the 44 websites, 11 reported the authors’ qualifications, one criterion for quality. Nine of the websites reported that their authors were healthcare professionals including nutritionists/dietitians, doctors or nurses/midwives; the authors of the other two websites had no professional expertise and were either journalists or mothers. In regards to the latest content update, eight websites had not been updated to reflect the most recent Infant Feeding Guidelines (National Health and Medical Research Council 2012); seven websites did not identify the date of last update.

The characteristics of websites that were rated as excellent compared to the websites rated poorly varied across the quality items measured. The majority of the websites rated as poor demonstrated minimal coverage of infant feeding topics; provided inaccurate information; required high reading levels for the text; were not updated with the latest Infant Feeding Guidelines (National Health and Medical Research Council 2012); lacked author’s credentials; and failed to provide external links to resources utilised.

Apps

Using the purpose-designed Quality Assessment Tool for apps, the median score for quality was 65% with an interquartile range of 58% to 71% (Figure 3.3). None of the apps scored ‘excellent’, ten apps achieved ‘adequate’ with app number 17 attaining the highest score of 83%, and the remaining 36 apps scored ‘poor’ with app number eight having the lowest quality score of 35%.

Using the QCSS tool, the median score was 49% with an interquartile range of 41% to 60%. One of the 46 apps were rated as ‘very good’, with app number 17 attaining the highest score of 70%. Whilst, 12 apps were rated as ‘good’ nine were ‘fair’ and the remaining 24 apps scored ‘poor’ Consistent with assessment using the Quality Assessment Tool, app number eight was rated as having the poorest quality at 15%. Ten of the 46 apps reported the author’s qualifications, four of which were health

professionals, including nutritionists/dieticians and nurses, and six had no professional expertise. The country of origin for the apps was unidentifiable, although from the language used in some apps, for example 'diapers' versus 'nappies', it can be deduced that there were some American, British and Australian apps. Five apps were last updated in 2011, thus not reflecting the most recent Infant Feeding Guidelines (2012).

Websites and apps that rates as 'poor' or 'adequate' shared many of the characteristics including: difficulty of navigation; poor design and colour; poor readability; poor accessibility including app functions such as text, font size, help requests, search options; limited coverage of topics from Australian Infant Feeding Guidelines (National Health and Medical Research Council 2012) and limited breadth of information provided.

In summary, the Australian government website (24), and a non-commercial website (29), attained the highest and the lowest quality scores, respectively. While the quality scores for apps, number 17, which is a non-commercial app, scored the highest quality and app 8 attained the lowest quality scores.

Comprehensiveness

Websites

Using the Australian Infant Feeding Guidelines (National Health and Medical Research Council 2012) to assess their comprehensiveness, websites numbers seven and 11 scored 100% for comprehensibility, where all eight topics about infant feeding were covered and the information provided was accurate (Appendix 3E). The two most commonly covered topics in websites were – 'Encouraging, supporting and promoting breastfeeding' (29/44) and 'Introduction to solids' (37/44). Websites number 22 and 40 had the lowest scoring of comprehensibility, scoring 5%.

Apps

Of the 46 apps assessed, app number 14 scored the highest for comprehensibility (78%) while apps one and seven scored zero. Similar to websites, – 'Encouraging, supporting and promoting breastfeeding' (30/46) and 'Introduction to solids' (30/46) were the two most commonly covered topics.

As illustrated in Figure 3.5, few websites provided information on all the subtopics about infant feeding practices measured in this study. No apps completely covered the breadth of each topic. Topic six, breastfeeding in specific situations was the least covered with only one website and no apps addressing this topic. Overall websites covered a wider range of infant feeding topics and provided more extensive information about each topic than the apps. Despite this, the information on each topic was rarely complete.

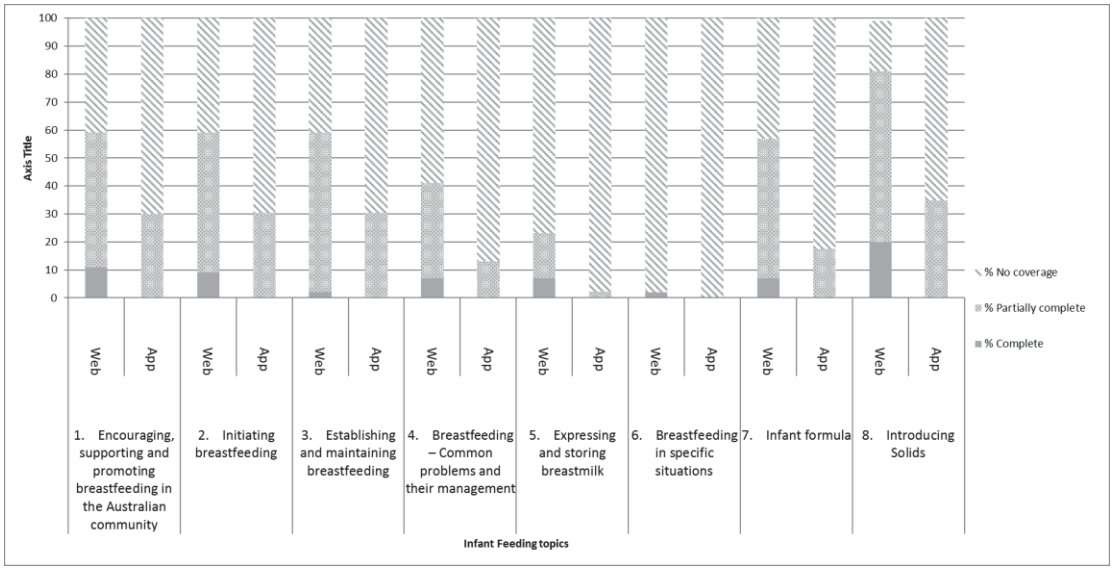

Figure 3.5 The breadth and coverage of topics from the Infant Feeding Guidelines provided websites and apps

Suitability of information

Suitability was measured using the Suitability Assessment of Material (SAM) grading scores (Doak, Doak & Root 1996).

Websites

Twenty websites (45%) achieved a 'superior' rating for suitability, 22 (50%) websites attained 'adequate' suitability and two (5%) websites were rated as 'poor'. Table 3.2 indicates the individual measures within the SAM criteria. Less than half the websites addressed learning stimulation or motivation. None of the websites addressed cultural specificity of information relating to infant feeding practices among people from diverse backgrounds and demographics. Overall, website five scored the highest suitability rating (87.5%) while website number 3 attained the lowest score (45%)

Apps

Seven apps (15%) achieved a ‘superior’ rating for suitability, 18 (39%) apps attained ‘adequate’ suitability and 19 (42%) apps were rated as ‘poor’. Similar to the website, none of the apps addressed cultural specificity of information relating to infant feeding practices among people from diverse backgrounds and demographics. Overall, apps number 17 and 35 attained the highest and lowest suitability scores, respectively.

Table 3.2 Adequacy of infant feeding websites and apps in addressing the Suitability of Assessment Material criteria

SAM Characteristic	Website (n= 44)		Apps (n= 46)	
	Superior[a]	Adequate[a]	Superior[a]	Adequate[a]
1. Content				
Purpose is evident	77%	23%	43%	17%
Content about behaviours	98%	-	94%	6%
Summary & review	7%	16%	-	11%
2. Literacy demand				
Reading grade level	3%	36%	-	39%
Writing style, active voice	89%	9%	89%	11%
Vocabulary uses common words	93%	7%	100%	-
Context is given first	93%	5%	100%	-
3. Graphics				
Cover graphic shows purpose	36%	50%	94%	-
Type of graphics	45%	20%	67%	-
Relevance of illustrations	66%	7%	50%	11%
List, tables, figures explained	7%	2%	-	-
Captions used for graphics	7%	7%	11%	89%
4. Layout and typography				
Layout factors	100%	-	100%	-
Typography	100%	-	100%	-
Subheads (chunking) used	75%	7%	100%	-
5. Learning stimulation, motivation				
Interaction used (question-and-answer format used)	-	9%	11%	11%
Behaviours are modelled and specific	7%	-	-	7%
Motivation	-	7%	-	-
6. Cultural appropriateness				
Cultural image and examples	-	-	-	-

[a] Required score for 'adequate' suitability- 40-69% and for 'superior' suitability- 70-100%

Readability

Readability grades for all evaluated websites and apps are shown in Table 3.3. While there was some variability in the actual readability grades attained, the results were similar using all three tools.

Flesch-Kincaid (F-K) readability grade

Websites

The mean F-K readability grade for websites was 10.2 (SD 2.1) using the F-K test on Microsoft Word® and the online F-K calculator. Ten websites were written at approximately 8th grade level or below. Website 43, a government website, was scored with the lowest readability at 6th grade six and websites numbers 14, 18 and 41 (all commercial websites) had the highest readability grades (above 12th grade).

Apps

The mean F-K readability grade level for apps was slightly lower than websites, (9.2, SD 2.1). There were 14 apps written at approximately 8th grade level or below. The app with the lowest readability level (5th grade) was app number 3, whereas the highest readability level was found in apps numbers 14 and 17 (above 12th grade).

SMOG readability grade

Websites

The median SMOG readability grade level was 10 (IQR 7-10). Using the SMOG formula, 16 websites were assessed as having a reading level suitable for 8th grade or below. Consistent with the F-K test, the SMOG formula identified website number 43 as having the lowest readability level (4th grade). Although, website number 23 scored the highest readability level (beyond 12th grade), which was different to that using the F-K test.

Apps

The median SMOG readability grade level for apps was 7 (IQR 7-8). Using the SMOG formula 20 of the apps were written at approximately 8th grade level or below. Similar to the F-K analysis, app number three was written at the lowest reading level (4th grade) and app number14 was written at the highest readability level (10th grade).

Table 3.3 Readability scores of websites and apps using the Flesch-Kincaid and SMOG test

	F-K grade[a]	F-K grade[b]	SMOG grade[c]
Websites	Median 9	Median 9	Median 10
	IQR 8-11	IQR 8-11	IQR 7-10
Apps	Median 8	Median 8	Median 7
	IQR 7-10	IQR 7-10	IQR 7-8

[a] Flesch-Kincaid (F-K) test: using Microsoft Word® function

[b] Flesch-Kincaid (F-K) test

[c] Simple Measure of Gobbledygook (SMOG)

3.5 Discussion

The aim of this study was to examine infant feeding websites and apps using a range of quality indicators. The findings of this unique analysis highlighted that very few websites and no apps available to consumers achieved an 'excellent' rating in presenting a variety of infant feeding topics. The main reasons that contributed to websites and apps being rated as 'poor quality' included limited coverage of infant feeding topics, high reading levels required of the text, lack of details about author credentials and poor design and layout, impacting on navigation. This study is valuable in that it was the first systematic analysis to evaluate websites and smartphone apps providing information on infant feeding practices.

3.5.1 Quality of infant feeding websites and apps

This systematic analysis found that the majority of the websites and apps on infant feeding were rated as 'poor' quality. In contrast, other studies which have evaluated health-related information from websites, using similar tools, reported 'adequate' ratings for the majority of the included websites (Nasser, Mullan & Bajorek 2012; Peterlin et al. 2008). Further, a study analysing apps for the management of obesity, rated the majority of the apps as 'fair' (Gan & Allman-Farinelli 2011).

The lower rating amongst infant feeding websites and apps may reflect the wide range of potential designers, including parents, infant food companies, journalists and professionals with expertise in this domain. This contrasts to apps and websites focussing on specific medical conditions which are likely to have been developed by health experts, consequently improving the quality of content, by increasing the

credibility of the source, accuracy and coverage of the information, and the inclusion of references. Low quality scores were influenced by number of resources developed by authors from a non-professional background, and the number of sites where limited information meant that author credibility could not be assessed. Information enabling consumers to ascertain website credibility can support them to judge the quality of information posted on sites (Rains & Karmikel 2009).

In this analysis commercial websites achieved the lowest quality ratings, a finding consistent with other studies (Thakurdesai, Kole & Pareek 2004; Van der Marel et al. 2009). This finding supports the proposition that commercially-motivated sites may set different criteria for information provision and may not represent the existing evidence base (Thakurdesai, Kole & Pareek 2004; Van der Marel et al. 2009). Further, a qualitative study which explored maternal perceptions of the trustworthiness of healthy eating information sources reported that food manufacturers were the least-trusted source for web-based health information (O'Key & Hugh-Jones 2010). However, there is a lack of information on the education levels of these participants. The results therefore may not be generalised particularly as people of disadvantaged background may have lower health literacy levels and differ in technique to identify a reliable source. To minimise the risk of disseminating misleading or inaccurate information, it is important that website developers consider using a tool such as the HON Code of Conduct (Health On Net Foundation 2010) in the early stages of development.

3.5.2 Certifying health websites and apps

Four websites stated that they had subscribed to HON code principles. Of these, two attained an excellent quality score. Therefore, using such a tool not only provides a certified and objective endorsement for consumers of its quality, but it also encourages website developers to maintain high quality standards. A qualitative study found that online health information seekers rarely evaluate the credibility of sources (Eysenbach & Köhler 2002). In that study, participants did not show an interest in assessing website credibility by using the "about us", disclaimer or disclosure sections on the website. Rather the participants' reported they assessed credibility by eye-balling the available source, the design and layout of the website, language used and ease of navigation. A method of certification could be promoted to assist consumers and in turn would help to ensure they are exposed to high quality information likely to promote health.

At the time of conducting the analysis no tools were available to analyse the quality of apps, which led the candidate to develop a Quality Assessment Tool. However, a recently published tool, the Mobile App Rating Scale (MARS), was developed to assess the quality of mobile health apps (Stoyanov et al. 2015). A majority of the indicators measured in the MARS tool, such as functionality, aesthetics and information quality, are similar to those measured in the tool utilised in the current study. An additional indicator of app quality in MARS that was not measured in this study is app engagement. The developers of the MARS tool undertook a more extensive analysis on its development and validation (Stoyanov et al. 2015) compared with that used in this study. It is therefore suggested that researchers consider utilising the MARS tool in the future to both develop and assess good quality mHealth programs.

In Australia medical apps which are used as a diagnostic or monitoring tool are currently subject to formal approval processes before being released to consumers or patients through the Therapeutic Goods Administration (TGA). However, general health and well-being (non-invasive) apps are not regulated (LifeScientist 2013). The Victorian Government have recently developed a program, 'Healthy Living apps', which informs consumers about recommended health apps that are available and effective for healthy behaviour change (Victoria Health 2016). The recommended apps were reviewed, assessed and rated by experts using the MARS tool (Stoyanov et al. 2015) and their effectiveness with regards to behaviour change was assessed using the Behaviour Change Wheel Model (Michie, van Stralen & West 2011). This is an innovative approach to guide consumers towards high quality health apps. It would be beneficial to further regulate the release of any health app until approved by a Government organisation before public release, as the TGA does with medical apps.

The use of certified endorsement to regulate the quality of websites and apps could also ensure that the information shared is constantly updated and in line with appropriate guidelines. In the current study the length of time since the last revision was found to be inversely related to quality, where the more recently updated websites and apps scored higher in quality than those with earlier dates of revision. Similar observations were reported in a study that assessed smartphone apps around pharmacology education. It reported that apps included in their study had not been updated for several years, thus questioning the reliability and accuracy of the content (Haffey, Brady & Maxwell

2014). With the rapid growth of apps and constant updates of app versions, there is a need to continuously assess and regulate these sources (Haffey, Brady & Maxwell 2014).

These findings are further reflected in a study that examined the evolution of asthma based apps and found that the number of apps on asthma more than doubled over the two years of the study (Huckvale et al. 2015). Although the study's findings reported no difference in the comprehensiveness of the information available in the newer apps, it did identify improvements in the features offered. Compared to the apps that had not been updated, later versions of apps included in this study scored better on presentation (e.g. ease of navigation, and appropriate layout and graphics) although not content.

The use of a certified endorsement scheme for apps and websites may be a useful strategy for policy makers to regulate the information on health websites and apps. Another policy innovation might include action by the National Health and Medical Research Council (NHMRC) to provide a publically available app with the release of health related guidelines – for example with the release in 2012 of the new Infant Feeding Guidelines. This innovation would be potentially powerful as the experts responsible for reviewing the evidence could contribute directly to the dissemination strategy (the app) thus reducing message dilution when translating evidence into implications for policy and practice.

Another factor contributing to the poor quality of the websites and apps was poor content comprehensibility, including the depth of topics addressed and the completeness of the information. Only two websites achieved well on this metric. Similar findings were identified in a study that analysed online information about dementia, where very few websites covered all relevant topics (Dillon, Prorok & Seitz 2013). Despite the efficiency and convenience of using the internet to obtain health information, its value to consumers becomes limited if it lacks accurate information (Benigeri & Pluye 2003). Thus consumers would be required to utilise a number of information sources on a particular health subject. Website and app designers should therefore consider providing health information on a range of topics or provide references on topics which are not covered in their resource (Dillon, Prorok & Seitz 2013). In addition to using appropriate specific guidelines and tools to develop good quality websites and apps, designers

should also consider assessing user requirements specific to health conditions and topics in order to meet the potential users' needs and expectations (Schneider, van Osch & de Vries 2012).

3.5.3 Adherence to health information best practice principles

The analysis rated a few websites with a high comprehensibility score as they addressed the widest range of topics and provided an appropriate level of detailed information consistent with the Australian Infant Feeding Guidelines (National Health and Medical Research Council 2012). Very few websites provided incorrect information. These results are consistent with other studies that have reported on the comprehensiveness of information related to health guidelines (Huckvale et al. 2012; Rains & Karmikel 2009). The incorrect information provided in resources may have serious implications, as the lay person may not be familiar with the Infant Feeding Guidelines and thus be misguided to incorrect infant feeding practice.

This study highlights that most of the websites and apps were written at a reading level of 12th grade. This analysis is consistent with other studies (Nasser, Mullan & Bajorek 2012; Wallace et al. 2005) and is important given that the average reading level has been reported to be between 7th and 8th grade (National Center for Education Statistics 2005; Statistics 2003). It is crucial that app and website developers write resources that are suitable for the literacy levels of the general population as health-related information may be challenging for users with low literacy skills (poorly educated, culturally diverse background) (Estrada et al. 2000). It is particularly important given those with lower reading skills may indeed be most at risk for those health behaviours likely to increase health risks across life. As such, this audience may benefit most from appropriately written, well-targeted information, advice and support.

In the evaluation of the suitability of infant feeding information, the majority of the websites were rated as 'superior' or 'adequate', while most of the apps were rated as 'poor'. Using the SAM criteria, the graphics and cultural appropriateness were the least well addressed factors in websites and apps. This finding is consistent with a study (Wallace et al. 2005) that reviewed web-based information on osteoporosis and reported that few websites were culturally appropriate. Australia is ethnically diverse and internet access is high across all social groups. It is therefore necessary to address this

limitation in both websites and apps, and provide more culturally appropriate information (Friedman, Hoffman-Goetz & Arocha 2006). However, achieving this is not simple. A study evaluating health information on websites about cancer therapy (Friedman, Hoffman-Goetz & Arocha 2006) illustrated the difficulty of presenting information to cater to all ethnic backgrounds. As infant feeding practices can vary between people from different cultural backgrounds (i.e. diets, religious beliefs), it is important for website and app developers to consider identifying how they might appropriately address these differences in the early stages of development.

3.5.4 Strengths and limitations

One of the major strengths of this study was the development and utilisation of a Quality Assessment Tool to analyse the apps. This tool not only enabled the candidate to comprehensively analyse infant feeding apps but it also helped highlight the need for the development of a good quality app to support parents with infant feeding. Further strengths of the study was the use of two existing tools to measure the quality and readability of the websites and apps, a method which in turn enabled a comparison of the results.

There were a number of potential limitations of this study. Firstly, the study was limited to evaluating websites and apps written in English, and specifically only targeting Australian websites. Therefore, the findings may not be representative of websites and apps written in other languages or from other countries. A related limitation is that this study included only Australian websites while the apps were included regardless of the country of origin. This may have influenced the findings about to the comprehensibility and accuracy of the content. It is possible that the websites attained higher comprehensibility scores compared to apps, as the websites were more likely to include information from the Australian Infant Feeding Guidelines (National Health and Medical Research Council 2012). It may be useful for future studies to consider using international guidelines such as those from the World Health Organization to analyse infant feeding apps.

Another limitation in the developed criteria is the inclusion of only free apps. This may have limited the findings in exploring the quality of paid infant feeding apps and identify whether there is a difference with the free apps. Despite that said, this specific

criteria was set to explore the quality of free services in which a larger demographic are likely to utilise.

Another limiting factor to be acknowledged is the infancy of the development of apps compared with the websites which have existed for much longer. This might explain the poorer scores attained by the apps compared with the websites. Internet and smartphone applications are continuously updated. If this study was replicated using the same search terms, it may yield different websites and apps, and thus different results. To minimise this limitation the candidate used Google Trends to identify commonly searched terms around infant feeding practices.

Other limitations identified are the subjective nature of some measures of quality such as the design of the website and app, and the cultural appropriateness and layout of information. This subjectivity may impact on the variability in scoring. To address this potential limitation, another researcher was involved in the analysis of the quality and suitability of the websites and apps, and the scores were cross-checked with one another. Any variances in the results between one another were discussed until consensus was met.

3.6 Conclusion

It is evident that there are key areas for improvement to help increase the utility of the information related to infant feeding practices on websites and apps. The majority of websites and apps assessed in this study were of poor quality, had inappropriately high reading levels and few were given a good rating on all the tools utilised. No apps in this study addressed all eight topics in the Australian Infant Feeding Guidelines.

The implementation by government of policy or certification systems such as Health On Net Foundation Code of Conduct (HONcode) would enable consumers to identify reliable and appropriate information. It would also ensure that the readability level is appropriate for vulnerable populations. Involving users earlier in the development of health apps is advised, as well as establishing ways to merge user requirements with evidence-based content to provide high quality apps.

In the following chapter we move from our assessment of the quality of apps to a study that explored interest among mothers from disadvantaged background in an mHealth program that would support them with infant feeding behaviours. Further, the study also explores barriers associated with the uptake of healthy infant feeding behaviours.

Chapter 4: Qualitative exploration of mothers' interest in an mHealth program to support infant feeding and their beliefs and behaviours on the introduction of solids: determining the intervention mode for delivery and content

4.1 Introduction

The previous chapter reported on the first comprehensive analysis of the quality of websites and smartphone applications targeted at parents and providing information on infant feeding. Results revealed the existence of very few reliable and credible websites and apps. The findings from that study identified an opportunity for researchers to explore the practicality of supporting parents with infant feeding through this mode. This chapter analyses qualitative interviews to explore mothers' interest in obtaining infant feeding information in an mHealth app. In addition, the candidate explored the beliefs and behaviours associated with decisions about the age of solid introduction. A part of this chapter has been published in *BioMed Central Pediatrics*[3] (this publication can be found in Appendix 4A).

The preceding chapters described the conceptual framework developed for this thesis, outlining factors that contribute to enhancing mothers' engagement with an mHealth intervention (Figure 4.1). These included mode of delivery, quality and the integration of a theoretical model. This chapter examines mothers' views on an mHealth program and features of interest to provide insight on modes of delivering an intervention among this demographic. The Behaviour Change Wheel model, COM-B system, was used to understand mothers' behaviours about solid introduction and the associated barriers to delaying solid introduction that needed to be addressed in the program.

[3] (Russell, Taki, Azadi, et al. 2016)

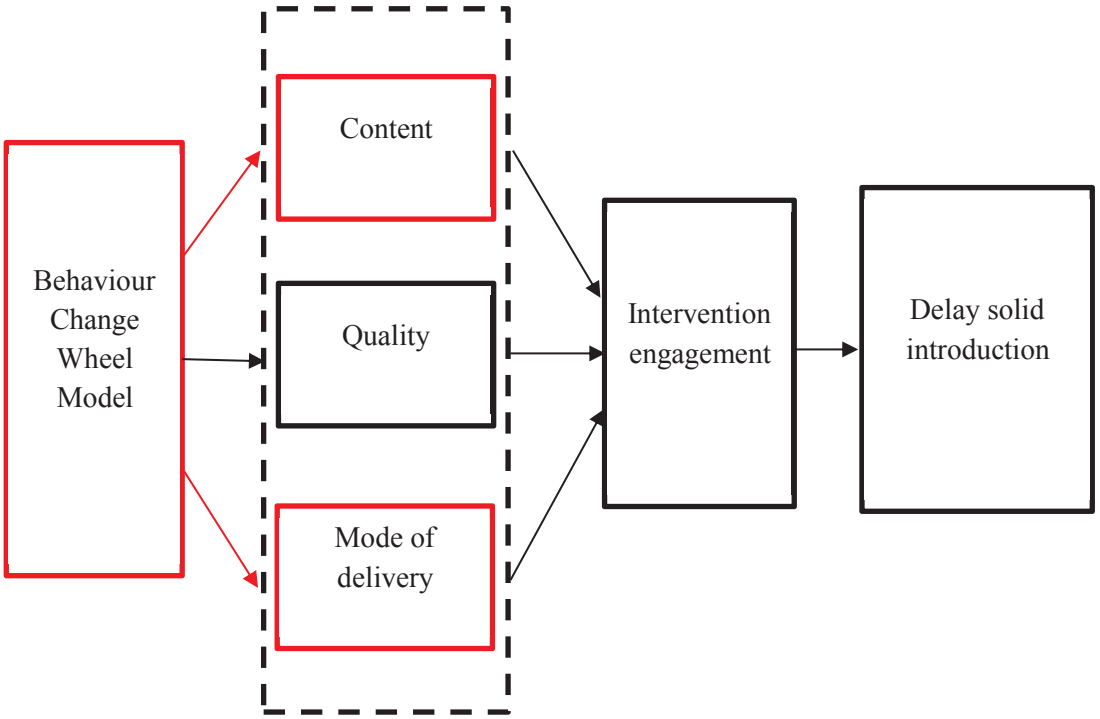

Figure 4.1 Relationships in the conceptual framework addressed in this chapter are highlighted in red

4.2 Aims

The study presented in this chapter addressed two key aims. The first aim was to investigate the interest of mothers in the development of a website and smartphone app (mHealth) that would provide information and support on healthy infant feeding practices. The second aim was to explore mothers' beliefs and behaviours on the introduction to solids.

The objectives of this chapter are to:

- identify features that would engage mothers to use an mHealth program that would provide information and support on healthy infant feeding practices; and
- explore (using the COM-B model) mothers' beliefs and behaviours related to the timing of solid introduction.

4.3. Methods

A qualitative study design was adopted to inform the development of an intervention on healthy infant feeding practices (Growing healthy program). This program was funded

by the Australian Primary Health Care Research Institute (APHCRI) which is supported by a grant from the Australian Government Department of Health and Ageing. The study was approved by the University of Technology Sydney Human Research Ethics Committee (ID 2013000463).

4.3.1 Recruitment

Mothers were invited to participate in this study through an advertisement on the Playgroups NSW e-newsletter between January and March 2014 (see Appendix 4B). Playgroups NSW is an organisation with 25,000 members who are predominantly parents and carers of children aged zero to five years. Monthly e-newsletters are sent to members. A banner for the study was included in the e-newsletter with a link to a web-based survey (Survey Monkey®) where the mothers were asked to provide demographic information and contact details.

Mothers were eligible to participate if they had not completed a university degree. Further, participants needed to be the primary caregiver, fluent in English, and have a baby less than one year old with no major health problems that may have affected the infant's feeding, eating and growth (for example chronic conditions). Mothers who expressed an interest in the study were contacted and screened accordingly to assess their eligibility to participate in the study. Eligible participants were sent a plain language statement and a consent form (see Appendix 4C) via email. Each participant was asked to provide verbal consent before participating in the telephone interview.

4.3.2 Data Collection

This study used semi-structured one-on-one telephone interviews. The selection of this methodology enabled the candidate to comprehensively explore each mother's interest in an mHealth program and the antecedents associated with delaying solid introduction. Although there are disadvantages to using telephone interviews, including the inability to observe facial expressions and body language (Berg, Lune & Lune 2004), telephone interviews were considered to be a suitable method for the target group. This approach allowed flexibility to schedule an interview convenient to the mother, which is essential to reach mothers with infants. Other advantages of this methodology include cost-effectiveness and greater participant anonymity which may reduce socially desirable response bias (Berg, Lune & Lune 2004; Novick 2008).

The semi-structured interview guide was developed to address the aims of this chapter (see Appendix 4D). One section of the interview schedule explored mothers' current access and use of technological devices (mobile phone, computer, laptop, iPad, notepad) and the internet. Their interest and preference in an mHealth program was explored with further questions obtaining their feedback on common modes of delivering an mHealth program. These included delivering the program through a smartphone application, website, text messages (including frequency of messages), forums, sharing information with other carers, recipes and videos on infant feeding (see Appendix 4D, Question 7).

Other questions addressed mothers' views regarding infant feeding practices such as milk feeding, age of solid introduction, first foods, and sleep and feeding patterns. For the purposes of this thesis, only questions associated with beliefs and behaviours about solid introduction were analysed (see Appendix 4D, Question 5). The questions on this topic were developed using the COM-B model (Michie, van Stralen & West 2011). Exploring the influence of mothers' Capability, Opportunity and Motivation on their Behaviour related to either early or delayed introduction of solids to their infant. To explore the mothers' capability about the commencement of solids, questions were shaped around knowledge and skills. For opportunity, mothers were asked about sources used to obtain information. Finally, to understand the mothers' motivation about introducing solids at the recommended age they were asked about influences on their decision making. An outline of the questions, mapped against theoretical domains of the COM-B model is provided in Table 4.1.

Interviews were conducted by either the candidate (n= 21) or an experienced researcher (n= 10) who was also involved in the study. Mothers were offered a $30 supermarket voucher to compensate them for their time. Interviews were audio-recorded with participants' permission and transcribed verbatim. All audio interviews were checked against the transcripts to ensure accuracy. The mean duration of the interviews was 43 minutes and ranged from 23 to 78 minutes.

Table 4.1 Qualitative questions developed to explore mothers' beliefs and behaviours on the timing of introducing solids using the COM-B model

COM-B Model	Intervention function	Interview questions
Behaviour		How old was your baby when you first introduced solids (regularly having solid foods)?
Capability	Knowledge	What kind of things made you decide or know when the timing was right to introduce solids?
Opportunity	Environmental context and resources	Did you receive any support or advice from anyone or anywhere about when to introduce solids foods to your baby?
	Social influence	What age do most of your friends introduce solids?
Motivation	Beliefs about consequences	The Australian Infant Feeding Guidelines (National Health and Medical Research Council 2012) have recommended that babies should start solids food at around 6 months of age. How do you feel about this recommendation? Do you think it is realistic?
	Intention	Have you thought about or planned when you would like to first introduce solids to your baby?
	Beliefs about capability	What kind of things made you decide or know when the timing was right to introduce solids?

4.3.3 Analysis

The qualitative analysis was undertaken in an iterative manner using a thematic analysis network approach (Attride-Stirling 2001). This method is data-driven and consists of three broad stages:

Stage A: breaking down the text, which included developing a coding framework and refining themes

Stage B: exploring the text, which included describing the themes; and

Stage C: integrating exploration, which included interpreting the themes derived from the analysis.

The transcripts were imported into the qualitative data analysis software package NVivo 10® and de-identified. The candidate and the senior researcher independently developed the coding manual. The COM-B model was used as a guide to developing the coding manual, but the identification of emerging codes was not restricted to this model. The analysis required repeated reading of transcripts, extraction and grouping of

relevant and recurring ideas, and identification of sub-themes and broader conceptual themes.

In developing the manual, two iterations took place with the candidate and the researcher each coding five transcripts until consensus was achieved. Any discrepancies in the allocation of codes were resolved through discussion. The inter-rater reliability of the coding was measured using the Coding Comparison query on NVivo 10®. This function calculates the percentage agreement represented by the number of characters that were coded similarly by both researchers against the total number of characters that are available in the document. This generates a Kappa Coefficient score, the statistical measure of inter-rater reliability where Kappa= 1 indicates complete agreement and 0 no agreement (Viera & Garrett 2005). Inter-rater reliability for the coded data on the mothers' *'technology use'* and *'interest in an mHealth program'* was rated as 'almost perfect agreement' (Kappa= 0.88) and for '*age of solids introduction'* was rated as 'substantial agreement' (Kappa >0.75) (Viera & Garrett 2005).

4.4 Results

4.4.1 Sample description

Table 4.2 provides socio-demographic characteristics of all the interviewees. Of the 120 mothers who expressed an interest in participating in this study, 29 were eligible and were interviewed between February and March 2014. The mothers were recruited from two regions in Australia, New South Wales (n= 16) and the Australian Capital Territory (n= 13). The sample were of Australian background (n= 20), aged 21-38 years, had completed trade certificates (n= 18) and were first-time mothers (primiparous) (n= 26). The infants were aged from 2-44 weeks (mean= 25.7 weeks) and included 13 males and 16 females. There were 19 breastfed, eight formula fed and two mixed fed (i.e. fed both breast and formula) infants. Of the 23 infants who had commenced solids, 19 had solids introduced before 26 weeks (six months).

Table 4.2 Demographic profile of participants and their infants' eating behaviour

	State	Age of mother (years)	Cultural background	Education level	Infant gender	Infant age (weeks)	Eating behaviour	Solid introduction (weeks)	Parity
1	ACT	38	Australian	Year 12	Male	30	Formula Feeding & Solids	18	Primiparous
2	ACT	21	Australian	Year 10	Male	28	Breastfeeding & Solids	17	Primiparous
3	ACT	26	Australian	TAFE	Male	44	Formula Feeding & Solids	17	Multiparous
4	NSW	26	Australian	Year 10	Male	28	Breastfeeding & Solids	13	Primiparous
5	ACT	32	Australian	TAFE	Female	36	Breastfeeding & Solids	24	Primiparous
6	ACT	25	Australian	TAFE	Female	32	Formula feeding & Solids	14	Primiparous
7	ACT	25	Australian	TAFE	Male	22	Breastfeeding & Solids	17	Primiparous
8	NSW	30	New Zealander	TAFE	Female	28	Formula Feeding & Solids	26	Primiparous
9	NSW	38	German	TAFE	Male	24	Formula Feeding & Solids	17	Primiparous
10	ACT	30	Australian	TAFE	Male	28	Formula Feeding & Solids	17	Primiparous
11	ACT	26	Australian	University (incomplete)	Female	16	Breastfeeding & Solids	16	Primiparous
12	ACT	37	Australian	TAFE	Female	44	Mixed Feeding & Solids	21	Primiparous
13	NSW	36	Australian	TAFE	Female	40	Breastfeeding & Solids	23	Primiparous
14	NSW	29	Australian	Year 12	Female	30	Breastfeeding & Solids	28	Primiparous
15	NSW	33	Australian	TAFE	Male	36	Formula Feeding & Solids	22	Primiparous
16	NSW	32	Malaysian	Year 12	Female	28	Breastfeeding & Solids	21	Primiparous
17	NSW	34	Australian	Year 12	Female	32	Breastfeeding & Solids	21	Primiparous
18	NSW	28	Australian	Year 12	Female	36	Breastfeeding & Solids	19	Primiparous
19	NSW	36	Australian	TAFE	Female	40	Breastfeeding & Solids	23	Primiparous
20	ACT	30	Australian	TAFE	Male	14	Formula Feeding & Solids	21	Primiparous
21	ACT	27	Australian	TAFE	Female	18	Breastfeeding & Solids	26	Primiparous
22	NSW	30	Australian	TAFE	Female	20	Breastfeeding	N/A	Multiparous
23	ACT	25	Australian	TAFE	Male	8	Breastfeeding	N/A	Multiparous
24	NSW	32	Australian	TAFE	Female	2	Breastfeeding	N/A	Primiparous
25	NSW	23	Australian	Year 10	Female	16	Breastfeeding & Solids	15	Primiparous
26	ACT	33	Australian	TAFE	Female	14	Mixed Feeding	N/A	Primiparous
27	NSW	23	Australian	Year 10	Male	12	Breastfeeding	N/A	Primiparous
28	NSW	30	Australian	TAFE	Male	16	Breastfeeding	N/A	Primiparous
29	NSW	27	Canadian	Year 12	Male	24	Breastfeeding & Solids	26	Primiparous

Not Applicable (N/A): participants did not introduce solids to their infant at the time of being interviewed
Technical and Further Education (TAFE)

4.4.2 Mothers' interest in an mHealth intervention

The majority of the mothers embraced the concept of an mHealth program that would support them with healthy infant feeding practices. Table 4.3 includes a summary of their use of information technology and interest in an mHealth program. Participants were asked of their opinion about various features described in Table 4.3, that they would like to see offered in an mHealth program. Overall there was consistency across all the participants in their belief that a program using this approach is beneficial.

Table 4.3 Mothers' use of technological devices and interest in modes of delivering the mHealth program (n= 29)

	Participants
Use of Information Technology	
Access to the internet	29
Device used to access the internet	
Computer/laptop	8
Smart phone	25
Tablet/ iPad	4
Location internet is accessed	
Home	24
Other	5
Internet sources accessed for infant feeding information	
Websites	27
Apps	9
Social networking	13
Elements of interest in an mHealth intervention	
Interest in an mHealth program	26
Features of interest	
Text messages	26
Video messages	16
Information and content about infant feeding practices	28
Weight tracking	15
Interconnectivity (sharing information)	18
Social networking or forums	27
Telephone or online support	26

Technology use

Access to the internet

The majority of the mothers (n= 25) reported using their mobile device to access the internet. Some reported using the phone in preference to the laptop or computer as it was more convenient and practical for them while looking after their infant ["*I probably use my internet phone a lot more … I'll just let her sleep in my arms, and I'll jump on my phone"* Participant 24]. In particular, the mothers' limited time was a common theme which influenced their choice of device used [*"In the early days with him, with feeding and that, it was probably my phone, but now that he's on a bit more of a longer routine in between feeds, maybe I'd say my iPad"* Participant 29].

Most of the participants reported using the internet on a daily basis ["*A lot. May be like 15, 20 times a day*" Participant 24]. The majority of participants (n= 24) accessed the internet at home for a variety of reasons. One of these included to access the Wi-Fi [*"At home because I use my Wi-Fi for all my devices"* Participant 6]. The mothers also felt they had more time to access the internet between their parental duties [*"No, mainly at home. I guess in between when she's sleeping I need some sort of outside world going on."* Participant18]. Others preferred to limit their technology use when they were out to enjoy their social life ["*Generally like I use it more when I'm at home, because if I'm out I'm pretty excited to be talking to other people"* Participant 24].

Websites accessed on the internet

Searching for infant feeding information was the main reason mothers reported using the internet. The most commonly-reported websites mothers searched for included 'Huggies', 'Australian Breastfeeding Association (ABA)', 'Essential Baby' and 'BabyCenter'. Although most mothers reported using Google as the 'Go to' source to answer specific questions about infant feeding and access appropriate websites. Those who reported using Google considered the first page of results as a measure of reliability of information [*"I'll type my question in to Google and whatever comes up and I usually use five websites…sometimes none of them are really true…just my common sense if I think it sounds like it would work or I'll give it a go"* Participant 28]. Others used forums or blogs to find solutions for their questions ["*When we were having difficulties, it always seemed to be in the middle of the night when you felt like*

you have no support…that covers partly why [I use] the Facebook page because there's always someone up feeding a baby or trying to settle a baby for you to talk to" Participant 4].

Compared to websites, very few mothers used apps for infant feeding information. Of the mothers who reported using apps, they were mainly used for tracking their baby's weight and timing the frequency of feeds [*"I was using an app when I was tracking feeding but I've stopped completely for a while"* Participant 21]. Apps were also used to help with settling techniques [*"Wonder Weeks…helped me when he was really fussy, because he was really unsettled"* Participant 28].

Engagement in an mHealth program

All mothers acknowledged that an mHealth program to support with infant feeding practices would be beneficial, although some mothers reported the usefulness would vary based on their personal experience. For example, multiparous mothers felt confident with infant feeding practices [*"Not for me, but I definitely would think a lot of first time mums in particular would"* Participant 7]. The mothers also considered their time as a potential barrier to usefulness of the program [*"Depending if I had time to read it or not"* Participant 22]. Others believed that a mother's instinct would be the main driver of her infant feeding decisions [*"It can be helpful, but you end up just going on your own, what your own needs are for the day, what you've got covered, what you feel like giving your baby"* Participant 8].

Interest in features for an infant feeding mHealth program

The mothers expressed various opinions about specific features that they were asked about which they would like in an mHealth intervention, and these are discussed below.

Frequency of messages

Mothers gave their views on the provision of text messages. They considered receiving individualised text messages or emails related to their infant's age and stage of feeding as useful. There were differences of opinion on how frequently messages should be sent. The majority (n= 18) suggested weekly messages would be appropriate [*"Yeah, probably weekly would be enough… but not in your face driving you mad that you just think 'oh God go away'"* Participant 24] and believed it was suitable as the infants'

needs change rapidly [*"Probably once a week because their feeding habits at a young age tend to change about once a week"* Participant 9]. While very few suggested they should be sent once a month (n= 1) or daily (n= 2) [*"probably like once a day or something, I wouldn't want it more than once a day"* Participant 12].

Telephone or online support

Most of the mothers felt positive about the idea of telephone or online support because of personal experience [*"Yeah, after being there you don't want other mums to have to experience it so if you can give them the information that'd be good"* Participant 28]. Some even reported using currently existing online and phone support programs [*"Yes, that would be - even a question page or feedback page…That's where BabyCentrer's good too"* Participant 13].

Social Networking or Forums

There were mixed feelings about the inclusion of social network groups or forums such as Facebook. Some felt it was a convenient method to communicate with other mothers [*"Yes that would be good, just talking to other mothers about similar experiences"* Participant 16] or that social networking groups would be useful to avoid feeling socially isolated or to use when other support was not available ["*that would be good, especially like living regionally…there's always another mum that's on at two or three in the morning*" Participant 24]. Mothers often used social networking sites to compare their experiences and confirm whether they are feeding their infant correctly [*"Yeah, I think that would be helpful. I don't post on that page, but I do read it… reading that you could say, oh I do that with Eric, so that must be okay"* Participant 10]. The majority of the mothers, however, felt there were already too many forums available [*"Yeah. But there are already a lot of avenues for that. So it would have to be something unique. Maybe if they had a doctor or like a specialist in the field telling or giving advice"* Participant 19].

Videos

The majority of the mothers expressed their interest in the inclusion of videos within an app to provide them with practical infant feeding skills [*"Yes…I'm not a great cook so if I knew how to do things it would be good"* Participant 13]. Similarly, mothers felt that the usefulness of videos would vary based on their knowledge or experience [*"I mean,*

that's good for first time mums definitely…when you get thrown in the deep end you're like 'What do I do?'" Participant 3].

Interconnectivity: Sharing app-based information

More than half of the mothers believed that sharing information from an mHealth program with a partner or another carer would be a beneficial feature if the information was reliable [*"Well I think it would be a good idea, because sometimes grandparents…a bit of an old fashioned view on what to do and how to feed the baby kind of thing"* Participant 2]. However, some disagreed and felt a program on infant feeding would not interest other carers of their baby [*"Not really. I mean, my husband -- he just wouldn't look at it anyway, to be honest. He just goes with what I say"* Participant 8].

Infant weight tracking

Tracking the infant's growth was the least favoured feature; the majority of mothers felt this feature was already available [*"Well you get that in the blue book so it's not really as important"* Participant 14]. Others felt it would cause them anxiety [*"See, I'm not too big on that… Only because you know she's kind of on the lower side and that freaks me out…Once a month is enough for me"* Participant 18].

Practical content and delivery

Many mothers voiced the need for updated and accurate information, as well as evidence-based guidance around infant feeding practices [*"Absolutely, yeah, very important…Examples of main meals…some more ideas on suitable finger foods that aren't a choking risk"* Participant 7]. While other mothers did not wish to receive information about the frequency of feeding their babies [*"I don't know about the when and how kind of thing, because you don't really go off – ...you know your baby – when you're a mum, you know"* Participant 4].

Several mothers referred to potential anxiety of receiving information that would cause guilt about their decisions with infant feeding [*"I guess things that are going to make parents feel bad about their decisions and, I don't know, push certain ideas too much"* Participant 21]. Some mothers referred specifically to messages about milk feeding practices [*"One thing you'd need to be careful about would be to make sure you know it*

doesn't become something on the breast - you know, they call [them] the breast Nazis, because breast is best and nothing else will do kind of thing…it would need to be balanced" Participant 1]. Some mentioned concern about messages about first foods introduced to their baby [*"if the website was offering advice etc and say if I wrote in saying I've decided to let [baby's name] have fish now, even though technically you're not supposed to give it until they're nine months, and if somebody came back to me saying I was doing it wrong"* Participant 20].

4.4.3 Behaviour – Introducing solids

The mothers ranged in the age they introduced solids to their baby from between 13 and 28 weeks (mean= 20 weeks). Of the 23 infants that had commenced solids, three mothers had adhered to the government Guidelines (National Health and Medical Research Council 2012) and introduced at around 26 weeks. Timing of solid introduction was closely tied to their 'knowledge' (Capability) about when to introduce solids, 'social influences' and 'environmental context and resources' (Opportunity) and also the mother's intention and beliefs (Motivation) about when to introduce solids. The infants' cues (Opportunity) appeared to have the strongest influence on the mothers' decision (Motivation) to commence feeding solids despite having knowledge (Capability) about the Guidelines.

4.4.4 Opportunities influencing mothers' decisions around the timing of introducing solids – environmental context and resources and social influences

A number of social and environmental factors influenced the mothers' decision on when to introduce solids. These included written sources, antenatal classes, midwives, nurses, relatives, friends, colleagues, mothers' groups, the infant's cues and forums. Some of the advice the mothers received was inconsistent with the NHMRC Guidelines, regardless of the source.

Advice from written information

Written information was one of the sources that influenced mothers' beliefs and intentions about when they should introduce solids. Some of the sources used, however, provided advice inconsistent with the government Guidelines [*"mostly…like on that book (Save Our Sleep by Tizzie Hall), which said four months"* Participant 1]. Other sources mothers used recommended introducing at six months [*"From our Welcome to Parenthood Group we had the one day on feeding and then like all the little kind of print offs they gave us… they also go off the Karitane Guidelines…Usually I think at six months as well"* Participant 19].

The internet was another popular source that mothers referred to for advice around feeding practices [*"I just googled it and went through a whole lot of baby websites and they do say don't introduce before four months because their digestive system isn't*

mature enough" Participant 17]. Social media websites such as Facebook was used by majority of the women this group, in particular a Facebook group known as 'Canberra Mums' which was mentioned by five mothers: [*"Also, we have a Facebook page for babies due in 2013 in Canberra and we just talk about a lot of things and sort of share experiences and a lot of people ask questions and ask advice"* Participant 7]. Despite the valuable peer support mothers received from these groups, the groups caused confusion for some mothers, as opinions posted about infant feeding practices were divergent: [*"I've just seen mixed comments on the Facebook group of when the girls have introduced their kids [to solids] – because… it's like anyone that's had a baby in 2013…"* Participant 1].

Mothers mentioned other online sources including WHO recommendations: [*"I just did a bit of research with my first…the World Health Organization recommending that you exclusively breastfeed until six months"* Participant 22]. Another mother reported reading the WHO recommendations along with other literature that conflicts with the advice, creating confusion in the participant's decision [*"I think maybe the World Health Organization said six months but then more recent studies about breastfeeding saying that nutrition is declining by a bit earlier…and it's better for them to start having solids before then but it's hard to know"* Participant 5].

Advice from health professionals

Mothers visited various health practitioners to obtain information about when to introduce solids. Parents also reported receiving some inconsistent advice from health practitioners, although health practitioners were generally viewed as a trustworthy source of information and mothers generally followed their advice. Some were advised to introduce solids at six months [*"in New Zealand they have Plunket, which is like the MCH nurses here and it's all very big, you don't start your kids until six months over there that's what they are sort of taught"* Participant 13]. Others were advised to introduce before six months [*"I asked the doctor what the current recommendation was because I know it changes all the time… the recommendation was for six months but that it was okay from about 17 weeks"* Participant 10]. Further, mothers reported that health practitioners encouraged following their infants' cues despite the recommendations [*"the community health nurse said at six months but from memory I think they also said that if they were showing interest you could do it from five months"*

Participant 16]. Infant reflux was another reason why some mothers were advised to introduce solids earlier [*"she suggested…that if he's ready, that we perhaps consider starting him on solids at about four months, and I mean if a GP says that to you, you kind of take that information and you go with it because you assume that they know what they're talking about"* Participant 3].

The majority of the mothers who were advised by a health practitioner to follow their infant's cues were happy to do so. However, this was not the case for one mother [*"I wasn't really confident with starting her when the paediatrician told me to, I kind of felt like I was pushed in to it…I probably would have waited until she was six months but, I was told to start earlier so you know, from medical advice"* Participant 19].

Social norms

Family and friends were another influence on the mothers' decisions to introduce solids. Mothers reported receiving advice from family and friends that was inconsistent with the government Guidelines. The majority of the mothers noted that most of their peers introduced solids to their babies at around four months, for example: [*"We were quite late compared to everyone else. Everyone else seemed to do it much sooner, so from four or five months"* Participant 5]. Some were much younger than six months [*"I had one friend who introduced solids at like eight weeks old"* Participant 2], while other were older than six months [*"There are some that haven't introduced it yet and their child is I think around seven and a half/eight months and then others introduced it at four months and a lot waited until six months"* Participant 10]. The influence of social peers varied, as some were more influenced by their peers and others followed their health practitioners' advice [*"Most of the mothers in that group started at three or four months…on the advice of their paediatrician…It did make me think. I did think oh, okay, maybe I should start. But again, I had that gut feeling she wasn't ready"* Participant 8].

Furthermore, some of the mothers' parents also encouraged many to commence earlier than the recommendation: [*"like I know in like my mother's generation they introduced it around six weeks, the first solids…So then my mother-in-law and my mother both go, 'Just start them, you know, whenever'…I wouldn't start them that early"* Participant 24].

Infant cues as an external influence

Regardless of the various information sources mothers accessed and the advice given to them, infant cues appeared to be the main influence on the mothers' feeding behaviour. Mothers reported that they focused on signs from their infant [*"Just that he was trying to take food off of our plate, that his lips were going and he was always kind of like making noises at you and trying to grab your fork and watching…"* Participant 2]. Others were aware of the recommendations to introduce solids at around six months, but believed they should introduce solids earlier [*"Yeah we were going to hold off a little bit longer, but she's been watching me eat and grizzle and trying to take food out of my hands…I guess they always say four to six months, and I guess in your head you go oh, you've got to go with later one, but it just doesn't happen"* Participant 26].

4.4.5 Mothers' Capability to introduce solids – knowledge/ belief about capability

Mothers' 'knowledge' (Capability) about the right time to introduce solids was not only shaped by information (Opportunity) provided to them but it was also driven by their beliefs (Motivation). The information and advice (Opportunity) mothers were provided with contributed to their knowledge (Capability) about when to introduce solids. Eight mothers followed the advice given to them regardless of whether the advice was in line with the government Guidelines. Some report introducing solids at around six months [*"…he just turned 6 months on Sunday – and I knew that after that 6 month mark, they start to need more iron, so it was more about a nutritional aspect…"* Participant 30]. Others followed the advice to introduce at four months [*"I got told four months is when you start to introduce solids so that's what I did"* Participant 8].

4.4.6 Mothers' Motivation – beliefs about consequences, intentions

Both Opportunity and Capability influenced the mothers' Motivation which is the key driver to the decisions that led the mothers' behaviour on when they introduced solids. A mother's decision around solid introduction was tied in with her beliefs about consequences and her intentions to introduce solids early.

Mothers' perceptions about the government Guidelines on solid introduction

On discussing the mothers' perceptions of the Australian Infant Feeding Guidelines, most agreed that the recommendation to introduce solids at around six months is realistic. However, the majority stated that infant cues should be the main influence on their decision regardless of whether they followed the Guidelines or not: [*"Yeah, I think it's fine. But obviously that's fine to start them earlier…I don't know if recommendations should be in place as such, because it really should be when you're ready…"* Participant 10]. One mother who introduced close to six months believed that babies' cues are often misinterpreted [*"other mums will say 'I had to start earlier because they were looking at my food and wanting to put it in their mouth' and I sort of think, well, babies look at everything and want to put it in their mouth"* Participant 8]. However, she also believed that mothers' natural instinct is to follow their infants' cues [*"…but I can understand, you know, if we didn't have all this information and if we were just left to our own devices and we were eating a meal and the baby helped themselves to a bit, well, we would kind of keep offering them little bits"* Participant 8].

Not surprisingly mothers who introduced solids to their baby well before six months had a stronger view that they should be led by the infant's cues [*"No, I don't think it's realistic at all. Every baby's different and if we had of waited for her to be six months, she wouldn't have been very happy at all"* Participant 6]. Specific cues which led mothers to introduce solids included the infant's wakefulness in the evening which was thought to be due to hunger [*"Both my babies were like bad sleepers at night, like waking all the time and I thought it was time to start feeding them more because obviously maybe they're hungry"* Participant 12]. The infant's weight also shaped the mothers' belief on the suitability of the Guidelines for their child: [*"No… I started him at about four months as well because he was huge…and the breast just wasn't enough for him and that was my GP told me to start him on solids at that age."* Participant 23]; or underweight [*"he was very skinny, I wanted to start solids as soon as I could."* Participant 24].

Plans on when to introduce solids

The six mothers who were still exclusively milk feeding their babies were questioned about their intentions on when they would introduce solids. Only one stated her intention was to introduce solids at around six months [*"I'm hoping to start at six*

months doing baby-led weaning" Participant 21]. Like the mothers who introduced solids based on their infants' cues, most of these mothers also believed their decision should be child-centred [*"I'm sort of conscious that people are doing it between four to six months…the community nurses talked about it, that you really should be doing it by six months. But we'll just be led by baby"* Participant 25]. One mother also felt the conflicting advice caused confusion in deciding when to introduce solids, for example [*"everyone tells you conflicting information. I've been told you can start them as young as four months, other people say 'No, not until six months'. A few of my friends have started around five months, so I thought we'll see how he's going by then, but still play it by ear…"* Participant 29].

4.5 Discussion

The first aim of this study was to explore mothers' interest in an mHealth program to support healthy infant feeding practices. The mothers held positive views about a proposed mHealth program and were interested to see various features included. First-time mothers were more enthusiastic about this mode of delivery compared with multiparous mothers. The second aim was to explore mothers' beliefs and behaviours related to the age of solid introduction, addressing barriers to adherence to the recommendations from the Infant Feeding Guidelines (National Health and Medical Research Council 2012) . Using the COM-B model to map the antecedents of this behaviour, the mothers' Motivation associated with beliefs about the consequences of early solid introduction appeared to be the main driver of their decision. Overall the findings of this study provided insights to inform the development of an mHealth infant feeding program.

4.5.1 Mothers' interest in an mHealth intervention

This study identified various reasons which support the idea for the development of an mHealth program for mothers of low educational attainment. Firstly, all mothers reported access to the internet, with smartphones being the most popular source used. The majority of the mothers regularly used the internet as a resource for infant feeding information and they voiced enthusiasm about receiving this information through an mHealth approach. These findings are similar to some recently-conducted studies, (Hearn, Miller & Fletcher 2013; McDaniel, Coyne & Holmes 2012), although other

literature reports less popularity among mothers from a low socioeconomic position (SEP) compared to their higher SEP counterparts (Gage et al. 2012; Grimes, Forster & Newton 2014). The differential use of online sources among the different SEP groups may result from limited experience in identifying trustworthy sources, compared with mothers with a tertiary education (Grimes, Forster & Newton 2014; Lagan, Sinclair & George Kernohan 2010). However, the increased rates of access to the internet as well as smartphones among various demographics (nielsen 2012) confirms our findings which illustrated that mothers of low educational attainment regularly access the internet.

In regards to the mode of delivering an mHealth program, the most popular features with the mothers included individualised messages, forums and information about healthy infant feeding practices. They felt that including these features would encourage them to use the mHealth program for infant feeding. Previous mHealth programs have highlighted the importance of using a number of features to engage participants (Baltierra et al. 2016; Michie et al. 2011). Utilising various modes of delivery in mHealth programs has also been found to increase intervention exposure and the uptake of desired behaviours (Baltierra et al. 2016). Conversely, studies that used stand-alone features (Jiang et al. 2014; Kirwan et al. 2012; McDaniel, Coyne & Holmes 2012) identified a decrease in participant engagement. As mHealth is still in its infancy, particularly for targeting infant feeding practices, further research is required to understand which combinations of features impact most effectively on engagement levels and uptake of desired behaviours.

Mothers in this study were interested in direct contact with participants through messages or emails. Their opinions varied about acceptable rates of contact by the program, ranging from once a month to once a day, a finding that is consistent with work considering pregnant women's preferences for information and support (Willcox, van der Pligt, et al. 2015). Several behaviour change interventions using direct messages or emails based the frequency of contact on the expected frequency of the target behaviour. For instance, in a physical activity intervention participants in the test group were sent five messages a week tailored to their individual needs to increase daily activity levels while the control group received no support (Hurling et al. 2007). The study observed an average increase (over the control group) of moderate physical

activity of 2 hours and 18 minutes per week. However, despite the demonstrated benefits of this feature in promoting short-term behaviour change, excessive contact was noted as a concern by mothers in this study and others (Obermayer et al. 2004; Willcox, van der Pligt, et al. 2015). It is necessary to explore acceptable rates of contact by interventions for behaviour change to prevent adverse effects such as increased recipient stress or program attrition.

Another feature that interested participants was support through social media groups. Social support for new parents has been shown to positively impact on maternal health and parent-child interactions (McDaniel, Coyne & Holmes 2012; Meadows 2010). The current study accords with other literature (McDaniel, Coyne & Holmes 2012; Rideout, Foehr & Roberts 2010) reporting that social media, such as Facebook groups or forums are highly used and in turn facilitate social connections. The mothers in this study considered these social networks useful. Specifically, social media groups contributed to their sense of belonging to a community during the early stages of parenting. They were used to gauging their infants' behaviours and feeding practices by comparing with other mothers' experiences. Despite the supportive environment created on these forums, a recent qualitative study explored the content of blogs and forums available to mothers and reported that a high rate of inaccurate information was shared (Appleton, Fowler & Brown 2014). Given the abundance of forums available, it is necessary to create a unique approach that would appeal more to mothers than other less accurate forums. For example, health practitioners could regulate the posts and provide evidence-based advice on these forums to support mothers.

All mothers in this sample were enthusiastic about receiving information and advice about infant feeding practices through an mHealth program. Yet they also emphasised their concerns regarding how the message on 'correct' infant feeding practices was portrayed. For example, they were wary about the conflicting advice about introducing solids at four months or six months, or about apps only advocating 'breast is best' and not providing information on healthy formula feeding practices (National Health and Medical Research Council 2012). Research has highlighted that if information is perceived as judgemental it can lead to increased stress, impacting on new parents' competency to adjust to their new role (Shieh, Broome & Stump 2010). It is therefore necessary to consider this in the design and evaluation of mHealth parenting

interventions. Further research is needed to understand what advice parents might consider judgemental by exploring how they interpret information. Message testing with a broad range of parents would inform appropriate ways of raising potentially sensitive issues.

4.5.2 Beliefs and behaviours associated with timing of solid introduction

This study outlined a number of influences on mothers' decision on age of solid introduction, such as infants' cues, advice received from health practitioners and limited confidence in their knowledge about the right age to introduce solids. An American longitudinal study, the Infant Feeding Practices Study II, identified similar findings, with the most common reasons mothers introduced solids early including perception of the infants' readiness, health practitioner advice and belief that it would help their infants sleep longer (Clayton et al. 2013). It is therefore necessary to address these factors in interventions to increase the likelihood of mothers following government Guidelines. For example, mothers need accurate information about when to introduce solids and how to interpret infant cues (Opportunity) (Brown & Rowan 2016). Information available from written sources and health practitioner advice need to be consistent with the latest Guidelines. If mothers receive consistent advice about the Guidelines, it will increase their knowledge, skills (Capability), confidence and beliefs (Motivation) regarding the appropriate timing of solid introduction. The COM-B elements are inter-related and influence the desired behaviour of delaying solid introduction.

The mothers' Capability to introduce solids at the recommended age included their knowledge about when to commence feeding solids. Responses varied: some were familiar with the six month recommendations; others had received conflicting advice and were informed that the recommendations stated four months. Some mothers were advised by health practitioners to allow their infants' cues to determine when they should introduce solids. Providing mothers with the correct information on solid introduction is essential (Vereijken, Weenen & Hetherington 2011). Yet the findings of the current study, consistent with other research (Moore, Milligan & Goff 2014), indicate that awareness and knowledge about the Guidelines were not the main

influences on the mothers' decision. Rather, Opportunity and Motivation, which influence the mothers' knowledge (Capability), played a major role.

The mothers' knowledge about commencing solids was influenced by the prevalence and quality of information presented to them. Sources included written materials, advice from health practitioners and from relatives and friends, and cues from the infant (Opportunity). These findings are consistent with other studies (Gildea, Sloan & Stewart 2009; Shieh, Broome & Stump 2010) one of which was conducted in the United Kingdom among 215 mothers of one year old infants, to investigate sources of advice that mothers used and perceived as valuable (Gildea, Sloan & Stewart 2009). The majority of the participants viewed health practitioners as a 'trusted source' and were influenced to follow their advice. It is evident that health practitioners have a crucial role in improving parents' adherence to Infant Feeding Guidelines.

However, conflicting advice on the recommended age of solid introduction from health practitioners was highlighted as a concern among mothers in this study and others (Arden 2010; Clayton et al. 2013). A quantitative study which explored advice mothers received from health practitioners on the timing of solid introduction, reported apparent inconsistency in how flexibly the Guidelines were interpreted (Moore, Milligan & Goff 2014). Some mothers reported that their health practitioners followed a rigid approach and recommended introducing solids from six months, while others promoted introducing at around six months in response to their infants' cues. Previous qualitative studies have suggested that conflict and confusion arise from the rigid recommendation on a behaviour which relies on developmental signs of the infant (Anderson et al. 2001; Arden 2010). It is important that health professionals are regularly provided with training and updated with the release of the latest recommendations, to address these inconsistencies. It is also necessary that the Guidelines clearly outline practical advice for health practitioners to promote best practice infant feeding consistently and to help empower the mother to respond to the needs of her child.

Social networking forums such as Facebook groups were a commonly used source of information among the mothers in this study (Opportunity). Although these social media groups have enabled mothers to feel connected to a community (McDaniel, Coyne & Holmes 2012), they may present inconsistent information. Very few mothers, however, were influenced by other mothers' choices about when they introduced solids.

In contrast, an Australian study, the Melbourne InFANT program, explored the influence of peers on breastfeeding discontinuation among primiparous mothers and identified that the mothers' social group influenced their own decisions with breastfeeding (Cameron et al. 2010). The variation in the findings of peer influence is that this study investigated the influence of online social networks (which are distant/remote networks) as opposed to InFANT which focused on social groups (which are closer/ immediate networks). Overall, using social networking programs as a medium for peer support may be useful, although it is important that the posts and advice provided in these forums and groups are controlled and monitored by health practitioners.

Despite having access to various sources and information, it is evident from this study that the mothers' Motivation influenced their decisions around which source of information to follow. For example, mothers had knowledge about the recommendation on when to introduce solids to their infants, yet their decision was influenced by other factors. These include mothers hypothesising that the infant cues identified before six months were indicators of the infants' readiness to commence solids (for example, wanting to put food in their mouths or looking at their mothers' food). Other indicators to commence solids sooner included infants waking up frequently throughout the night or parents' concerns regarding low weight. These findings are consistent with an American longitudinal Infant Feeding Practice Study which explored mothers' reasons for introducing solids before four months of age. In that study the primary reason for early introduction of solids was reported as mothers being child-centred and basing their decisions on their infants' behaviour (Clayton et al. 2013). Other studies have reported beliefs that infants need to commence cereal early because their nutrient requirement exceeds that which breast milk or formula milk can provide (Corbett 2000).

While the infant cues are an important indicator of their readiness to wean onto solids, they can be confused amidst more general signals of their growth and development (Arden 2010). There are a number of biological phases within the progress of infants' growth. From birth to three months, functional behaviour is expected such as hand-to-mouth movements to suck on the thumb or fingers and the infant's developing ability to self-regulate (Pridham 1990). From three months to approximately nine to 12 months the infant develops the ability to use the sensorimotor repertoire such as reaching and

grasping, developing awareness of their surrounding and initiating social exchanges (Pridham 1990). Parents may perceive these behaviours as an indication their infant is ready to commence solids. However, by six months of age the infant has the capacity to modulate attentions, social exchanges and expression of interest in reaching for things other than food. Overall, signs of readiness for progression onto solid foods include a combination of the infant's developing oral, body positioning, and fine motor skills. In particular it is the modulation of attention and assertion of preferences for particular things operates as the motivating force towards introducing solids (Kopp 1982; Pridham 1990). Education on understanding these developmental phases of infants' growth is necessary, for not only mothers, but also for health practitioners. It has been suggested that targeting health practitioners' knowledge and confidence to follow the latest Guidelines may potentially increase the likelihood of parents practising healthy infant feeding behaviours (Feldman-Winter 2013).

According to the BCW (Michie, van Stralen & West 2011), targeting one or more of the COM-B components will improve the effectiveness of interventions. The analysis of the data from the current study suggests that changes should be directed at the information that is provided to the mothers (Opportunity) and that these many sources must be consistent with Guidelines. In addition, information about infant developmental cues should be explained clearly to parents by health practitioners. This will enhance the mothers' knowledge (Capability) to identify infants' milestones regarding expectations of their readiness cues. Targeting these components may influence mothers' beliefs and decisions (Motivation) to follow the Guidelines and delay solid introduction.

4.5.3 Strengths and limitations

One strength of this study was the inclusion of mothers in the development of an intervention, to investigate their opinions on an mHealth program for infant feeding. Involving the target demographic during the development of an intervention is considered best practice (Craig et al. 2008; Organization 2002). The findings generated insights on mothers' perspectives and beliefs on what would be useful features for an mHealth program. Further, including participants from a low educational background made it possible to identify their needs, to help enhance engagement levels and reduce program attrition. In addition to mothers expressing their interest in an mHealth

program, their response to online recruitment adds evidence to the acceptability of online sources for information for this group of parents.

Other strengths of this study include its use of a qualitative methodology to explore and generate new understanding of mothers' behaviours about solid introduction. The generation of a coding framework, developed by two researchers and cross-checked to ensure inter-rater reliability in coding, will also add to knowledge in this area. Further, the use of telephone interviews was a more convenient process, given new mothers' lack of time flexibility, allowing them to answer the questions in depth. The use of e-newsletters to recruit the mothers was beneficial and reduced the recruitment time, with a population usually considered to be difficult to reach.

Using the COM-B model (Michie, van Stralen & West 2011) has helped understand the barriers and antecedents related to mothers' behaviours around solid introduction in relation to the Guidelines. The model has supported the generation of a greater understanding of modifiable behaviours that can be targeted in a program to encourage mothers' decision to delay solid introduction. However, interpreting findings is complicated as a degree of subjectivity is inevitable in considering so many concepts.

A limitation of this study is that the sample was not sufficiently ethnically diverse to obtain insight into beliefs and behaviours of mothers from a range of ethnic backgrounds. The results may therefore not be representative of populations known to be at risk of social disadvantage and in turn poor health. These groups may also be at higher risk of practising unhealthy infant feeding behaviours (Kuswara et al. 2016).

4.6. Conclusion

This chapter has outlined a qualitative study identifying perspectives on an mHealth program to support parents with infant feeding and on influences on mothers' decisions about the age of solid introduction. This study reports a range of positive maternal perspectives that may inform the development of an mHealth program that would provide support for healthy infant feeding practices in mothers from a low socioeconomic position. As there are a number of features which mHealth programs can offer, this research identified mothers' perspectives on integral elements that would encourage them to use the program.

The study also identified that mothers access various sources to obtain information about infant feeding and often receive inconsistent advice on the recommended age of solid introduction. However, infant cues were a major influence on many mothers' decisions on when to introduce solids. These findings indicate the need to provide mothers with accurate information on the Guidelines, particularly from sources they consider trustworthy (Opportunity). The intervention should also aim to improve mothers' knowledge (Capability) regarding the interpretation of infant cues and to encourage decisions to delay solid introduction (Motivation).

These qualitative results serve to inform the development of the mHealth intervention (Growing healthy). The next chapter discusses the development of the Growing healthy program.

Chapter 5: Overview of the Growing healthy program

5.1 Introduction

The previous chapter described a qualitative study to explore mothers' thoughts on an mHealth program to support infant feeding practices. It also explored barriers associated with delaying solid introduction. This chapter will describe the development and testing of, Growing healthy, which was designed to address these gaps.

5.2 Chapter aims

The aim of this chapter is to describe the methods of the Growing healthy study, in which this thesis is nested. This will include a description of the study rationale, intervention development and participant recruitment along with the data collection and analysis process. It will distinguish the aspects of the overall study design that are relevant to this thesis, as well as the role of the candidate within the broader study. A more detailed explanation of the methods relevant to each of the studies presented in this thesis will be provided in individual chapters.

5.3 Aims of the Growing healthy study

The aims of the Growing healthy study were to assess:

1. the feasibility of Primary Health Care (PHC) practitioners referring mothers of low socio-economic status to an mHealth intervention and reinforcing key messages as part of routine baby health checks; and
2. the effectiveness of an mHealth intervention in terms of its reach, use, acceptability, cost and impact on key infant nutrition and feeding outcomes.

5.3.1 Growing healthy program overview

The Growing healthy program was delivered via a smartphone app and website to support parents of young infants with healthy infant feeding behaviours, the published protocol can be found in Appendix 5A (Denney-Wilson et al. 2015). It was developed

by experts in infant feeding. The program provided advice and suggestions, consistent with national guidelines on infant feeding in the first nine months of the baby's life.

The objectives of the program were to:

- promote breastfeeding;
- if breastfeeding is not possible, promote best practice formula feeding;
- delay the introduction of solids to around six months of age and not before four months;
- promote healthy first foods;
- promote healthy infant feeding practices (including feeding to appetite, repeated neutral exposure to healthy food and avoiding the use of food as a reward); and
- optimise infant dietary exposure to fruits and vegetables.

The participants were provided with the Growing healthy application (app) and could choose to receive three tailored push notifications through the app each week of the intervention. Push notifications were personalised with the mothers' and baby's name, to parents' feeding mode (breast, formula or mixed) and their infants' age, with links provided to further information in the app. The age-appropriate content coincides with the information provided by clinicians at well-baby or ages-and-stages health checks. To ensure participants received the appropriate milk feeding messages, they were able to update their milk feeding status on their profile which then automatically placed them in the appropriate group within the database.

Participants who did not own a phone that was compatible with the app were offered access to the Growing healthy website (www.growinghealthy.org.au). Participants who used the website were sent three text messages and one weekly newsletter that provided links to further information (Denney-Wilson et al. 2015). Eligible participants were also offered the opportunity for another carer (e.g. father or grandparent) to access the app and were also invited to join the Growing healthy Facebook group. For the purpose of this thesis only participants who used the app program will be included.

5.4 The Growing healthy program methods

The Growing healthy study used a non-randomised quasi experimental design (Denney-Wilson et al. 2015).

5.4.1 Intervention development

The process of developing the Growing healthy program was informed by the Behaviour Change Wheel (BCW) model (Michie, van Stralen & West 2011). The model includes three broad stages and a total of eight steps (Michie 2014) include:

1. Understanding the behaviour:
    - *Step one*: defining the problem in behavioural terms;
    - *Step two:* selecting the target behaviour;
    - *Step three:* specifying the target behaviour;
    - *Step four:* identifying what needs to change;
2. Identifying intervention options:
    - *Step five:* identifying appropriate intervention functions;
    - *Step six:* identifying policy categories;
3. Identifying content and implementation options:
    - *Step seven:* identifying Behavioural Change Techniques (BCTs); and
    - *Step eight:* determining the mode of delivery.

Table 5.1 illustrates the various studies implemented to develop, implement and evaluate the Growing healthy intervention, and how these relate to each stage of the BCW process. Each stage of the intervention development is summarised briefly below, including studies that were conducted although not part of this thesis. Studies led by the candidate are represented in italicised text.

Table 5.1 Growing healthy studies mapped to the Behaviour Change Wheel model

BCW Stages	Studies implemented in Growing healthy	BCW Steps	Timeline
Stage 1: Understanding the behaviour	1. Systematic review: parental beliefs and child characteristics 2. Systematic review: effective strategies for promoting healthy weight gain in low SES and Indigenous infants *3. Systematic analysis on the quality of infant feeding websites and apps (Chapter Three)*	1 to 4	Jul 2013 – Dec 2014
Stage 2: Identifying intervention options	*Qualitative interviews with mothers of infants less than one year of age (Chapter Four)*	3 to 5	
Stage 3: Identifying content and implementation options	*Parent focus groups: confirmation of design, including content and mHealth delivery mode (this study was excluded from this thesis)*	7 to 8	Oct 2013-Jun 2014
	Final intervention design		
Intervention evaluation	*1. Analysis of quantitative surveys and evaluation of participant app usage (Chapter Six)* 2. *Qualitative feedback from mothers (Chapter Seven)*		Dec 2014-Apr 2016

5.4.2 Details of the studies implemented at each stage of the BCW to develop the intervention

Stage one: Understanding the behaviour

Systematic Reviews

Two systematic reviews were conducted. One review focused on the effects of mothers and families behaviours on children's weight status in socio-economically disadvantaged families and Indigenous families (Russell, Taki, Laws, et al. 2016). This study identified that limited literature exists about obesity prevention interventions in infants tailored to specific socio-demographic characteristics such as ethnicity or parental education. The second review examined the effectiveness of interventions in promoting healthy weight in children aged zero to five years from socio-economically disadvantaged and Indigenous families (Laws et al. 2015). The findings suggest that interventions which targeted the prevention of obesity during infancy had a positive effect on behaviours related to obesity, yet very few interventions assessed the long term effect on healthy weight gain.

Systematic analysis of infant feeding website and apps

The candidate led a systematic analysis on the quality of infant feeding websites and apps (Chapter Three) (Taki et al. 2015). The findings of this study highlight the importance of website and app developers merging user requirements with evidence-based content to provide reliable and engaging information for consumers. Further, there are currently only limited online resources that provide evidence-based information on infant feeding. This study informed the development of the Growing healthy program.

Stage two: Identifying intervention options

Qualitative interviews with mothers of infants less than one year of age

To inform the development of the intervention, qualitative interviews mothers with low educational attainment were conducted (Chapter Four). This study aimed to understand the determinants of infant feeding behaviours that were identified in the systematic reviews and could be potential targets in the intervention.

The mothers' use of technology and their attitudes towards an mHealth intervention were also explored. The results informed the selection of Behaviour Change Techniques (BCT) implemented in the intervention. The BCT aimed to influence the participants' uptake of healthy infant feeding behaviours (Table 5.2). Further, all the mothers in the study owned and used the internet for infant feeding information and expressed their interest in an mHealth intervention that would support them with infant feeding practices. More details of this study can be found in Chapter Four.

Survey and interviews with nurses

One aim of the Growing healthy study was to deliver an intervention through Primary Health Care (PHC) (Laws et al. 2015). To explore the potential of conducting the intervention in a PHC setting, Maternal and Child Health (MCH) nurses from three local government areas in Victoria and Practice Nurses (PN) from one Medicare Local district in New South Wales (NSW) were invited to complete an online survey. The aim of this survey was to explore nurses' perceptions of their current role and practices in infant and child obesity prevention. A subset of respondents agreed to participate in telephone interviews for more in-depth questions about their current practice and perceived barriers and facilitators to healthy infant feeding practices and following the Government recommendations. The results of this study identified that nurses have a great opportunity to address healthy infant feeding practices with mothers, as they are generally consulted for advice and they believe that preventative care is part of their role. This study was not part of this thesis although it identified MCH nurses and PNs as professionals for referring mothers to the Growing healthy program.

Stage three: Identifying content and implementation options

Behaviour change can be assisted or impeded through targeting specific behaviours using Behaviour Change Techniques (BCT) (refer to Chapter Two for more details of this model). Table 5.2 describes the ways in which constructs of the BCW have been used to inform the Growing healthy study illustrating the objective to 'delay the introduction of solids to around six months of age and not before four months'. It describes the intervention targets, the function and BCT applied to influence the intervention targets and gives an example of how they are applied in the intervention.

Table 5.2 Applying the COM-B system to encourage participants to 'delay solid introduction to around 6 months and not before 4 months'

Intervention targets	COM-B Component	Intervention functions	Strategies for change (BCT) to deliver intervention function	Example of intervention	
				Push notification	Content on app
Knowledge about the recommendations to delay solids to around 6 months and not before 4 months	Capability: Psychological	• Knowledge • Training • Environmental restructuring	• Cognitive and interpersonal skills: Instruction on how to perform a behaviour • Information about health consequences	Know mums who are confused about when to start solids? Remind them that experts say 6 months is best. Read more here and share with mums. *(Sent at 19 weeks of age)* Did you know babies milk-fed exclusively until 6 months tend to be healthier? However, if [y] is showing readiness to eat, see more here. *(Sent at 21 weeks of age)*	Information on the importance of delaying solid introduction for the infants' physical development and nutritional needs as well as health consequences. This is presented through written information and through a video.
Access to formal information sources either from a health professional or	Opportunity: Physical	• Environmental context and resources (Prompts/cues)	• Adding objects to the environment	Mothers receiving the push notifications as a trigger for behaviour.	Providing access to the app with infant feeding information, including both written and videos.

written sources		• Enablement			
Paying attention to multiple signs of readiness before introducing solids	Motivation: Reflective	• Persuasion • Education	• Verbal persuasion to boost self-efficacy • Information about health consequences	Wondering if it is time to introduce solids? Click here for some tips on recognising the signs that [y] is ready. *(Sent at 20 weeks of age)*	Written information on signs of developmental readiness for solids.
Belief that introducing solids at 4 months won't help baby sleep longer	Motivation: Reflective	• Persuasion • Education	• Belief about capabilities: verbal persuasion to boost self-efficacy • Belief about consequences: information about health consequences	Feeling exhausted [x]? Wondering if introducing solids will help [y] sleep? Click here for advice on when to introduce solids. Did you know that introducing foods before [y] is 6 months old is unlikely to help them sleep at night? For sleep tips, click here. *(Sent at 14 weeks of age)*	Written information about why the mother should delay solid introduction. Information about techniques to help settling the baby rather than resorting to solid introduction.

Focus groups with mothers: confirmation of design, including content and mHealth delivery mode

The candidate led three focus groups with a total of 16 first-time mothers to obtain feedback on the initial design and content of the app, although, the finding of this study is not part of this thesis. The mothers viewed a number of screenshots of the app presenting the sample homepage and the subheadings included in each topic of the app. They were also asked to express their preferences for push notification messages to suit the baby's age and stage of feeding and about the frequency of messages to be sent from the program. The mothers preferred an app design that included a simple background while using positive images to represent each topic in the app. They expressed their thoughts on information they believed would be useful in each infant feeding behaviour topic, the order of information and headings for the topics included. They suggested it would be appropriate to receive two to three push notifications a week if these were specifically tailored to suit each individual (including feeding method, baby's milestones, and immunisation reminders). The majority of the mothers emphasised the importance of including positive messages that would not make them feel guilty about their infant feeding decisions. This finding was consistent with that presented in the qualitative study in Chapter Four. The focus group schedule, app screenshots and messages presented to the mothers can be found in Appendix 5C.

Focus groups with practitioners

Focus groups were conducted with MCH nurses in Victoria to obtain feedback about the design and content of the Growing healthy app. The candidate and other members of the research team conducted these groups. As with the focus groups conducted with the first-time mothers, the nurses viewed a number of screenshots of the app presenting the sample homepage and the subheadings included in each topic of the app. The nurses provided detailed suggestions about the order of the content presented in the app, considering the potential influence this may have on the mothers' infant feeding practices. They also made recommendations on the appearance of the app including the appropriate images that reflect recommended practices around breastfeeding and sleep positions. All recommendations were subsequently incorporated into the app. The nurses acknowledged that the content was consistent with the guidelines and advice they provide to mothers and agreed to participate in the feasibility study of the program.

5.4.3 Other decisions related to the app development

Selecting a platform

Designing mobile apps includes selecting the most appropriate platform to deliver the service. Due to the increase in use of information technology, particularly smartphones (International Data Corporation 2015), a number of mobile platforms are available (Dalmasso et al. 2013). Apps are developed for either one (*native)* or more than one operating system *(hybrid apps/cross platform approach)* such as iOS, Android, Blackberry, Bada and Symbian. Native apps are commonly used platforms for operating systems. They run locally on the specific smartphones to utilise the existing hardware available such as the camera, geographical-positioning or call logs. Hybrid apps are a combination of both mobile-web and native apps. They are installed from an app store e.g. Google Play store (Android) or app store (iOS) and are embedded into the smartphone in a similar way to the native app (Dalmasso et al. 2013; Serrano, Hernantes & Gallardo 2013).

The app developer and research team chose a hybrid app as there was no need to use the hardware on the phone. This enabled access to the app using a range of operating systems while limiting the internet data usage required. Another benefit of using the hybrid app was that it enabled the developer to target more than one mobile platform as they are built using a combination of web technologies. To maximise potential participation in the study, the app was developed to suit the most commonly used smartphones at the time of conducting the study including iPhone (4, 4s, 5, 5s, 5c) and Android models (Samsung Galaxy S4, S5, Nexus 5 and HTC One). Given that iPhones are commonly owned by consumers from a higher socio-economic background (PEWResearchCenter 2013), having the app accessible across a range of platforms was important to reach mothers from various demographics. Further, the hybrid app enabled the team to track user interaction with the app during the intervention period by allocating each participant with a unique identification code to download the app on their phone.

Selecting features of the Growing healthy program

The research team decide to include a number of features in the Growing healthy program which aimed to enhance participant engagement. These features include:

- tailored push notifications linked to the baby's age and stage;
- ability to share the app with another carer;
- ability to exchange information from the app with others; and
- videos on infant feeding and settling techniques
- Growing healthy Facebook group.

5.4.3 Testing the app

Utilising the app quality assessment tool to measure the quality of the Growing healthy app

An external researcher applied the quality assessment tool for analysing the quality of infant feeding apps (Chapter Three) to the Growing healthy app, to avoid bias and to ensure it met the recommended criteria for reliability and high quality. Using both the quality assessment tool (93%) and the Quality Component Scoring System (84%) the app was rated as excellent. The readability level was ≤8 using both the Flesch-Kincaid and Simple Measure of Gobbledygook (SMOG) tool (McLaughlin 1969), which is the advised level for online resources (National Center for Education Statistics 2005). Using the Suitability Assessment Material (SAM) tool (Doak, Doak & Root 1996), the Growing healthy app was given a Superior rating (92%). Despite its high quality rating, there were a number of features that were not included in this version of the app due to limitations with funding and the intervention timeframe. These features included: making the app available in other languages; making it culturally specific; enabling users to zoom in and out of each page; and enabling goal setting with real time feedback.

Beta testing and finalising the Growing healthy program development

To finalise the development of the Growing healthy app, researchers within the team undertook beta-testing of the program before launching it with the recruited participants. This included testing the questions in the baseline survey and the link between the survey information and the mothers' profile on the app. Each team member trialled the app using different smartphone models to test for technical bugs, usability and accessibility of the app. Push notifications were also tested to ensure the correct messages were sent according to the infant's age and the selected feeding method (breast, formula or mixed feeding).

5.4.4 Intervention implementation

Sample size

The Growing healthy study aimed to recruit around 200 parent/child dyads. The initial plan for recruitment was through PHC settings (general practices and MCH services) in disadvantaged suburbs in NSW and Victoria. The anticipated recruitment rate was 25% of the births in the local government areas. As this is a feasibility study, sample size is not based on a statistical power calculation. The purpose was to test the intervention feasibility to provide the evidence to conduct a randomised controlled trial.

Participant eligibility

Eligibility criteria included: expectant parents (30+ weeks' gestation) or parents with an infant less than three months of age, literate in English, living in Australia, 18 years or older and with access to any type of mobile phone or internet.

Recruitment methods

Practitioner referral

Initially participants in the Growing healthy program were recruited through three PHC settings: 1) MCH services in two of the lowest Socio-Economic Indexes for Areas (SEIFA) in Melbourne, Victoria; 2) Outpatient antenatal services at a large Melbourne hospital in a low SEIFA region; and 3) General practices in the Illawarra/Shoalhaven Medicare Local; a low SEIFA area in NSW. Sites were approached to assist with recruitment if they were located in socio-economically disadvantaged communities (based on the SEIFA geographic indicator) and had a relatively high birth rate. A researcher from the project visited the sites that had agreed to participate and conducted a briefing session with practitioners such as MCH nurses, PNs and midwives, about the Growing healthy app and recruitment strategies for participants. Details of the recruitment methods for the Growing healthy program has been published in the Journal of Medical Internet Research found in Appendix 5B.

The recruitment strategies included:

- Handing out the program brochures to potential participants;

- Displaying posters within the waiting rooms of the clinics that were involved in the study;
- Asking interested mothers to complete an expression of interest form (MCH services only). On these forms mothers provided contact details and gave permission for the research team to email them directly with information about the study. This approach responded to MCH nurses' concern that interested mothers with young infants may need reminding to enrol; and
- Sending out letters about the program to mothers with infants less than three months of age or in their final trimester of pregnancy who attended the clinics involved in the study (general practice only).

In NSW, PNs in general practice were permitted to use passive recruitment strategies only (i.e. displaying posters/brochures in waiting areas of practices and sending letters to potential participants) in accordance with University of Technology Sydney ethics requirements. The use of an active approach, such as practitioners physically handing brochures to potential participants and informing them about the study was considered as potentially coercive due to the existing patient-practitioner relationship. The ethics committees that oversaw the study in Victoria (Department of Education and Early Childhood Development (DEECD) and Deakin University) approved both passive and active promotion by MCH nurses and midwives. This method was agreed on the basis that practitioners emphasised that the choice to participate was voluntary and would not affect usual services provided.

Face to face recruitment

Face to face recruitment was also conducted via first-time parent groups in participating MCH services within suburbs in Victoria with low socio-economic index scores. A research assistant involved in the program provided the mothers who attended the first-time parent groups with a program brochure and collected the names and email addresses of interested mothers. These mothers were subsequently emailed a web link inviting them to enrol in the program.

Online recruitment

Due to the slow recruitment rate via practitioners during the initial six month period, the research team adopted online recruitment techniques. The Growing healthy program

was advertised online through a range of Australian parenting websites and forums, Facebook groups and web pages targeted at mothers of young infants. Participants invited family and friends on Growing healthy Facebook posts. The relative recruitment strategies and findings have been published (Laws, Litterbach, et al. 2016).

Parents willing to participate in the study completed an online survey which was accessed via the Growing healthy website. The survey included an eligibility screening form. If participants met the study inclusion criteria, they were required to give consent and complete a baseline survey (see section 5.5.1). Participants received an email which included a code to download the app free of charge from either App Store (iPhone users) or Google Play (Android users). Participants who did not own a phone that was compatible with the app were provided with a login for the Growing healthy website.

Compensation for participation

The Growing healthy program was a nine month intervention. Participants were invited to complete three surveys (when babies were aged three, six and nine months). Participants who did not complete the six month survey were still invited to complete the nine month survey. Further, participants who completed the survey beyond the six month cut point (24-32 weeks old) or nine month cut point (39-50 weeks) were excluded from the analysis. Regardless, after completion of each survey they received a $20 gift voucher to compensate them for their time.

Participant retention strategies

In the 18 months of the Growing healthy program, unexpected technical issues such as smartphone system upgrades and participants upgrading their phone, impacted on the participants' engagement in the program. This is discussed in detail in Chapter Six.

5.5 Measurements

Participants completed surveys at baseline (baby ≤3 months of age), when their infant was six months and nine months of age. The surveys included data on socio-demographic characteristics, infant feeding practices and perceptions about the usefulness of the Growing healthy intervention. The questions utilised in each survey included a combination of validated and purpose-designed questions. A copy of the

Growing healthy T1 (baseline), T2 (six months) and T3 (nine months) surveys are included in Appendix 5D, 5E & 5F, respectively.

5.5.1 Quantitative survey

The questions included in the surveys were sourced from several validated instruments including: Baby Eating Behaviour Questionnaire (Lakshman et al. 2014); National Infant Feeding Survey 2010 (McAndrew et al. 2012); The Melbourne Infant Feeding Activity and Nutrition Trial (InFANT) Program (Campbell et al. 2008); the Longitudinal Study of Australian Children (Australian Institute of Family Studies 2005); and the Infant Feeding Questionnaire (Baughcum et al. 2001). Some purpose designed questions were also included. Chapter Six describes the questions utilised in this thesis.

Socio-demographic characteristics

Socio-demographic questions included gender, country of birth, language spoken at home, age, postcode of residence, relationship status, employment status, level of household income and education qualification level (Appendix 5D, T1:Questions D1-D9). The intervention aimed to target mothers from low socio-economic backgrounds, which in this study was defined by mother's education level (Zarnowiecki et al. 2014).

Child characteristics

All three surveys included questions regarding the child's date of birth, gender, birth weight and length (Appendix 5D, 5E &5F, T1: Question A2, A3 and A8). For the baseline survey, the date of birth was then utilised to calculate the child's age, to determine whether they were eligible to participate in the study, and to tailor the push notifications. Participants were asked to report the infant's weight and length at birth and the most recent measurement from their infant health record (also known as the "blue book" in NSW or the "green book" in Victoria) at each time point.

Feeding mode

Parents were asked whether they were breast, formula or mixed feeding at each time point and this data was used to tailor the content of the push notifications sent to the mother.

Introduction to solids

At the six month survey, participants were asked whether they had commenced solids with their infant and at what age (in weeks) they introduced solids (Appendix 5E: Question B3) and the reasons for introducing solids. The question provided a number of options ranging from the infants' cues, written or verbal information such as internet sources, the Growing healthy program, health practitioners, and friends or family.

Perceived satisfaction with the Growing healthy program

The nine-month survey included questions about the participants' satisfaction with the Growing healthy program (adapted from EMPOWER, an Australian mHealth intervention aimed at weight loss in adults (Ball et al. 2014) and the app quality assessment tool described in Chapter Three). The questions addressed the design, layout and features of the program. Participants responded on a five point Likert-scale from 'Strongly disagree' to 'Strongly agree' or 'Didn't use' (Appendix 5F; T3: Question Q D1). These questions were utilised in an 'Engagement Index' tool developed by the candidate to measure the participants' engagement with the app (Chapter Six).

5.5.2 Evaluation of the Growing healthy app data

The participants' use of the Growing healthy app was captured using the app data analytics. These metrics provided objective data to understand how participants were using the app throughout the intervention. Data included when the participant accessed the app, which content/pages were viewed and how many push notifications were opened by the participant. These metrics were utilised in the Engagement Index tool developed for this thesis and further discussed in Chapter Six.

The Growing healthy website was open for the public to use without a login. Therefore exploring each participant's unique interaction with the website was not possible.

Parent qualitative interviews

After completion of the nine month survey a sample of highly- and poorly-engaged app users were contacted and invited to participate in an interview. The interview schedule included questions about the participants' experiences with the Growing healthy app, their perceptions about the design and layout, and the acceptability of the features of the program such as the content, push notifications, the Facebook group and the videos. The

candidate conducted one-on-one semi-structured telephone interviews with 20 mothers. A detailed description of this study can be found in Chapter Seven.

5.6 Data management and analysis

Data management adhered to guidelines set out in the *Australian Code for the Responsible Conduct of Research* (National Health and Medical Research Council 2007) in relation to data storage, retention, disposal, and access. Electronic data files were stored on the hard drive of a computer with a password-protected directory. The data was also stored on password-protected cloud-based service, Microsoft 365, which enabled the research team access the data virtually from any location which was crucial as the intervention was conducted across two states.

An experienced data manager conducted the data management and data cleaning following a protocol developed by the research team. Where data was missing or appeared to be recorded incorrectly, participants were contacted via SMS, prior to de-identifying them for analysis. All quantitative data was transferred from a Microsoft Excel spreadsheet to IBM SPSS Statistics version 22 for analysis. Further, the app data captured by a unique ID code attached to each participants email address was transferred from the app database to Microsoft Excel and managed by the candidate. A series of logical checks were performed to remove duplicates, to check for consistency in formatting of dates and numerical data and to generate data for the Engagement Index (see Chapter Six).

The qualitative interviews exploring the mothers' experiences using the Growing healthy program were transcribed verbatim and analysed by the candidate using NVivo Data Qualitative Analysis Software (QSR International Pty Ltd 2015). Further details of the analysis and findings of this study are reported in Chapter Seven.

5.7 Ethics approval

The Growing healthy study was approved by Deakin Human Research Ethics Committee (HREC) and DEECD (reference number 2014_093) as well as University of Technology Sydney HREC (ETH15-0110).

5.8 Discussion

The Growing healthy program is to our knowledge the first mHealth intervention that targets infant feeding and parenting behaviours. The development of this complex intervention included utilising the Intervention Mapping framework and the Behaviour Change Wheel to address the public health issues related to unhealthy weight gain in infancy. The aim of the Growing healthy study was to examine the feasibility of introducing an mHealth intervention among mothers of low socio-economic background through monitoring their interaction with the intervention and the uptake of healthy infant feeding behaviours.

This study was designed to be applicable in a real-world setting. In particular, the intervention was developed by experts in the field to complement the practices of PHC providers. The low dose and relatively low cost of this intervention mean that it would be feasible to deliver at a population level (Laws, Litterbach, et al. 2016).

This chapter outlined a detailed summary of the Growing healthy program. The following chapter outlines the development of an Engagement Index and examines associations between engagement and Growing healthy intervention outcomes, specifically the age of solids introduction.

Chapter 6: Assessing participants' engagement with the Growing healthy app and the association with intervention outcomes

6.1 Introduction

The previous chapter outlined the development and the methodology of the Growing healthy program. This chapter describes the development of the Engagement Index (EI) to measure the participants' engagement with the app. It also presents characteristics of the participants in the Growing healthy program, the analyses of the participants' engagement and the relationship between the age at which participants introduced solids to their infants and their engagement level. This chapter has been accepted to be published in the *Journal of Medical Research*[4] (Appendix 6A).

6.1.1 Measuring user engagement in mHealth programs

Internet-based interventions (mHealth) delivered via computers or mobile devices have many advantages compared with traditional in-person interventions. One advantage, explored in this chapter, is the opportunity to measure participant engagement (Baltierra et al. 2016). Interventions delivered by this method allow the collection of basic usage data, including frequency of access, page views, push notifications opened and average time spent on a page (Web Analytics Association 2008). Such data can be used to understand the dynamics of engagement and to determine whether the intervention design needs to be improved to reduce participant attrition and increase intervention exposure (Crutzen et al. 2009; Danaher et al. 2015). Yet as this method of delivering health interventions is still in its infancy, there are current gaps in understanding how engagement should be measured and how best to define participant engagement (Couper et al. 2010). Although these data are useful, very few mHealth programs have used them comprehensively to analyse participant engagement or to consider associations with desired outcomes (Baltierra et al. 2016; Couper et al. 2010; Davies et al. 2012).

[4] (Taki et al. 2017)

Even though some mHealth interventions have used basic metrics to measure engagement such as frequency of app access (Bricker et al. 2014), the growth in technology and the enhancements of the features available means that these basic metrics no longer suffice to fully capture the many aspects of consumer engagement. Consumer engagement has been explored more thoroughly by the digital advertising and marketing fields for some time (Peterson & Carrabis 2008). Traditionally, market research organisations have used simple metrics to measure consumer interaction with websites. However, to more accurately understand behaviours and the influences on users, organisations such as Web Analytics Demystified (Peterson & Carrabis 2008) and Forrester (Schadler & McCarthy 2012) have developed 'engagement indices' that calculate consumers' overall interaction with online technologies. These engagement indices provide evidence regarding the strengths and weaknesses of website and app features that lead to optimal participant engagement and sustainable long-term use of the app.

6.1.2 Measuring the effectiveness of mHealth programs on health behaviours

The Growing healthy program aimed to influence infant feeding outcomes. The assessment of levels of participant engagement with the Growing healthy app and the association between participant engagement and the intervention outcomes are both important contributions to the limited literature. To assess this relationship an Engagement Index was developed and applied (Figure 6.1). In the current literature, there are no published mHealth studies to the candidate's knowledge which have applied an Engagement Index to measure participant behaviour and interaction with a health promotion program.

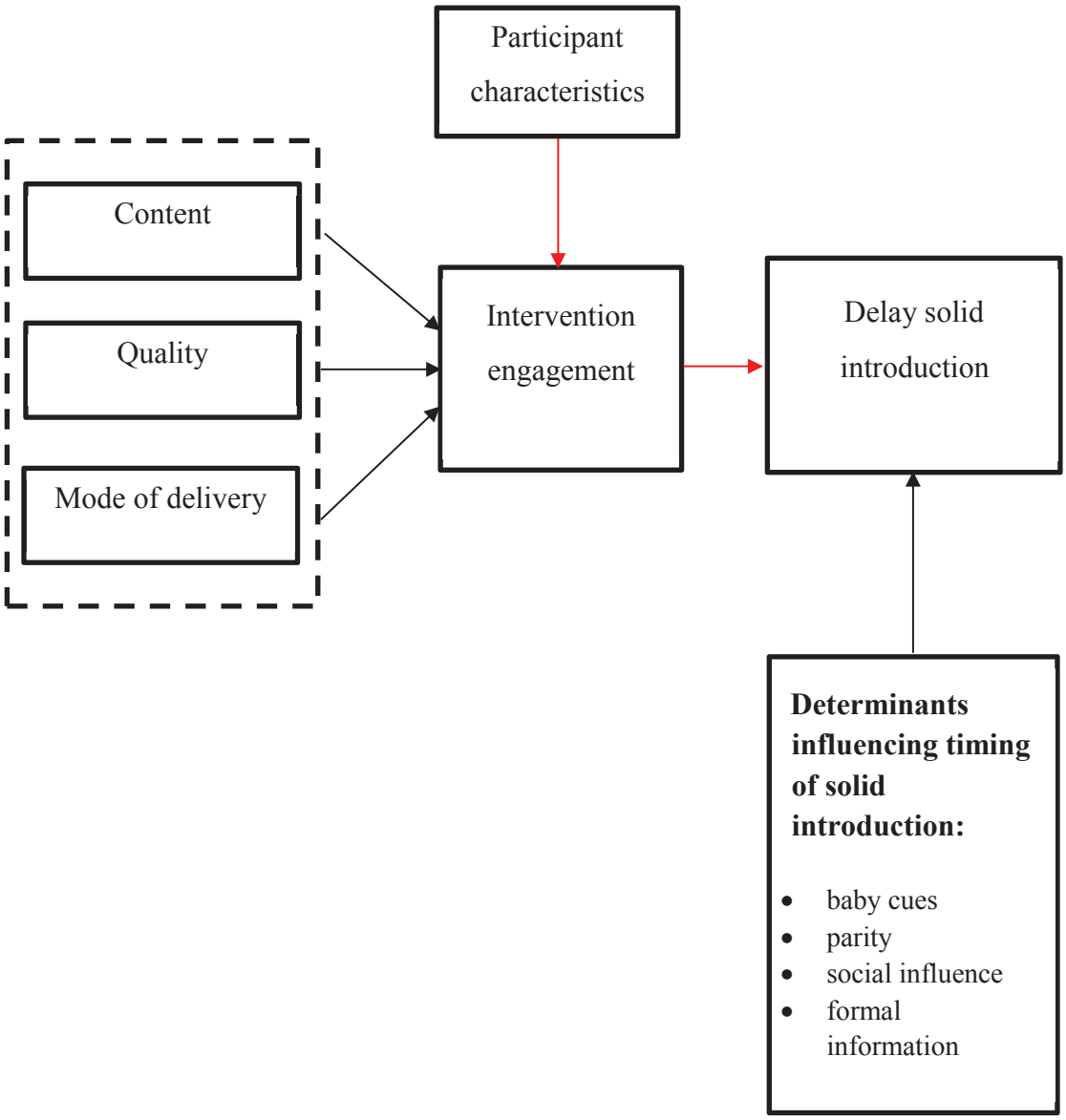

Figure 6.1 Relationships in the conceptual model addressed in this chapter are outlined in red

6.2. Aims

The study presented in this chapter addressed two key aims. The first aim was to examine determinants associated with the participants' engagement with the Growing healthy program app. The second aim was to assess the influence of participants' engagement with the Growing healthy app on the age at which they introduced solids to their infant.

The objectives of this chapter are to:

- provide a rationale and description of the development of an Engagement Index to measure the participants' behaviour utilising the Growing healthy app
- assign cut-off points for poorly, moderately or highly engaged users of the Growing healthy app
- describe the demographic characteristics of Growing healthy participants included in this study
- explore independent variables (predictors) that are significantly associated with participant engagement with the Growing healthy app; and
- explore the association between the participants' engagement with the app and the timing of solid introduction.

It was hypothesised that participants who had a higher level of engagement with the Growing healthy app were more likely to delay solid introduction in line with the national recommendation as advocated in the Growing healthy program. The recommendation suggests parents introduce solids 'at around six months of age but not before four months'.

6.3. Methods

This study utilised an array of data collected from the Growing healthy program. As discussed in Chapter Five, participants from the study were asked to complete three quantitative surveys, at: baseline (T1) (infant age ≤3 months); infant aged six months (T2) and nine months (T3). The surveys included questions on demographic details and feeding behaviours. The participant app usage data indicated how the Growing healthy app was utilised. This chapter uses data from both sources as depicted in Table 6.1.

Table 6.1 Variables and categories used for analysis from each data source of the Growing healthy program

Data	Outcome variables	Categories
Metrics from the Growing healthy app database	Frequency of app usage	per day/ week/ month
	Number of push notifications sent and opened	Per day/ week/ month
	Number of pages viewed	Per day/ week/ month
	Type of system used	App only **(**access to app and push notifications) Both (access to app, push notifications and weekly emails) SMS only (access to SMS, weekly emails and website)
Growing healthy Baseline Survey	Participant's age at registration	In years
	Mother's education level	**University –** 'University degree' /'Higher university degree' **No university –** 'No formal qualifications', 'Year 10 or equivalent', 'Year 12 or equivalent', 'Trade or apprenticeship', 'Certificate/diploma'
	Level of household income	**Below average –** '$1-$119 per week', '$120-$299 per week',' $300-$599 per week', '$600-$799 per week', '$800-$999 per week' **Average – '**$1,000-$1,499 per week' **Above average –** '$1,500-1,999 per week' **Higher income – '**$2,000 or more per week'
	Marital status	**Relationship –** 'Married', 'Living in a defacto relationship' **Single –** 'Separated', 'Divorced', 'Widowed', 'Never married'
	Daily Activity	**Working/studying –** 'Full/part-time/casual paid work' and 'Full/part-time studying' **Not in labour force –** 'Keeping house and/or raising children full-time' and 'Unemployed or laid off'
	Parity	Primiparous Multiparous
	Country of birth	Australia New Zealand UK Other
	Method recruited	**Practitioner –** 'Midwife at antenatal appointment', 'General Practitioner', 'Practice Nurse, Maternal and child health nurse', 'brochure /poster in waiting

		room', 'Brochure in letter from council', 'Brochure in pack of information provided by maternal and child health nurse' 'Mums group' **Online –** 'Baby Hints and Tips (Facebook page)', 'Mum Central (Facebook page)', 'Mum's Pantry (Facebook page)', 'Canberra Mums', 'Essential Baby', 'Facebook advertising', 'The BubHub' **Family/Friends**.
	Phone type	iOS Android Other
	Infant age at registration	In weeks
	Infant Date of Birth	Date (dd/mm/yyyy)
	Infant weight at birth	In grams
	Infant gender	Female Male
	Milk feeding at registration	Breastfeeding, Formula feeding, Mixed feeding
Growing healthy T2 survey (Six months of age)	Age at solid introduction	In weeks
	Reasons for introducing solids	See Table 6.9
Growing healthy T3 survey (Nine months of age)	Participant satisfaction with the Growing healthy app	See Table 6.7

6.3.1 The Engagement Index for the Growing healthy program

The Engagement Index developed for this study was used to understand participant interaction with the app by extracting metrics from the app database. This database, designed by the app developer, is used to monitor participant app usage behaviour. Table 6.1 indicates the metrics extracted from the database. The Digital Analytics Association have defined metrics that can be collected from online devices such as apps and websites (Web Analytics Association 2008) including 'session duration', 'page views per session', 'number of sessions', 'conversion rate' (i.e. clicking on an advertisement, registering to a newsletter) and 'satisfaction'. These measures capture participant behaviour in relation to their use of the app and other subjective markers such as feedback and satisfaction. These metrics are important to this study as they

provide insight into participant usage of the program and whether their interaction influenced behaviours targeted by this intervention.

For this study, the Visitor Engagement Index developed by Web Analytics Demystified (Peterson & Carrabis 2008) was adapted for application to the Growing healthy program. The original Index was made up of seven sub-indices to measure: Click-depth, Loyalty, Recency, Interaction, Feedback, Brand and Duration. The Growing healthy Index included the first five of these sub-indices (see Table 6.2 for definitions of included sub-indices).

The purpose of this Index is to calculate a score for each participant that is a measure of their overall engagement with the app against pre-determined criteria. The criteria from the Visitor Engagement Index have been altered to suit the Growing healthy program (as described in Section 6.3.2). This Index was selected given the availability of detailed descriptions on how to develop and apply it. Similar indices (Schadler & McCarthy 2012) had limited access and were part of a paid service. Unlike Google analytics which simply track and report website traffic (Google 2016b), the Growing healthy Engagement Index combines the metrics to determine an engagement score.

Table 6.2 Definitions of the sub-indices in the Engagement Index designed for the Growing healthy program

Sub-indices	Definition	Formula	Calculation period	Final calculation
Click-Depth Index (C_i)	Number of app pages a participant viewed per session (1 day)	$\frac{Sessions\ having\ "at\ least\ 2\ pages\ viewed"}{All\ sessions}$	• Initial C_{i1}= 0-3 months • Interim C_{i2}= 3-6 months • Final C_{i3}= 6-9 months	$= \sum_{j=1}^{n} C_{ij}/n$
Loyalty Index (L_i)	Frequency of participant access to the app	$1 - \left(\frac{1}{Number\ of\ sessions\ accessed\ during\ the\ timeframe\ of\ the\ program} \right)$	• Initial L_{i1}= 0-3 months • Interim L_{i2}= 3-6 months • Final L_{i3}= 6-9 months	$= \sum_{j=1}^{n} L_{ij}/n$
Interaction Index (I_i)	Number of push notifications opened out of those sent through the program.	$\frac{Number\ of\ push\ notifications\ opened}{Total\ number\ of\ push\ notifications\ sent}$	• Initial I_{i1}= 0-3 months • Interim I_{i2}= 3-6 months • Final I_{i3}= 6-9 months	$= \sum_{j=1}^{n} I_{ij}/n$
Recency Index (R_i)	Time difference between participant access sessions.	$\frac{1}{Average\ number\ of\ days\ between\ visits}$	• R_{i1}= days between registration and app activation • R_{i2}= 3-6 months • R_{i3}=6-9 months	$= \sum_{j=1}^{n} R_{ij}/n$
Feedback Index (F_i)	Subjective measure of the participants' satisfaction with the app assessed in the program's nine-month survey (questions included: ease of navigation, readability, quality and usefulness of app content).	$\frac{Number\ of\ positive\ responses}{Number\ of\ questions\ asked\ about\ their\ satisfaction\ with\ the\ app}$	• F_i= 9 months infant's age	$= \sum_{j=1}^{n} F_i/n$

Where n= 3 for C_i, L_i, I_i and R_i (sum of calculation period) and n= 37 for F_i (sum of questions available in Table 6.7)
Where *i*= *i*th person
Where j= *j*th time period

6.3.2 Development of the Engagement Index

The development and application of the Engagement Index involved a two-step process. Step one involved preparing the app data in three phases: 1) cleaning and compilation, 2) coding and computation and 3) identifying data for sub-indices (Table 6.3). The second step was the development and application of the Index which involved identifying appropriate formulae for each sub-index to align with the Growing healthy program. Development of the Index was an iterative process which required frequent revisions and ongoing edits within the above phases as more data became available. The development and application of the Engagement Index used Microsoft Excel version 2013.

The candidate was the main contributor to the development of the Engagement Index and was involved in each phase. A number of chief investigators from the Growing healthy team provided advice and guidance throughout the development process. The University of Technology Sydney Human Research Ethics Committee approved the use of the app data from the Growing healthy program for this purpose (HREC 2013000463).

Table 6.3 Summary of development of the Engagement Index

Step	Phase	Process
Step 1	1. Cleaning and compilation	Removed duplicate data, removed ineligible participants, conducted checks and balances, formatted dates
	2. Coding and computation	Formatted numeric app data into a categorical format
	3. Identifying data for sub-indices	Outlined metrics to calculate the sub-indices
Step 2	Development and application of the index formulae and calculations	Calculated each sub-index and the overall Engagement Index score for each participant

Step 1: Data preparation

A key benefit of an mHealth approach is the availability of real time data, including the measurement of participant behaviour using the app. App programs are unique in purpose and features they offer, requiring an understanding of the type and nature of data collected.

The app developer automated a registration process using the data collected from the baseline survey including phone type, infant age and feeding method. This information allowed participants to register into either the app or Short Messaging Service (SMS) program and receive tailored messages according to their infant's age and stage of feeding. Participants who were eligible for the app were given a unique code to activate the app, which tracked their app interaction in the app database. Each participant in the app program was allocated a unique identification (ID) code to link their app interaction into the app database. The app data output included variables such as ID code, email address, dates of app access, app pages the participant opened and push notifications which were sent and opened.

Phase 1: Data cleaning and preparation

Data cleaning consisted of two processes. Firstly, the candidate exported the latest app usage datasets to an Excel database at weekly intervals, using a read-only link created by the app developer.

Secondly, the candidate removed duplicate data from the dataset and conducted consistency checks to eliminate errors during analysis. Unique participant IDs and app codes were matched to simplify tracking an individual's interaction with the app. Dates were checked and corrected for consistency in formatting including the participant registration date, infant's date of birth, app activation date and participant app access. A regularly-updated participant registration list obtained from the baseline survey (T1) was linked to the raw data spreadsheet. Any unidentified participants in the app dataset that were not linked with the T1 survey registration list were noted. The candidate identified and removed ineligible users within the app dataset, including healthcare practitioners involved in recruitment for the program, colleagues involved in the development of the program and participants in another sub-study of the Growing healthy program. Finally, the candidate tested each participant's unique ID to ensure there was no duplication and that IDs linked with the app metrics, including the sessions on the app, pages visited and push notifications sent and opened. Using Visual Basic for Applications in Microsoft Excel the candidate created macros to automate tasks and to apply these checks on the ongoing updates from the app database.

Phase 2: Coding and computation

As illustrated in Chapter Five, the baseline survey collected information on the type of phone and operating system participants used (android or iOS) to determine the program (app or SMS) to which they would be allocated. Firstly, phase two involved formatting numeric data into a categorical format. The variables from the baseline survey and the app data were then matched with the unique participant ID code.

Secondly, this phase explored the participants' use of the app from the point of registration until the infant was nine months old. The candidate analysed descriptive data on participant app usage, including number of sessions (one day was equal to one session), number of pages accessed per session, and push notifications sent and opened. This allowed identification of any technical and functional problems related to android and iOS app updates and their respective impact on participation rates throughout the intervention period.

During the course of the program, a number of participants ceased opening push notifications, leading the chief investigators to send all the participants weekly emails to encourage engagement. Therefore, participants who used the app program and accessed weekly emails were labelled as 'both'.

Phase 3: Identifying data for sub-indices

Once the database processing was finalised, the candidate identified the metrics needed to calculate the sub-indices (outlined in Table 6.2) of the Engagement Index. The Feedback Index, the only sub-index which did not use the app data, was informed by the nine-month survey (T3). The final formula used to score the participants' engagement in the program incorporated data from five sub-indices (Click-depth, Loyalty, Recency, Interaction, Feedback) and is shown as Equation 1. The Engagement Index was presented as a percentage (i.e. a value between zero and 100).

Engagement Index Formula

$$\mathrm{EI} = \sum(C_i + L_i + I_i + R_i + F_i) \times 100 \qquad (1)$$

Where:
EI is Engagement Index
C_i is Click-depth Index
L_i is Loyalty Index
I_i is Interaction Index
R_i is Recency Index
F_i is Feedback Index

Step 2: Applying the Engagement Index

Participants

As indicated in Chapter Four, the Growing healthy program enabled participants to join either the app or SMS/website version of the intervention depending on the mobile phone model and operating system they used. The Engagement Index was developed and utilised with a selection of participants in the Growing healthy program. The eligibility criteria for inclusion in Engagement Index scoring required participants to have:

- registered (Baseline Survey) to the Growing healthy app program and to be eligible;
- activated and accessed the app at least once; and
- used the 'app' (app and push notifications) or 'both' systems (app and weekly emails).

The Engagement Index scoring excluded SMS-only users as their interaction metrics were limited. During the course of the program, participants had the option to switch from using the app system to the SMS system. This option became available after technical issues with the upgrades of smartphone operating systems caused the app to become dysfunctional. As outlined in phase two, participants in the app program received weekly emails which included links to the Growing healthy website instead of the app. Due to the limited data that are not available on participant usage of the website including the number of visits and pages viewed, it was not possible to calculate an engagement score for participants using the website only.

The Engagement Index was developed to measure the participant experience during the Growing healthy program and the effectiveness of the intervention at the end of the program. The data period analysed ranged from date of registration through to nine months from infants' date of birth.

Calculating the Engagement Index for the Growing healthy program

The score for each sub-index except the Feedback Index was calculated for three time periods, including initial (0-3 months), interim (3-6 months) and final (6-9 months); the scores were then averaged. This decision was based on the review of the data distribution which showed an initial intense usage followed by sparse participant access towards the end of the nine-month program.

A detailed explanation for the calculation of each sub-index follows:

Click-Depth Index (C_i)

This sub-index focused on the number of pages a participant viewed in each session of app access. The calculation of C_i used two metrics: the number of sessions in the time period and number of pages viewed per session. The original formula for this sub-index required using a threshold. As presented in Table 6.2 a threshold of two was applied to the formulae for the number of pages viewed per session. As this is the first mHealth intervention to utilise an Engagement Index, there was no current benchmark for an effective click-depth. Number of pages is an absolute value (i.e. non-negative integer values) requiring the threshold to be attained through appropriate statistics. The threshold was therefore based on the median distribution of the number of pages viewed per session by participants, which was two.

The overall C_i score is the mean of each time period calculation: C_{i1}, C_{i2} and C_{i3}.

Loyalty Index (L_i)

This sub-index calculated the frequency of app access throughout the nine-month program. The calculation for L_i used the number of sessions, transformed to a value between zero and one by taking the reciprocal. The total score was dependent on when participants activated the app. This was used to determine the length of time (days) they

were part of the program by subtracting it with infants' age at nine months, with 272 days (9 months) being the maximum number of days.

The overall L_i score is the mean of each time period calculation: L_{i1}, L_{i2} and L_{i3}.

Interaction Index (I_i)

This sub-index focused on the number of push notifications opened versus total sent throughout the nine-month program. This formula was calculated each month based on the infant's age according to when the participant activated the app. The scores were then averaged based on the three time periods, including initial (0-3 months), interim (3-6 months) and final (6-9 months).

The overall score of I_i is the mean of each time period calculation: I_{i1}, I_{i2} and I_{i3}.

Recency Index (R_i)

This sub-index focused on the number of days between each session. The R_i was calculated at three different time points: the number of days elapsed from registration to when the participant first accessed the app (R_{i1}), the mean number of days between sessions when the participant accessed the app between three to six months (R_{i2}) and between six and nine months (R_{i3}). The data are transformed by taking the reciprocal of each R_{i1} to R_{i3}.

The overall R_i score is the mean of each time period calculation: R_{i1}, R_{i2} and R_{i3}.

Feedback Index (F_i):

This sub-index was a self-reported measure of participant satisfaction with the app collected in the nine-month survey (T3) rather than through app data. Constructive feedback was scored positively as one and negatively as zero.

The nine-month survey asked 37 questions, used to calculate participant satisfaction ($F_{i)}$. Each question (Appendix F; T3: Question Q D1) used a five point Likert scale which ranged from 'strongly agree' to 'strongly disagree' or 'didn't use'. The responses were dichotomised as either one or zero according to whether they answered an extreme positive response or not; for example: Strongly agree= 1, Agree= 0, Neither here nor there= 0, Disagree= 0, Strongly disagree= 0, Didn't use= 0. Extreme positive scoring

was reversed on the Likert scale for negative questions indicated with an asterisk (Table 6.7).

Two data issues impacted the calculation for F_i. Some app users (n= 15) reported in the T3 survey that they were using the Growing healthy website rather than the app. In addition, a number of participants (n= 102) did not complete the T3 survey so a score for F_i could not be calculated. In consultation with the chief investigators, the candidate decided that, for participants who completed the satisfaction survey for the website, the total score of the Engagement Index was the mean of the four sub-indices scores that were available. For participants who did not complete the T3 survey, their F_i was scored zero and the Engagement Index was the mean of all five sub-indices.

6.3.3 Data preparation for the Growing healthy quantitative surveys

Entry, cleaning and coding

The data from the Growing healthy questionnaires was entered onto Microsoft Excel by several researchers involved in the intervention and a data management expert. Discrepancies identified in each questionnaire (baseline, T2 and T3) were discussed and resolved by the senior researchers in the study.

The candidate reviewed descriptive statistics for both continuous and categorical variables to assess data variability, identified typographical errors and out-of-range values and recoded the variables appropriate for the purpose of this thesis (discussed in Chapter Three).

Establishing normality of variable distributions

Univariate normality for continuous outcome data was assessed, using statistical and graphical methods (Field 2009). To determine whether continuous variables met assumptions of normality, the following two criteria were considered:

- Values of skewness and kurtosis were between -2.58 and 2.58 (significant at $p < 0.01$); and
- Histograms were symmetrical and bell-shaped.

Outliers and missing data

The candidate examined outliers to establish if extreme responses for key variables were a true representation of the sample or due to data errors. The data included in this thesis had few outliers identified. One participant had inconsistently reported her infant's date of birth for all three surveys and was excluded from the dataset. Outliers were present in the age of solid introduction (weeks), with participants reporting introducing solids as early as four weeks and as late as 36 weeks. The age of solid introduction in weeks was not normally distributed. A previous study focusing on factors associated with solid introduction conducted in the United Kingdom found the age of introducing solids reported by mothers was between six and 32 weeks, similar to this study (Brown & Rowan 2016). Whilst extreme, these values were considered to be within a range of possible values and were retained in the analysis.

6.3.4 Data Analysis

Data from the Engagement Index and the quantitative surveys were analysed using version 23.0 of the Statistical Package for Social Sciences (SPSS) (IBM Corp, Armonk, NY, USA).

Descriptive statistics were calculated on all key variables for:

- the thesis sample (Table 6.4)
- the thesis sample by Engagement Index level (Table 6.5); and
- the thesis sample by timing of solid introduction (Table 6.8).

Categorical data were described with frequencies and percentages. For continuous, normally-distributed variables, means and standard deviations were reported, while medians and interquartile ranges were used to summarise non-normally distributed variables (Osterlind, Tabachnick & Fidell 2001). For group comparisons, t-tests and ANOVA were used for normally-distributed continuous and categorical variables respectively. Group comparisons for non-normally distributed continuous and categorical variables, the Mann-Whitney U-test and Kruskal-Wallis test respectively were applied. Correlations were calculated using Pearson correlation for normally-distributed continuous variables and Spearman correlation for continuous variables which were not normally distributed.

To analyse the data using the Engagement Index scores, cut-off points were developed to group the scores into Engagement Index levels. Web Analytics Demystified (Peterson & Carrabis 2008) categorised participants as highly or poorly engaged, if they were above or below the mean, by calculating the average engagement score of the total population. Given there are no current mHealth interventions which have utilised an Engagement Index, the level of engagement was determined from the distribution, rather than the average of the Engagement Index scores of the total sample. The interquartile ranges were used to determine the engagement levels, where:

- ≤ Quartile 1= Poor engagement
- Quartile 1 to 3= Moderate engagement
- ≥ Quartile 3= High engagement

Multiple linear regression

Predictors of the Engagement Index scores were determined with the use of multiple linear regression. A series of multiple linear regression models were developed taking the participants' Engagement Index score as the dependent variable. Variables from the univariate models were included in the full linear regression model if $p \leq 0.25$ (Hosmer Jr & Lemeshow 2004). The variable which attained the highest p-value was removed from the model (full model) until all variables were statistically significant ($p \leq 0.05$).

Survival Analysis

Survival analysis was conducted to examine the mean infant age at which participants introduced solids for the three Engagement Index levels (poor, moderate and highly engaged). Survival analysis is a collection of statistical procedures for data analysis for use when the outcome variable of interest is time until an event occurs. In this study, time refers to 'infant's age' (weeks) and the event is the age of 'solid introduction'. This technique is applicable to data which is continuous, non-normally distributed and censored (i.e. contains incomplete responses). Censored responses resulted if: 1) participants did not complete the T2 survey or 2) they had not introduced solid food at the time of completing the T2 survey. Censored data require utilising the latest record of the infants' age that was available from the survey data. The latest age was obtained from the last survey completed by the participant.

Kaplan-Meier curves were used to estimate the mean and median of the age at which participants introduced solids in each Engagement Index level. Differences between each level were assessed using Log-rank, Breslow and Tarone-Ware tests. Cox proportional hazard regression was performed to examine the hazard ratio of participants delaying solid introduction which was stratified by Engagement Index level. All of the covariates were included in the model (full model) until all variables were statistically significant ($p \leq 0.05$).

Logistic Regression

A logistic regression analysis was performed to explore the significant predictors (Engagement Index score, maternal/infant characteristics) for each reason for introducing solid foods. A separate logistic regression model was performed for each reason. Variables were included in the model if they were statistically significant ($p \leq 0.25$) from the univariate modelling.

6.4 Results

6.4.1. Sample size

Figure 6.2 illustrates the number of participants who were enrolled in each program (app and website/SMS) and the non-completion rate of the baseline, six month and nine month surveys.

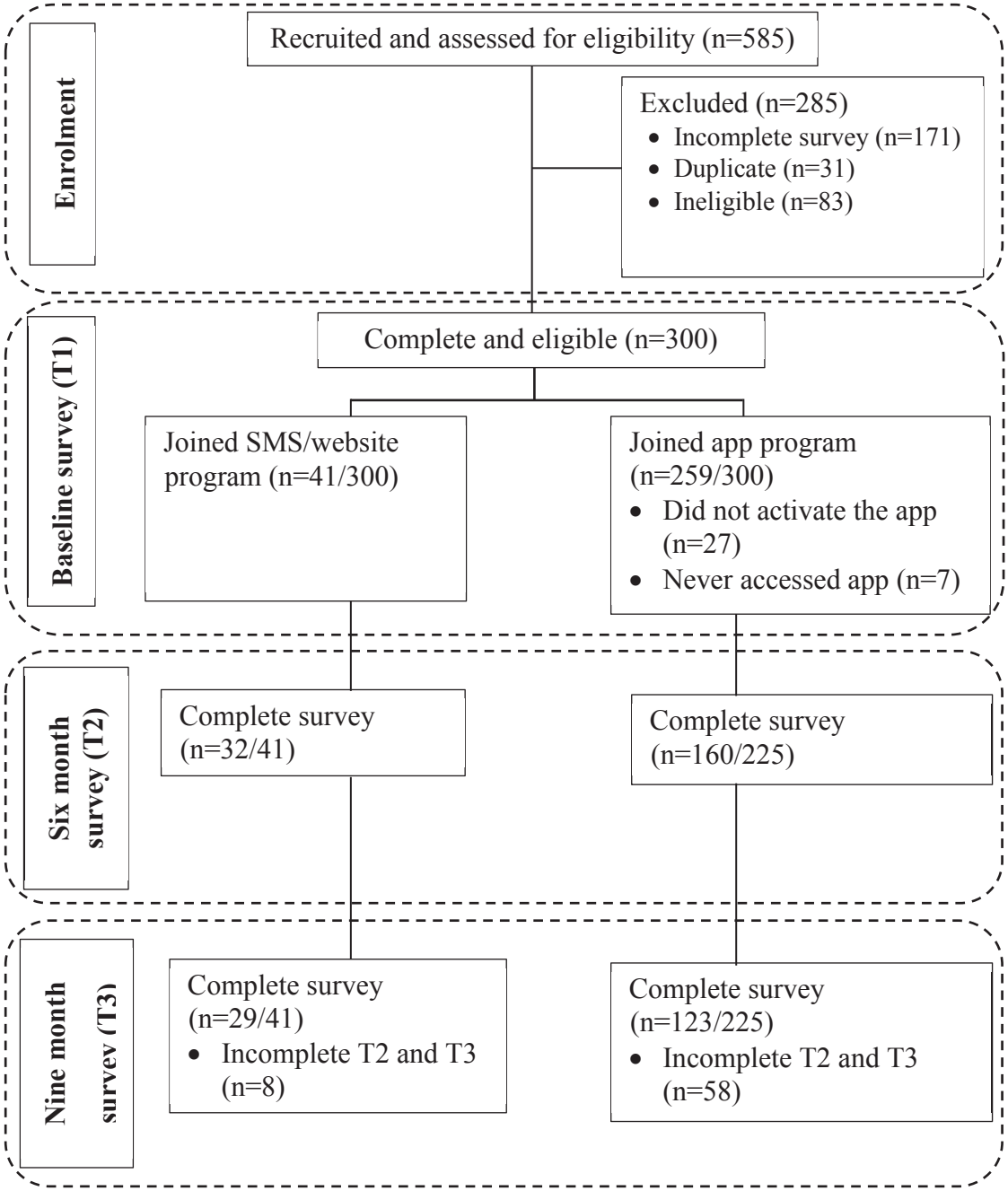

Figure 6.2 Participant recruitment, enrolment and completion of baseline, six month and nine month surveys

6.4.2 Thesis sample characteristics

A total of 75% (225/300) of participants included in the Growing healthy program met the criteria for inclusion in the thesis sample. Table 6.4 outlines maternal and infant dyad baseline socio-demographic characteristics. The majority of participants were primiparous (140, 62.2%); aged between 18 and 42 years (mean: 30.5 ± 4.47 years); earned an above average income >$1500per week (113, 50.2%); were living with a partner (217, 96.4%) and were full-time carers of their infant (not in the labour force) (189, 84%). Of the participants who reported their education (96.4%), less than half had a university degree (112/217, 49.7%). Of the infants 50.7% were male; most were between six and 14 weeks at baseline (mean= 6.9 ± 3.68 weeks); and 56.4%, (127/225) were breastfed.

Table 6.4 Baseline demographic characteristics of thesis sample (n= 225)

Variable	**Level**	**n**	**(%)**	**Mean ± SD (Range)**
Participants Characteristics				
Age	Years			30.5 ± 4.47 (18-42)
Education level (n= 8)	No University	112	49.7	
	University degree	105	46.6	
Household gross weekly income ($AUD)	Below average (<$1000/week)	25	11.1	
	Average ($1000-<$1500/week)	50	22.2	
	Above average ($1500-<2000/week)	50	22.2	
	Higher income ($2000/week or more)	63	28.0	
Marital status	Single	8	3.5	
	Relationship	217	96.4	
Employment status	Not in labour force	193	85.7	
	Working/studying	32	14.2	
Parity	Primiparous	140	62.2	
	Multiparous	85	37.7	
Country of birth	Australia	187	83.1	
	New Zealand	4	1.8	
	UK	5	2.2	
	Other	29	12.9	
Recruitment method	Practitioner	106	47.1	
	Online	91	40.4	
	Family/friends	28	12.4	
Device type	iOS	161	71.6	
	Android	64	28.4	
System type	App only	65	28.8	
	Both (app and email)	160	71.1	

Infant Characteristics				
Age	Weeks			6.9 ± 3.68 (0.6-14.7)
Birth weight (n= 3)	Grams			3513 ± 494.14 (2350-4950)
Gender	Male	114	50.7	
Baseline feeding Status	Breastfeeding	127	56.4	
	Formula Feeding	62	27.6	
	Mixed Feeding	36	16	

Data provided at baseline or T1 (age ≤3 months)

(n values) reflect missing data or outliers from participants included in this thesis

6.4.3 Participant Engagement

Analysis of the Engagement Index (EI) scores

The mean EI score was 30.0%, the median was 30.2% and the standard deviation was 11.5% (range 1.8-57.6%). The EI levels were defined by the quartiles (Figure 6.3), including:

- ≤Quartile 1 (≤21.1%)= Poor engagement
- Quartile 1 to Quartile 3 (21.1-37.1%)= Moderate engagement
- ≥Quartile 3 (≥37.1%)= High engagement

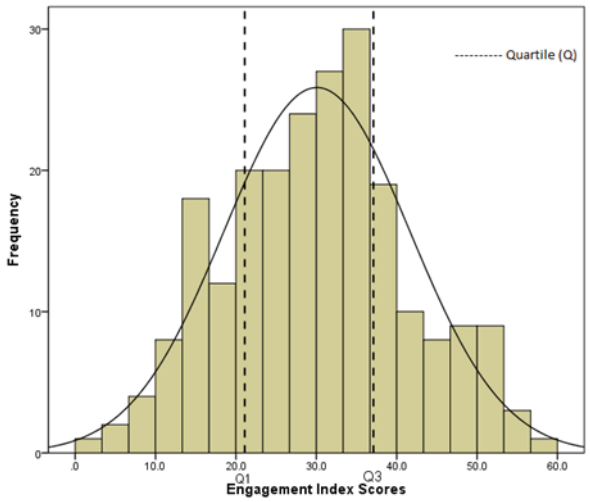

Figure 6.3 The distribution of Engagement Index scores

Table 6.5 presents the characteristics of participants categorised as having poor, moderate and high engagement. There were significant differences in three participant sub-group characteristics. Participants with a high EI level were likely to be first-time

parents, using both the app and opening weekly emails, and to have joined the program with a younger infant (5.6±3.4 weeks). Higher education was associated with higher engagement: 64.3% of participants with high engagement had attended university, compared with 46.1% of those with moderate and 44.7% of those with poor engagement, although the association was not statistically significant.

Table 6.5 Characteristics of Growing healthy participants by Engagement Index level (n= 225)

Variables	**Poor engagement (n= 56) 15.1±4.6**	**Moderate engagement (n= 113) 30.0±4.3**	**High engagement (n= 56) 45.0±5.5**	**p**
		Mean ± SD or % (n)		
Participant characteristics				
Age (years)[a]	30.3±4.4	30.5±4.4	30.6±4.5	.613
Education (No university)[b]	55.3 (31)	53.9 (61)	35.7 (20)	.119
Income (Higher income)[c]	25.0 (14)	31.8 (36)	23.2 (13)	.703
Marital status (Relationship)[b]	96.4 (54)	97.3 (110)	94.6 (53)	.597
Employment status (Not in labour force)[b]	91.0 (51)	85.8 (97)	80.3 (45)	.149
Parity (Primiparous) [b]	51.7 (29)	61.9 (70)	73.2 (41)	.004*
Recruitment method (Practitioner) [c]	48.0 (24)	47.9 (52)	48.0 (30)	.061
Device type (iOS) [b]	67.8 (38)	72.5 (87)	64.2 (36)	.735
System type (both app and email users) [b]	46.4 (26)	72.5 (82)	92.8 (52)	.0001*
Infant characteristics				
Age at registration (Weeks)[a]	7.3±3.6	7.4±3.6	5.6±3.4	.023
Birth weight (grams)[a]	3468.7±591.8	3470.6±593.3	3466.9±592.3	.208
Gender (male)[b]	55.3 (31)	46.9 (53)	41.0 (23)	.344
Baseline feeding status[c]				
Breastfeeding	62.5 (35)	56.6 (64)	50 (28)	.136
Formula feeding	25 (14)	22.1 (25)	41 (23)	
Mixed feeding	12.5 (7)	21.2 (24)	8.9 (5)	

Engagement Index cut-points for scores: Poor engagement= <21.1, moderate engagement= 21.1-37.1, high engagement= >37.1

Data provided at baseline or T1 (age ≤3 months)

[a] Pearson correlation; Mean ± standard deviation (SD) reported

[b] t-test; % within group (count) reported

[c] Based on ANOVA; % within group (count) reported

* Statistically significant engagement level and independent variable <0.05

Predictive characteristics for Engagement Index scores

Table 6.6 displays the predictors for the Engagement Index Scores. Of the 14 variables considered as potential predictors, eight met the screening criterion of $p \leq 0.25$ in the univariate modelling and were included in the full model (Hosmer Jr & Lemeshow 2004). Four independent predictors for the Engagement Index scores were identified in the final model. Participants were likely to score a higher Engagement Index score if they were primiparous, used both the app and the email, and were recruited by their health practitioner. By contrast, participants who registered when their infant was closer to three months attained a lower Engagement Index score. No other variables examined had statistically significant associations with level of engagement.

Table 6.6 Linear regression to explore the predictors of Engagement Index scores

Variable	Univariate Model (B)	p	Full Model (B)	p	Reduced Model (B)	p
R^2			0.154		0.164	
Parity		0.004		0.006		0.005
Multiparous	1.00		1.00		1.00	
Primiparous	4.532		4.147		4.209	
Recruitment method		0.061		0.067		0.020
Family/Friends	1.00		1.00		1.00	
Practitioner	5.346		6.423		4.221	
Online	2.795		4.267		0.989	
System type		<0.001		<0.001		<0.001
App only	1.00		1.00		1.00	
Both (app & email)	7.977		-6.426		-6.937	
Infant age at T1(Weeks)	-0.477	0.023	-0.522	0.016	-0.459	0.005
Income		0.703				
No response	1.00					
Below Average	-0.033					
Average	2.921					
Above Average	0.061					
Higher income	1.181					
Marital status		0.597				
Relationship	1.00					
Single	2.208					
Employment Status		0.149		0.084		
Working/studying	1.00		1.00			
Not in labour force	-3.189		-2.927			
Country of birth		0.313				
Other	1.00					
Australia	-2.389					
New Zealand	-0.074					
United Kingdom	6.9.41					
Device type		0.735				
iOS	1.00					
Android	0.580					
Birth weight (grams)	0.002	0.208	0.001	0.424		
Gender		0.344				
Male	1.00		1.00			
Female	-1.462		-0.440	0.769		
Baseline feeding Status		0.136		0.166		
Mixed feeding	1.00		1.00			
Breastfeeding	-0.401		0.524			
Formula feeding	3.124		3.941			

Analysis of the Sub-indices

Click-depth Index (Ci)

The median score for Click-depth index (C_i) was 30.8% and interquartile range was 21% to 37.2%. Of the 303 pages that were available to view, the mean number of pages viewed was 30 (Range: 1-156) and a median of 24. Although, throughout the program, participants viewed a mean of 44.2 pages (Range: 1-316) and a median of 29. The median number of pages viewed per session was two. The most commonly viewed pages on the app are illustrated in Figure 6.4 with the solids section viewed the most and mixed feeding section viewed the least.

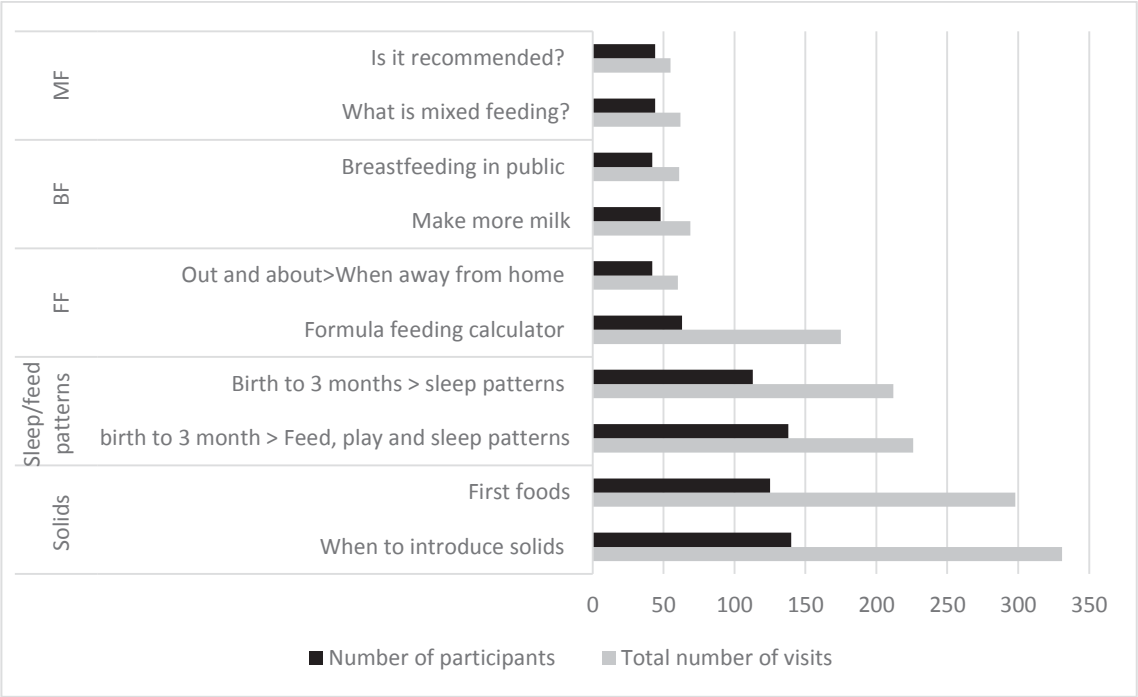

Figure 6.4 Number of participants and total number of times participants visited each section of the Growing healthy app

Loyalty Index (Li)

The Loyalty Index (L_i) had a median score of 50.7% and the interquartile range was 26.6% to 75.7%. The mean number of sessions participants visited the app was 11.6 times (range 1-64) throughout the program period and a median of nine.

Recency Index (Ri)

The Recency Index (R_i) had a median score of 34.4% and the interquartile range was 10.6% to 37.3%. Participants were sent a unique code to access the app on the day they registered to the program; on average participants took 14 days to activate the app (range 0-184 days).

Interaction Index (Ii)

The Interaction Index (I_i) had a median score of 8.8% and an interquartile range of 1.9% to 18.3%. On average 91.8 (range: 16-216) push notifications were sent and 11.1 (range: 0-70) were opened. Participants who both used the app and opened weekly emails scored lower on I_i compared to participants who only used the app.

Feedback Index (Fi)

The Feedback Index (F_i) was calculated for 154 participants, because another 71 participants either did not complete the nine-month survey, or reported using the website. The F_i had a median score of 2.7% for the 154 participants and the interquartile range was 0% to 16.2%.

The app features participants were most satisfied with were the language used, and the utility of sharing the app with another carer. Participants were least satisfied with the push notifications, including the number of push notifications sent (too few or too many), and the technical problems experienced by a large number. Although 122 participants reported receiving the push notifications, approximately 90% of these participants had a low satisfaction with regards to retrieving and opening the push notifications. Further, there was a low satisfaction rate on the videos that were available on the app. Participants did not feel the app covered a range of information to answer all their queries on infant feeding.

Table 6.7 Participants' reported satisfaction with aspects of the Growing healthy Program (F_i) (n= 154)

Satisfaction questionnaire	**Scores n**
I found the Growing healthy app easy to use	46
I liked the layout/"look" of the app	34
I found it hard to navigate through the app*	23
The Growing healthy app didn't take long to load information	45
The Growing healthy app failed to work at times*	28
The different sections of the app worked well together	20
The language used in the app was easy to understand	57
The app did everything I expected it to do	31
I couldn't find all of the answers I needed in the app*	11
I had to use the search feature to find what I was looking for	14
Using the app was an enjoyable experience	22
I found the app complicated*	43
I can trust the information on the Growing healthy app	39
I felt confident using this app	40
I found the information for mums useful	31
I found the information on feed and sleep patterns useful	29
I found the information about breastfeeding useful	20
I found the information about formula feeding useful	17
I found the information on mixed feeding useful	15
I found the information on solid feeding useful	27
I found the videos on the app useful	12
I found the recipe section of the app useful	22
I shared the information from the app with other friends and family	16
I was concerned about the internet data usage on my phone when using the app*	47
I found the information provided easy to understand	36
Overall, I liked the Growing healthy program	36
I would recommend the Growing healthy program to a friend	45
I found it helpful to share the app with my partner or another carer	48
The Growing healthy program covered all of the things about infant feeding that I wanted it to	25
I received push notifications on my phone, from the Growing healthy program**	122
The push notification messages often disappeared before I had a chance to tap on them*	12
I didn't know how to retrieve push notification messages once they disappeared from screen*	12
I would prefer to receive text messages rather than push notifications from the app	19
I was happy with the number of notifications/messages received each week	6
I was happy with the time that the notification was sent to me during the day	18
I found the notifications/messages helpful	16
I found the notifications/messages suited my baby's age and stage of development	23

Total scores only include the extreme positive responses based on scoring criteria:

[*] ***Likert scale scoring reversed for these questions:*** Strongly disagree (1), Disagree (0), No strong feelings either way (0), Agree (0), Strongly agree (1), Didn't use (0)

[**] ***Response option and scoring:*** Yes, I received weekly push notifications (1), No, I received text messages instead of push notifications (1), and No, I disabled my push notifications so I didn't receive any weekly messages (0)

Figure 6.5 illustrates the variation of the scores for C_i, L_i, R_i and I_i at each time point (Initial, Interim and Final). The scores decreased over the course of the program for each sub-index, although the R_1 fell most sharply. C_i and L_i shared similar scores during the initial (0-3 months) and final period (6-9 months), while for the interim period (3-6 months) the mean score was lower for C_i (43.7%) compared to L_i (54.6%).

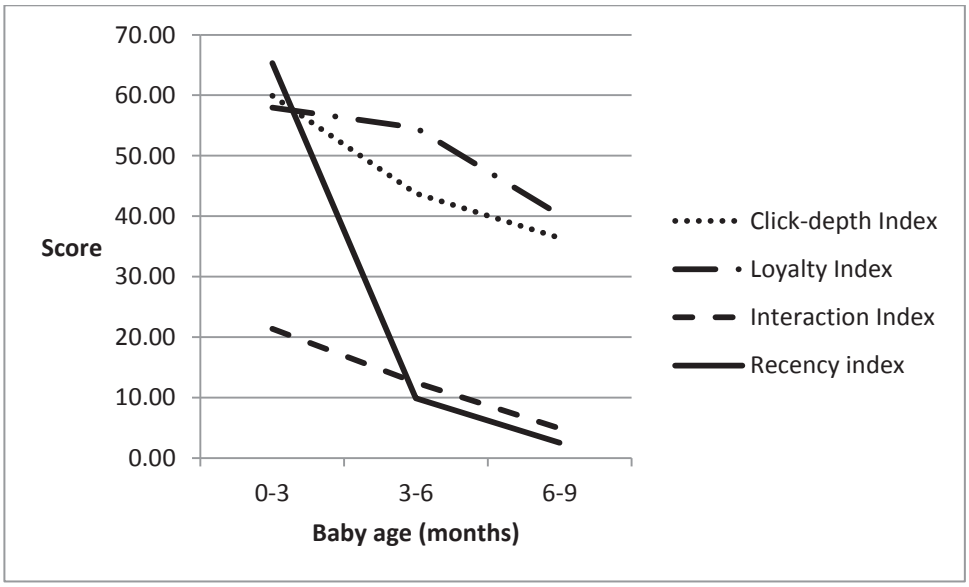

Figure 6.5 Mean scores for Ci, Li, Ii and Ri at each time point (Initial, interim and final)

6.4.4 Timing of solid introduction

A total of 174 participants reported the age (in weeks) at which they introduced solids to their infant. The median age of solid introduction was 20 weeks and the interquartile range was between 18 to 24 weeks (overall range: 4-34 weeks). Of these participants, 14% (n= 25) introduced solids before 17 weeks (very early), 78% (n= 136) introduced between 17.3 and 25 weeks (early) and 13 participants (7.5%) introduced solids at 26 weeks or older (recommended age).

Table 6.8 indicates differences in the age of solid introduction by participant characteristics. There were significant differences according to three characteristics.

The Mann-Whitney U test showed that participants with a lower education level were likely to introduce solids earlier than participants of a higher (university degree) education level ($Z= -2.526$, $p= 0.027$). Further, this test also showed that multiparous participants were likely to delay solid introduction compared with primiparous participants ($Z= -3.196$, $p= 0.001$). Lastly, the Kruskal-Wallis test showed that there was a statistically significant difference between the recruitment method and the age of solid introduction ($\chi^2= 6.092$, $p= 0.048$) where participants recruited online (rather than by their health practitioners) being significantly more likely to delay solid introduction.

Table 6.8 Participants' characteristics and engagement level by timing of solid introduction (n= 174)

Variables	Very early % (n= 25)[b]	Early % (n= 136)[b]	At recommended age %(n= 13)[b]	p
Participant characteristics				
Engagement Index level[d]				
Poor	21.2 (5.3)	21.2 (28.9)	21.5 (2.8)	0.963
Moderate	50.4 (12.6)	41.25 (56.1)	50.7 (6.6)	
High	28 (7.0)	23 (31.3)	28.4(3.7)	
Age at registration (years)	28.8±5.3	30.4±4.6	30.9±3.8	0.875
Education (No university)[c]	46 (11.5)	51.2 (69.7)	52.3 (6.8)	0.027*
Parity (Primiparous)[c]	62.8 (15.7)	62.6 (85.2)	62.3 (8.1)	0.001*
Household income (Higher income)[d]	28 (7)	29.4 (40)	53.8 (7)	0.760
Employment status (Not in labour force)[c]	80 (20)	85.2 (116)	69.2 (9)	0.088
Recruitment method (Practitioner)[d]	56 (14)	48.5 (66)	15.3 (2)	0.048*
System type (Both)	68 (17)	77.9 (106)	30.7 (4)	0.342
Infant characteristics				
Age at registration (Weeks)	7.1±4.0	7.5±4.9	6.7±3.8	0.585
Gender (Male)[c]	64 (16)	85.2 (70)	53.3 (7)	0.185
Weight (grams)	3466.8 ±596.77	3467.8 ±592.0	3462.0 ±610.9	0.425
Baseline feeding status [d]				
Breastfeeding	54.4 (13.6)	54.5 (74.2)	54.6 (7.1)	0.300
Formula feeding	28.8 (7.2)	27.2 (39.1)	28.4 (3.7)	
Mixed feeding	16.8 (4.2)	16.6 (22.7)	16.9 (2.2)	

n= total number of participants

Very early= ≤17.3 weeks, Early= 17.3<26 weeks and at the recommended age= ≥26 weeks

Engagement Index cut-points for scores: Poorly engaged= <21.1, moderately engaged= 21.1-37.1, highly engaged= >37.1

[a] Variables are based on data provided at baseline or T1 (age ≤3 months)

[b] Variables are based on data provided at the six month survey or T2

[c] Based on Mann-Whitney U test

[d] Based on Kruskal-Wallis H test

* Statistically significant engagement level and independent variable <0.05

Association between age solids were introduced and Engagement Index score

Figure 6.6 illustrates the Kaplan Meier time-to-event curves which include all participants including the censored participants. It was estimated that 7.1%, 4.4% and

7.1% for the poorly, moderately and highly engaged participants respectively, delayed solid introduction until the infant was 26 weeks. The majority of the participants (78%) introduced solids by 21 weeks (5 months). The mean age at which solids were introduced for poorly engaged participants was 22.4 weeks (95% CI: 20.1, 24.7), 23.0 weeks (95% CI: 21.3, 24.6) for moderately engaged and 22.1 weeks (95% CI: 20.6, 23.6) for highly engaged participants. Using the Log rank (p= 0.881), Breslow (p= 0.999) and Tarone-Ware (p= 0.940) tests, there were no statistically significant differences in the mean age at which solids were introduced amongst the participants at the three engagement levels. Five variables met the screening criterion of p ≤0.25 from the univariate modelling for age of solid introduction and were included in the full model using Cox proportional hazard regression. The Engagement Index score was not significantly related to age of solid introduction even after controlling for these covariates.

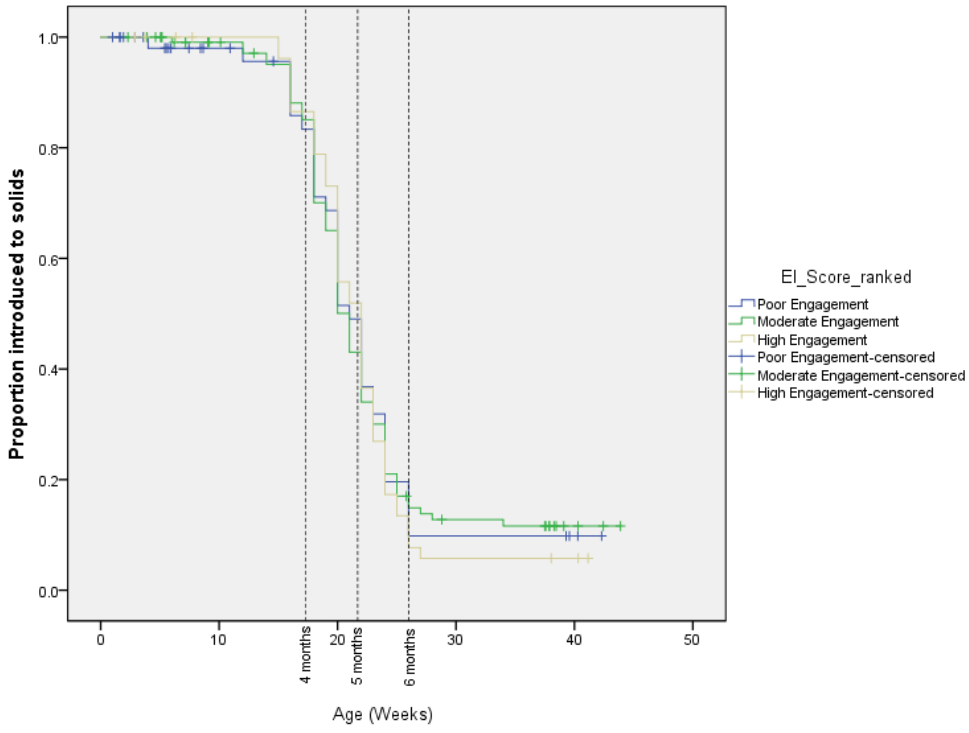

Figure 6.6 Survival curves for the age at which participants introduced solids and the Engagement Index levels

Reasons for introducing solid foods

Participants were provided with 11 common reasons that have previously been associated with solid introduction. They were asked to tick up to as many reasons that

applied to them. The three most popular reasons for introducing solids in the sample (n= 174) were 'baby seemed ready for solids' (85.6%), 'baby able to sit up and hold food in hand' (38.5%) and 'previous experience (with another baby)' (36.2%). A total of 9.1% of participants who chose to introduce solid foods based on the advice provided from the 'Growing healthy program'.

Relationship between engagement and reasons for introducing solids

Participants with higher Engagement Index scores with the Growing healthy app appeared more likely to introduce solids for reasons related to advice from 'leaflets/or other information', from the 'Growing healthy program', or from friends or relatives, or because 'baby was not gaining enough weight' and 'baby able to sit up and hold food in hand'. Conversely, reasons such as 'baby was not satisfied with milk', 'baby was waking up during the night', 'other mums with babies around the same age were starting solids', 'previous experience' and 'doctor/nurse/other health professional advised me to' were associated with lower Engagement Index scores. Reasons which were significantly associated with the Engagement Index scores were 'baby was not gaining enough weight' ($t= 2.358$, $p= 0.020$) and 'baby waking up during the night' ($t= -2.379$, $p= 0.018$) (Table 6.9).

Regardless of EI scores, primiparous participants chose to introduce solids for reasons including 'read leaflets/or other information', 'baby was not gaining enough weight', 'baby able to sit up and hold food in hand', 'friends or relatives' advice', 'other mums with babies around the same age were starting solids' and 'doctor/nurse/other health professional advice'. Conversely, multiparous participants were significantly more likely to introduce solids to their infant based on their 'previous experience'. Participants who were recruited by their health practitioner were likely to introduce solids because 'baby was waking up during the night'. In addition, full-time carers were significantly more likely to introduce solids for reasons based on 'read leaflets/or other information' provided and the 'Growing healthy program' than other reasons.

Infant Characteristics

Breastfed infants were more likely than other reasons of introducing solids because 'baby was not satisfied with milk' ($\chi^2= 7.519$, $p= 0.023$). Male infants were

significantly more likely than female infants to be introduced to solids for the following reasons: ‘baby was waking up during the night’, ‘baby able to sit up and hold food in hand’ and ‘advice from friends or relatives’ (Table 6.10).

Table 6.9 Association between participant factors and reason for introducing solid foods, proportion of sample (n= 174) who stated each reason by participant characteristics

Reasons for introducing solids		**Education**		**Employment Status**		**Parity**		**Recruitment method**			**EI Score** (mean %)
		No university	University degree	Not in labour force	Working/ studying	Primiparous	Multiparous	Family/ Friends	Practitioner	Online	
Read leaflets/or other information that advised me	%	7.4	7.4	10.3	4.5	12.0	2.8	1.7	7.4	5.1	14.9
	p	χ^2=0.092, *p*=0.762		**χ^2=5.092, *p*=0.024**		**χ^2=4.69, *p*=0.030**		χ^2=0.587, *p*=0.746			t=1.152, p=0.251
Baby was not satisfied with milk	%	6.8	6.3	12.6	1.1	9.1	4.5	2.2	5.7	5.7	13.7
	p	χ^2=0.258, *p*=0.612		χ^2=1.192, *p*=0.275		χ^2=0.284, *p*=0.594		χ^2=0.602, *p*=0.740			t=-0.971, p=0.333
Baby was not gaining enough weight	%	1.1	4.0 (2)	4.0	1.1	5.1	0	0	1.7	3.4	5.1
	p	χ^2=2.397, *p*=0.122		χ^2=0.286, *p*=0.593		**χ^2=5.883, *p*=0.015**		χ^2=3.147, *p*=0.207			***t=2.358, p=0.020***
Baby was waking up during the night	%	5.1	8.6	12.6	1.1	8.6	5.1	4.0	6.3	3.4	13.7
	p	χ^2=1.076, *p*=0.300		χ^2=1.192, *p*=0.275		χ^2=0.006, p=0.936		**χ^2=8.077, *p*=0.018**			***t=-2.379, p=0.018***
Baby able to sit up and hold food in hand	%	20.6	17.2	32.7	5.7	28.7	9.7	5.7	18.3	14.3	38.5
	p	χ^2=2.334, *p*=0.127		χ^2=0.076, *p*=0.783		**χ^2=7.747, *p*=0.005**		χ^2=0.896, *p*=0.639			t=0.112, p=0.911
Baby seemed ready for solids	%	39.6	43.1	70.6	14.9	54.5	31.0	10.3	42.5	32.7	85.6
	p	χ^2=0.188, *p*=0.664		χ^2=2.218, *p*=0.136		χ^2=2.030, p=0.154		χ^2=3.430, *p*=0.180			t=-0.471, p=0.638
Friend or	%	4.5	4.5	8.0	1.1	8.6	0.5	0.5	4.0	4.5	9.1

relatives advised me to	*p*	χ^2=0.053, *p*=0.818	χ^2=0.151, *p*=0.697	**χ^2=7.651, *p*=0.006**	χ^2=0.959, *p*=0.619		t=0.749, p=0.455
Other mums with babies around the same age were starting solids	%	9.1 8.6	14.9 2.8	14.9 2.8	1.1 7.4	9.1	17.8
	p	χ^2=0.540, *p*=0.462	χ^2=0.002, *p*= 0.967	**χ^2=7.846, *p*=0.005**	χ^2=2.416, *p*=0.299		t=-0.700, p=0.485
Previous experience (with another baby)	%	10.3 13.7	21.8 2.2	0.5 22.9	2.8 8.6	12.6	24.3
	P	χ^2=0.441, *p*=0.507	χ^2=1.688, *p*=0.194	**χ^2=83.295, *p*=0.000**	χ^2=3.446, *p*=0.179		***t=-2.808, p=0.006***
Doctor/nurse/ other health professional advised me to	%	16.0 20.1	32.1 4.0	27.0 9.1	2.2 19.5	14.3	36.2
	P	χ^2=0.327, *p*=0.567	χ^2=1.706, *p*=0.192	**χ^2=6.986, *p*=0.008**	χ^2=3.956, *p*=0.138		t=0.868, p=0.387
Growing healthy program	%	5.7 6.8	8.6 4.0	8.04 4.5	0.5 7.4	4.5	12.6
	P	χ^2=0.045, *p*=0.832	**χ^2=4.729, *p*=0.030**	χ^2=0.047, *p*=0.828	χ^2=2.097, *p*=0.351		t=1.365, p=0.174

Statistically significant figures are highlighted in bold

Table 6.10 Association between infant factors and reason for introducing solid foods, proportion of sample (n= 174) who stated each reason by infant characteristics

Reasons for introducing solids		**Age of solid introduction**			**Baseline feeding**			**Gender**		**Birth weight**	**Age at registration**
		Very early	Early	At recommended age	BF	FF	MF	Male	Female	Grams (mean %)	Weeks (mean %)
Read leaflets/or other information	%	2.2	12.0	0.5	8.0	4.5	2.2	6.8	8.0	14.3	14.9
	p	χ^2=0.410, p=0.815			χ^2=0.124, p=0.940			χ^2=0.387, p=0.534		t=1.792, p=0.075	t=-0.113, p=0.911
Baby was not satisfied with milk	%	3.4	10.3	0	4.0	5.7	4.0	8.6	5.1	13.7	13.7
	p	χ^2=3.651, p=0.161			***χ^2=7.519, p=0.023***			χ^2=1.290, p=0.256		t=1.686, p=0.094	t=-0.224, p=0.823
Baby was not gaining enough weight	%	0	4.5	0.5	1.7	2.8	0.5	4.0	1.1	5.1	5.1
	p	χ^2=4.409, p=0.110			χ^2=3.503, p=0.174			χ^2=2.575, p=0.109		t=0.766, p=0.445	t=0.040, p=0.968
Baby was waking up during the night	%	1.1	12.6	0	9.1	1.7	2.8	10.9	2.8	13.7	13.7
	p	χ^2=1.405, p=0.495			χ^2=3.415, p=0.181			***χ^2=8.404, p=0.00***		t=0.051, p=0.960	t=0.063, p=0.950
Baby able to sit up and hold food in hand	%	4.0	33.9	0.5	21.8	8.6	8.0	15.5	22.9	37.9	38.5
	p	χ^2=1.328, p=0.515			χ^2=2.375, p=0.305			***χ^2=5.823, p=0.016***		t=0.039, p=0.969	t=-0.386, p=0.700
Baby seemed ready for solids	%	12.0	71.8	1.7	48.2	22.4	14.9	43.6	41.9	84.4	85.6
	p	χ^2=0.882, p=0.643			χ^2=2.537, p=0.281			χ^2=0.278, p=0.598		t=0.477, p=0.634	t=0.555, p=0.579
Advice from	%	1.7	7.6	0	4.5	3.4	1.1	7.4	1.7	9.1	9.1
	p	χ^2=0.789, p=0.674			χ^2=0.824, p=0.662			***χ^2=6.150, p=0.013***		t=0.785, p=0.434	t=-0.886,

friends or relatives											p=0.377
Other mums with babies around the same age were starting solids	%	0.5	16.6	0.5	10.3	4.5	2.8	8.6	9.1	17.8	17.8
	p	χ^2=3.499, p=0.174			χ^2=0.177, p=0.915			χ^2=0.173, p=0.677		t=0.755 p=0.451	t=-1.024, p=0.307
Previous experience	%	3.4	19.5	1.1	14.3	5.1	4.5	12.6	11.4	23.5	24.3
	p	χ^2=1.466, p=0.481			χ^2=1.281, p=0.527			χ^2=0.008, p=0.927		t=-0.075, p=0.940	t=-0.187, p=0.852
Doctor/nurse/other health professional advised me to	%	2.8	31.6	1.7	16.0	16.6	36.2	18.3	17.8	36.2	36.2
	p	χ^2=4.903, p=0.086			χ^2=4.261, p=0.119			χ^2=0.038, p=0.846		t=1.00, p=0.319	t=-0.393 p=0.695
Growing healthy program	%	1.7	10.3	0.5	7.4	4.5	0.5	5.7	6.8	12.0	12.6
	p	χ^2=0 522, p=0.770			χ^2=3.086, p=0.214			χ^2=0.363, p=0.544		t=0.659, p=0.511	t=0.962 p=0.337

Baseline Feeding mode: BF= Breastfeeding, F= Formula, MF= Mixed Feeding

[b] Variables are based on data provided at the six month survey or T2

Statistically significant figures are highlighted in bold

Characteristics associated with reasons why participants introduced solids

Table 6.11 identifies the variables that remained significant in the logistic regression model while also controlling for Engagement Index score. Participant Engagement Index score remained a predictor and directly associated with introducing solids for the reason 'baby was waking up during the night'. Parity was a predictor of introducing solids for the reasons 'read leaflets/or other information', advice from 'friends or relatives', 'doctor/nurse/other health professional', 'baby able to sit up and hold food in hand' and 'other mums with babies around the same age were starting solids'. Specifically, these reasons were negatively associated with multiparous participants and positively associated with primiparous participants. On the other hand, multiparity was positively associated with 'previous experience'. Notably, breastfeeding remained a predictor and positively associated with the reason 'baby was not satisfied with milk', while for formula and mixed feeding participants it was negatively associated with this reason. Participant employment status, particularly caring full-time for infants, was positively associated with and predicted introducing solids for reasons of 'read leaflets/or other information' and the 'Growing healthy program'.

Table 6.11 Logistic regression analysis for predictors of reasons for introduction to solids and association with participant Engagement Index scores (controlling for significant variables)

Reasons for introducing solids	Variable	B	SE	df	OR	CI 95%,	p	Cox and Snell R^2
Read leaflets/or other information	Parity	-1.073	0.540	1	0.342	0.387-2.663	0.036	0.031
	Employment	1.062	0.508	1	2.892	0.984-7.68	0.054	
	EI score	-0.010	0.020	1	0.990	0.936-1.019	0.267	
Baby was not satisfied with milk	Baseline feeding mode	-0.696	0.275	1	0.496	0.291-0.855	0.011	0.042
	EI score	0.019	0.020	1	0.499	0.980-1.060	0.350	
Baby was waking up during the night	Gender	1.624	0.551	1	5.073	1.723-14.935	0.003	0.091
	EI score	0.058	0.022	1	1.060	1.014-1.107	0.010	
Baby able to sit up and hold food in hand	Parity	-0.911	0.355	1	0.402	0.201-0.807	0.010	0.072
	Gender	-0.701	0.327	1	0.496	0.261-0.942	0.032	
	EI score	0.004	0.015	1	1.004	0.976-1.033	0.780	
Friends or relative advised me to	Parity	-2.587	1.061	1	0.075	0.009-0.602	0.015	0.101
	Gender	1.751	0.674	1	5.759	1.536-21.595	0.009	
	EI score	-0.001	0.026	1	0.999	0.949-1.052	0.970	
Other mums with babies around the same age were starting solids	Parity	-1.493	0.530	1	0.225	0.080-0.634	0.005	0.059
	EI score	0.024	0.019	1	1.024	0.988-1.062	0.198	
Previous experience (with another baby)	Parity	5.116	1.039	1	166.704	21.762-1277.031	0.000	0.429
	EI score	0.033	0.023	1	1.034	0.988-1.082	0.154	
Doctor/nurse/other health professional advised me to	Parity	-0.885	0.354	1	0.413	0.206-0.826	0.012	0.042
	EI score	-0.006	0.015	1	0.994	0.966-1.023	0.700	
Growing healthy program	Employment	1.009	0.523	1	2.744	0.984-7.649	0.054	0.031
	EI score	-0.024	0.021	1	0.976	0.937-1.018	0.260	

B= Beta, SE= Standard Error, df= degrees of freedom, OR= Odds Ratio, CI= Confidence interval

6.5 Discussion

There are two key aims addressed in this chapter. The first aim was to examine the study participants' engagement with the Growing healthy app. The findings showed there were a number of correlates of the level of engagement. Primiparous participants, those recruited through health practitioners and those who used both the app and email were likely to attain a higher engagement score. In addition, participants who joined the program with an older child (i.e. infant closer to three months of age at baseline) were likely to have a lower engagement score.

The second aim was to assess the influence participants' engagement with the Growing healthy app had on the age at which they introduced solids to their infants. The results showed that there was no statistically significant relationship between the level of participant engagement and the age at which solids were introduced. Interestingly, the most cited reason for introducing solids related to parent's beliefs that the 'baby seemed ready for solids', with information from the app cited as the least influential reason. This study is novel and valuable in that it develops the first tool, to the candidate's knowledge, to prospectively analyse engagement and its association with intervention effect in mHealth programs.

6.5.1 Exploring participant engagement using the Engagement Index

This is one of the first studies to conduct an mHealth program supporting parents with healthy infant feeding practices through a smartphone app. Comparing results to other studies in this field is therefore limited. However, this area is changing rapidly as a number of protocols have recently been published describing mHealth interventions to encourage the uptake of healthy infant feeding behaviours. These interventions are delivered through app (Wen 2015; White et al. 2016), website (Campbell et al. 2016; Uesugi et al. 2016), and social media (Horodynski et al. 2015). Further, as this is the first study to utilise an Engagement Index to capture user experience, it provides a unique contribution to not only the field of infant feeding, but more broadly to the literature on mHealth interventions.

The present study developed a criterion to label participants as either poorly, moderately or highly engaged with the Growing healthy program based on their overall

Engagement Index score. In previous interventions, researchers have arbitrarily labelled the outcome of their program engagement as either high (Guertler et al. 2015) or low (Partridge et al. 2015) based on the frequency with which participants accessed websites or apps. There are currently very few studies that have considered participant engagement based on their interaction with a number of intervention elements. For instance, one study promoting healthy living by reducing high-risk sexual behaviours developed a point system to gauge individual user activity with the program features, including frequency of access, profile modification, messages viewed, articles viewed, completion of quizzes, number of pages viewed and updates of personal goals (Baltierra et al. 2016). Another mHealth program which targeted physical activity levels, developed a model to measure participants' engagement through frequency of access, average daily steps and the number of days since participants last accessed the program (Davies et al. 2012). Hence, it is evident that engagement can and will most likely continue to be measured using various approaches, much like the measurement of the quality of apps as described in Chapter Three This thesis is unique in that the Engagement Index was also utilised to predict outcomes measured in the intervention.

The main purpose of the index is to measure the magnitude of participant engagement with the intervention and its impact on behaviour. Providing a systematic approach to measuring engagement with mHealth programs was therefore necessary to enable the comparison of impact across similar interventions and to identify strategies that were more successful. The Engagement Index utilised in this study enabled the candidate to comprehensively measure participant engagement with the Growing healthy program and to assess its association with the age when solids were introduced. In addition, it identified predictors and factors influencing participant engagement, which is beneficial for future enhancements of this program. Despite the Engagement Index being based on a model originally developed to measure consumer engagement with online products, this study confirms that adjusting the index to measure engagement with an mHealth program is possible. The metrics measured are the same, although the content and behaviour measured vary (Peterson & Carrabis 2008).

The current study examined participant app use over the nine-month period. The participants' engagement was initially high after joining the program but decreased from three months onwards. This finding is not surprising as previous mHealth

programs targeting long- and short-term behaviour change have identified similar outcomes (Dennison et al. 2013; Guertler et al. 2015; Neve, Collins & Morgan 2010). Attrition within mHealth programs may be influenced by factors including lack of participant commitment (Dennison et al. 2013), participant confidence in their knowledge in managing the targeted behaviour (Guertler et al. 2015) and programs that are perceived as overly burdensome (Baltierra et al. 2016). For future interventions that aim to target long-term behaviour change, mHealth developers need to consider novel strategies that will keep participants engaged throughout.

The Growing healthy program was a 'just in time' resource (Danaher et al. 2015), that is, it was targeted to suit a specific event that needed to be delivered at the appropriate time for optimal use and benefit (Patrick et al. 2016). This program was developed to provide infant feeding information up to nine months of age. The most important feeding milestones are choice at birth such as breastfeeding or healthy formula feeding, maintenance of best practice feeding practices and timing of introduction to solids. It is likely that once knowledge on these behaviours is achieved app use will drop off (National Health and Medical Research Council 2012). This contrasts to longer-term diet (Partridge et al. 2015) and physical activity (Davies et al. 2012) behaviour change programs where designers plan for long term engagement. However, this is possibly unrealistic given qualitative findings that suggest users prefer to engage with apps periodically (Dennison et al. 2013). Understanding app users' behaviour is important if there is a more appropriate time to engage them to join the program; it is also important to identify factors that lead to disengagement and to consider strategies that will maintain participants' engagement.

In this study, participants who accessed both the website and the app attained a significantly higher Engagement Index score than participants who just used the app. This finding supports the notion that utilising a number of modes of delivery enhances engagement and intervention exposure (Baltierra et al. 2016; O'Brien & Toms 2008). Yet there are also limitations associated with these findings that need to be acknowledged. Firstly, a number of technological issues experienced by users when receiving and opening the push notifications led the chief investigators of this study to send weekly emails well. Therefore, while some participants were interested in using emails, others may not have found it as convenient as the push notifications on their

mobiles. This encapsulates the importance of app quality influencing participant engagement (Eysenbach et al. 2002; Hides et al. 2014; Taki et al. 2015). The participants' responses from the satisfaction survey (Feedback Index) further emphasised the impact of the technological challenges experienced on their engagement with the program, as push notifications attained the least satisfaction. Another limitation was that the weekly emails contained links to the Growing healthy website rather than the app. While participant access to the emails and the links to the website was available, data on participant behaviour on the website, such as the number of pages viewed, was not available on an individual level. This explains the increase in Loyalty Index during the three to six month period, due to including participant access to email links, while the Click-depth Index decreased at that time because the number of pages viewed on the website could not be measured. Overall the Engagement Index score calculated for the participants who accessed the website may not be a true representation of their engagement with the program.

This program included some features that were not measured in the Engagement Index due to the lack of or difficulty in obtaining data. For instance, the program did not assess participant use of the Growing healthy Facebook group, sharing the app with other carers or sharing information from the app with others (interconnectivity). Although participant interaction with these features was not measured, they were asked about their satisfaction and use of these features in the nine-month survey included in the Feedback Index. Unfortunately, several participants did not complete the nine-month survey and missing data reduced the ability to assess these features on participant engagement. This limitation of data collection might be addressed in future studies through the use of regular and ongoing app based assessments, for example, pop-up quizzes, feedback questions, or features such as a star rating (Baltierra et al. 2016).

6.5.2 Socio-demographic and program features as determinants of engagement with the infant feeding program

One covariate that significantly contributed to the participants' Engagement Index score in this study was parity. Primiparous participants attained significantly higher engagement with the program than did multiparous women. This was an expected finding, as most of the primiparous participants interviewed expressed their interest in the program, while multiparous participants suggested the resource would have been

more useful for a first-time parent (Chapter Four). Unfortunately parity and participant engagement were not measured in the other similar mHealth programs (Jiang et al. 2014), so the results cannot be compared to extant literature.

Despite multiparous participants being less engaged, a reasonable number of participants from this demographic were initially engaged to join the program (37.7%). Initial engagement is an important step in any intervention, while sustaining engagement is equally important but difficult to achieve (Baltierra et al. 2016; Morgan et al. 2016; O'Brien & Toms 2008). Previous studies assessing characteristics that influence user engagement with mHealth interventions indicate that novelty and relevance are the main contributors to the sustainability of user engagement in apps (Aboulafia & Bannon 2004; O'Brien & Toms 2008; Webb et al. 2010). It is possible that the Growing healthy app was not sufficiently novel, as evidenced by their drop in engagement levels from three to six months. This may also explain the lower engagement of multiparous participants (who have developed their thinking around infant feeding already) and indeed, may explain the reduced use of the app among all participants over the course of the study. Exploring aspects which impacted on intervention novelty qualitatively would help clarify these findings and enhance the program.

The infant's age at baseline (when they downloaded the app) was another covariate that remained a predictor of Engagement Index scores. Participants who joined the program when their infant was younger attained a higher engagement score compared to those who joined when their infant was closer to three months of age. Much like the traditional interventions that have targeted prevention of childhood obesity (Askie et al. 2010), the results from this study indicate that early recruitment is necessary to increase participant engagement. Early recruitment is likely to increase intervention exposure, which is associated with an increased likelihood of uptake of the desired behaviours (Guertler et al. 2015). This is important to consider in interventions targeting infant feeding behaviours particularly because infant developmental growth occurs rapidly within the first year of life (Birch & Doub 2014). The app would therefore be most useful and provide novel information to mothers if they were recruited from early post-partum.

The method of recruitment was also an important predictor of engagement, with participants who were recruited by their health practitioner significantly more likely to attain a higher score. It is possible that engagement is higher because mothers perceive health practitioners to be a trustworthy source, as identified in previous literature (Gildea, Sloan & Stewart 2009) and in the study presented in Chapter Four. This further emphasises the importance of involving health practitioners particularly those who are involved in the routine checks of infants during the first few years of life such as Maternal and Child Health nurses and practice nurses (Goldfeld, Wright & Oberklaid 2003) as the 'referral pathway' to evidence-based apps. This proposition could be further developed by conducting qualitative studies and translational research to determine how to effectively implement this intervention more broadly within diverse health care settings with the potential to support the prevention of childhood obesity.

One of the broader aims of this thesis was to influence the uptake of healthy infant feeding behaviours among mothers from disadvantaged backgrounds, who this study defined as participants with lower educational attainment (no university degree). Several studies have illustrated that mothers from disadvantaged backgrounds were less likely to use the internet as a source of information for infant feeding (Gage et al. 2012; Gazmararian et al. 2012). Unlike other mHealth programs targeted at infant feeding (Gazmararian et al. 2012), this study was successful in attaining approximately equal numbers of participants with high and low educational backgrounds. The participants with university education attained a lower Engagement Index score, although this finding was not statistically significant. This study further supports the findings from the qualitative interviews described in Chapter Four on the feasibility of conducting an mHealth program to support and reach mothers of low educational attainment about healthy infant feeding behaviours. Qualitative research with women from both high and low socio-economic backgrounds, as described by a range of indicators (e.g. education level, income) would enrich our understanding of engagement with infant feeding apps and help inform the development of better utilised health apps.

6.5.3 Influencing introduction to solids through an mHealth program

In this study, there was no statistically significant association between the participants' Engagement Index level and the age at which they introduced solids to their infant. Despite this, it is important to acknowledge that the findings of this thesis do not

represent the full impact of the Growing healthy program on intervention outcomes. In order to explore the impact this study had on the intervention outcomes it would be essential to compare the results of the participants included in this study and the non-randomised comparison group (Denney-Wilson et al. 2015), which was not included in this thesis. Further, the large variation in confidence intervals regarding the age at which participants introduced solids is due to the small sample size. Therefore, conducting this study on a larger scale may provide statistically significant associations between the Engagement Index levels and the timing of solid introduction.

The majority of the participants in this study introduced solids between 17 and 26 weeks, which is in line with the average age of solid introduction nationally (Australian Institute of Health and Welfare 2010). The current findings are similar to the mHealth program conducted in China targeting healthy infant feeding practices through text messaging (Jiang et al. 2014), which found that some participants were encouraged to introduce solids at four months by their Community Health Centres, despite the fact that the program actively promoted delaying until six months. Further, participants who were recruited online were significantly more likely to delay solid introduction than participants recruited by their health practitioners. A qualitative study conducted with the health practitioners involved in recruiting and promoting the key messages of the Growing healthy study, indicated that they rarely had time to discuss these messages with the mothers (Laws, Litterbach, et al. 2016). Nonetheless, the fact that participants recruited by their health practitioners did have a higher engagement score indicates the potential to effectively influence the uptake of healthy infant feeding behaviours through mHealth promoted by practitioners. In order to effectively influence the uptake of these behaviours, other strategies, for example, the timing of engagement with the app, need to be considered.

Parity was also a predictor for the age of solid introduction, where multiparous participants were more likely to delay introducing solids compared with primiparous participants. These findings are similar to a study conducted in New Zealand suggesting that mothers with more children may potentially find continuation of breastfeeding or formula feeding easier than introducing solids (Cameron, Heath, et al. 2015). In this study primiparous participants were significantly more likely to introduce solids based infant developmental cues, advice from written sources and social influences, a similar

finding to another study (Brown & Rowan 2016). While multiparous participants were significantly more likely to introduce solids based on their pervious experience. The current findings on age of solid introduction coupled with the analysis showing lower engagement levels among multiparous participants suggest that future interventions need to consider parity specifically. Different antecedants influence the uptake of healthy infant feeding behaviours among multiparous parents that should be targeted (Kieffer et al. 1997).

6.5.4 Strengths and limitations

The development and utilisation of the Engagement Index to assess how participants interacted with the app and to predict the association between their engagement and intervention outcomes are important strengths of this study. The utilisation of an index to measure participant engagement has not previously been implemented in mHealth interventions. The Engagement Index provided detailed analysis regarding how frequently participants accessed the app and push notifications, how many pages they accessed per session and their satisfaction with the program across the nine months of the program. The Engagement Index also enabled analysis of the association between participant engagement and the age at which they introduced solids to their infant. Doing so has enabled the researchers to understand the efficacy of the intervention and to identify potential methods of improving the program to further enhance the uptake of desired behaviours.

An important potential limitation is that the Engagement Index has not yet been validated. The formulae used to calculate participant engagement for this program may not be appropriate for other mHealth programs which may for example, use different time points for intervention and evaluation. Therefore, further iterations of the index might need to be considered if utilised in future mHealth studies. Chapter Seven describes a qualitative study which explored the participants' experience with the program. Participants were recruited from various Engagement Index levels to further explore whether engagement level was a reflection of their usage of the program. Other studies have conducted qualitative interviews to validate the scoring of quantitative tools (Chibanda et al. 2016).

Another limitation is that the Engagement Index is that did not apply weighting to any of the sub-indices, which assumes that they are all of equal value. More analysis of the impact of each sub-index on the overall Engagement Index score is required.

Further, unforeseen technical issues limited participant access to the app and push notifications during the course of the program. This issue led some participants to utilise the Growing healthy website, which did not track access data for each participant. As a result, the findings may not be a true representation of the engagement with an mHealth program from this group of participants.

Another limitation which may have impacted on the comparability of the findings on the age of solid introduction with other studies is the definition used to describe the appropriate age. The Infant Feeding Guidelines recommend that solids be introduced at around 6 months and do not prescriptively define the appropriate age as 26 weeks which was used in this thesis. A month is often considered to be four weeks in duration, hence 6 months of age as 24 weeks rather than 26 weeks. The variation in defining 'at around 6 months' presents a problem to researchers, health professionals and mothers when deciding what the appropriate age is to introduce solids. Therefore, it is suggested that a more liberal definition on 'recommended age' is considered by future researchers.

6.6 Conclusion

This chapter has shown that utilising the Engagement Index provided a comprehensive understanding of participant behaviour with the app over the nine-month period of the Growing healthy program. The participants' engagement with the Growing healthy app was determined by various factors including participant characteristics, novelty, intervention exposure time and the app quality. Primiparous participants, those who accessed the emails and the app, those who were exposed to the program for a longer period and those who were recruited by their health practitioners all attained higher Engagement Index scores. The use of the Engagement Index in this study demonstrates that rich and useful data can be collected and used to assess the strengths and weaknesses of the app and to inform future iterations of the app.

Participant engagement was not associated with the age of solid introduction. The majority of participants introduced solids between 17 and 26 weeks, with multiparous

participants and participants recruited online (rather than by their health practitioners) being significantly more likely to delay solid introduction. Despite limited apparent associations between engagement and the target behaviour, it would be beneficial to conduct this study on a larger scale. Future interventions require further exploration of how to influence mothers' beliefs and perceptions that their infant is not ready to commence solids earlier than six months.

Future research should investigate the factors which influenced participants' engagement with the Growing healthy app and their behaviour with regards to introducing solids. This will provide a more comprehensive understanding to inform future interventions. Chapter Seven explores the characteristics that correlated with participant engagement and behaviour regarding solid introduction, through a qualitative study exploring participant experiences with the Growing healthy program.

Chapter 7: Qualitative exploration of factors influencing participants' engagement with the Growing healthy app and the age at which solids were introduced

7.1 Introduction

The previous chapter analysed the participants' engagement level and associated variables, including maternal and infant socio-demographic characteristics and feeding behaviours. This chapter includes an analysis of qualitative interviews conducted among a sub-sample of participants from the Growing healthy app program. This study focused on exploring factors associated with participants' engagement, as measured by the Engagement Index levels, described in Chapter Six, and relationships to their decisions on when to introduce solids.

7.1.1 Measuring engagement in mHealth interventions

There are many advantages to conducting mHealth interventions; these include collecting real time data, tailoring information to suit individual participants' needs, and targeting participants who are typically hard to reach with health interventions (Fjeldsoe, Marshall & Miller 2009; Tate et al. 2013). To enhance the effectiveness of mHealth interventions, it is essential to engage participants with the program in order to effectively influence the primary outcomes of the intervention (Baltierra et al. 2016). The current literature in mHealth research uses various methods to measure engagement (Baltierra et al. 2016; Guertler et al. 2015). Studies have measured participants' engagement using metrics such as frequency of website or app access (Bricker et al. 2014), response to text messages sent (Partridge et al. 2015), or logging outcome behaviours such as physical activity (Davies et al. 2012). There are, however, relatively few studies that have qualitatively explored those factors that have an impact on engagement (Dennison et al. 2013).

As described in Chapter Two, factors reported to influence participant engagement with mHealth interventions and the uptake of healthy behaviours include the mode of delivery, quality of the program and the nature of the content, as well as the application of a theoretical model (Michie, van Stralen & West 2011). These elements were considered in the development of the Growing heathy program and are the focal point of this thesis, as illustrated in the conceptual model (Figure 7.1). The current study explored the impact these elements had on the participants' engagement with the Growing healthy program as well as their personal characteristics.

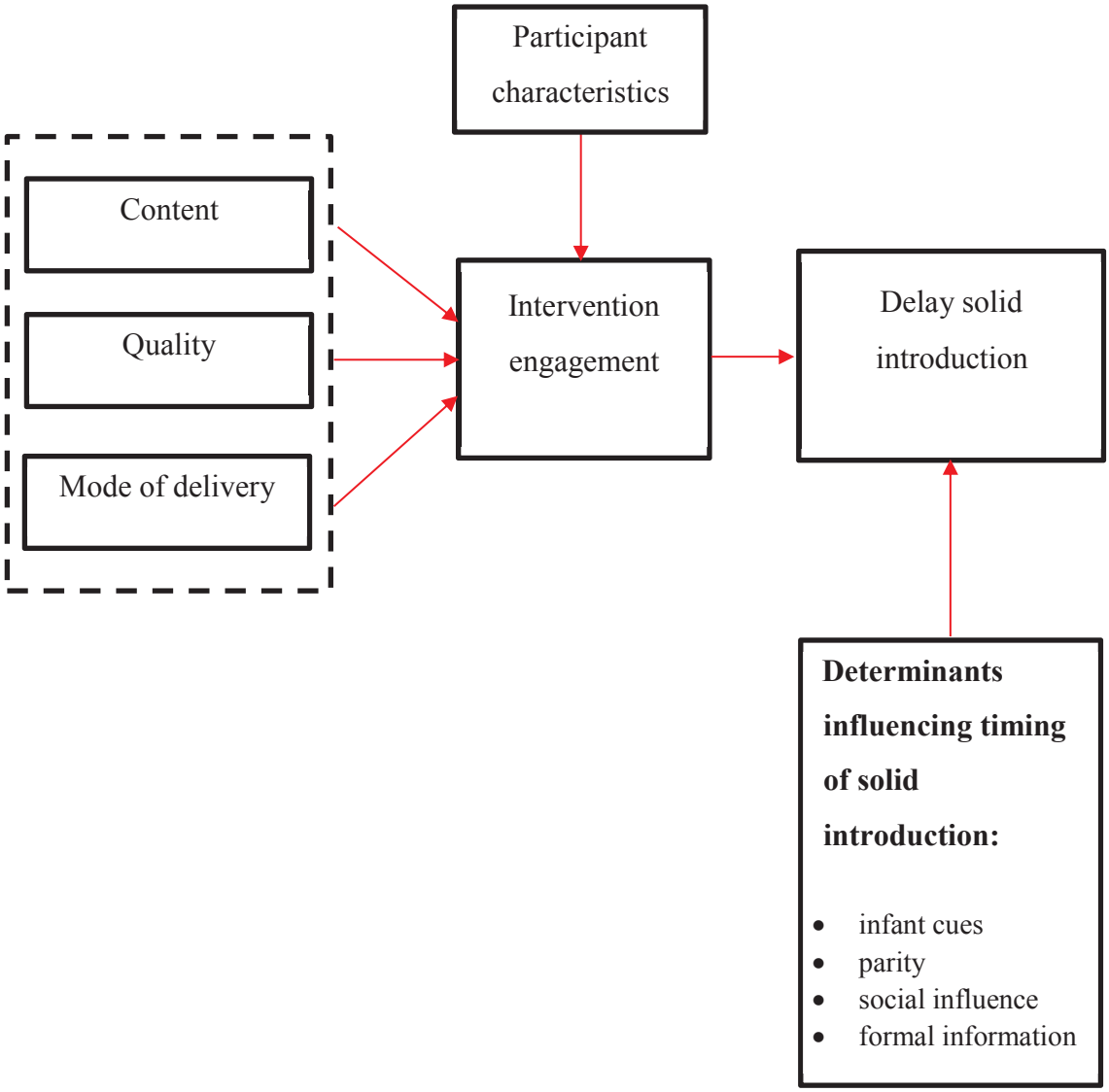

Figure 7.1 Relationships in the conceptual framework addressed in this chapter are highlighted in red

7.2 Aims

The aims of this chapter are to firstly identify how the program elements (i.e. mode of delivery, quality, content or participant characteristics) impacted on participant engagement (as measured by the Engagement Index). Secondly, this study aimed to determine whether higher engagement with the mHealth intervention was more likely to lead to the desired behaviour (delaying solid introduction).

The objectives of this chapter are to:

- describe the variation in participants' interaction with the Growing healthy app between those who were categorised (quantitatively) as either poor, moderate or highly engaged
- identify how the elements (content, quality, mode of delivery) that were considered to enhance the Growing healthy program and participant characteristics affected Engagement Index levels, and
- explore whether higher Engagement Index scores were related to any of the precursors to the target behaviour (delayed introduction of solids) as specified in the COM-B model (Chapter Five).

7.3 Methods

7.3.1 Recruitment

Ethics approval to conduct qualitative interviews with a sub-sample of Growing healthy participants was granted by the University of Technology Sydney Human Research Ethics Committee (ETH14-0123). To be eligible, participants had to have completed the Growing healthy nine-month survey, and expressed an interest in participating in a telephone interview. Interested participants were then screened based on the eligibility criteria (described in section 7.3.2) and contacted by the candidate. Participants received a plain language statement and a consent form (see Appendix 7A) which the Candidate sent via email prior to the interview. Participants were asked to provide verbal consent before conducting the telephone interview. Interviews took place from December 2014 until August 2015.

7.3.2 Participants

Participants were recruited for this study based on the Engagement Index scores they attained for the Growing healthy program. As described in Chapter Six, Engagement Index scores were calculated for each participant upon completion of the nine-month program. Engagement levels were then developed based on the distribution of the Engagement Index scores for the total sample of the Growing healthy app users. Participants were grouped as either poor (<21.1), moderate (21.1-37.1) or highly (>37.1) engaged (further details in Chapter Six). To understand the factors that contributed to engagement, participants were recruited from each of the poorly, moderately or highly engaged groups. Chapter Six also highlighted variations in the participants' engagement based on their characteristics, which were also considered in selection for recruitment in this study. These included participant education level (university/no university), parity (primiparous and multiparous) and recruitment method (practitioner/online/face to face).The variation in participants' engagement levels were also explored based on their characteristics.

7.3.3 Data Collection

The study used a sequential mixed methods data collection strategy (Creswell et al. 2011). To attain a greater understanding of the participants' Engagement Index scores, their behaviour with the app was further explored in this study via semi-structured one-on-one telephone interviews. This method enabled the candidate to explore whether participant engagement level with the app reflected their experience with the program. Participants were encouraged to look at the app during the interviews to aid with the questions related to features on the app. Participants were offered a $30 supermarket voucher to compensate them for their time. Each interview was scheduled to run for approximately 30 to 40 minutes.

The semi-structured interview guide was developed to cover the two main aims of the study. The first part of the interview addressed the first aim, namely, the effects of the program on the participants' engagement. Questions were developed based on the elements (content, quality, mode of delivery and participant characteristics) measured in the conceptual model used in this thesis (Figure 7.1). The quality of the app included exploring participants' experiences and opinions on those factors thought to influence

engagement, namely usability, navigation, design, trustworthiness and the technical utility of the app. The interview also explored participants' usage of the various modes of delivery used in the intervention including the app, push notifications, Facebook group, videos, sharing information from the app (interconnectivity) and app access to another carer.

The second part of the interview addressed the second aim of the study, which was to explore the impact the Growing healthy program had on participants' decisions regarding the timing of solid food introduction (Table 7.1). The COM-B model guided the questions (described in Chapter Five).

The interview schedule was developed using an iterative process. The candidate pilot tested the interview three times with colleagues who were part of the Growing healthy team. The feedback was utilised to ensure the interview schedule addressed the study objectives, flowed smoothly and avoided repetition of questions.

Table 7.1 Interview questions to explore how Capability, Opportunity and Motivation influenced the participants' Behaviour on the age at which they introduced solids to their infant

Intervention function	**COM-B model**	**Examples of interview prompts**
	Behaviour	• Do you remember at what age you introduced solids to your baby?
Knowledge Training	Capability	• Before looking at the app did you know much about when you should introduce solids to your baby?
Environmental context and resources Enablement	Opportunity	• Have you used the solids section of the app? • In what way, if any, did this section help you? • Do you have any suggestions on how we can improve any parts of this section? (prompt: simpler language, images, goal setting)
Persuasion Education	Motivation	• What were the main reasons why you introduced solids at that particular time?

Intervention Function: means by which an intervention can change behaviour in each element of the COM-B model of the Behaviour Change Wheel (BCW) (Described further in Chapter Two).

7.3.4 Analysis

Interviews were electronically recorded with participants' permission, transcribed verbatim and all the interviews were checked against the transcripts to ensure accuracy. The transcripts were then de-identified, stored, coded and analysed using NVivo 10® software (QSR International Pty Ltd 2015). Similar to the qualitative study described in Chapter Four, this study also used thematic analysis networks (Attride-Stirling 2001) whereby the data were analysed in an iterative manner. The questions asked in the interview (Section 7.3.3) shaped the initial themes of the coding manual. Multiple passes of the transcripts identified new codes and sub-codes associated with the participants' experience with the mode of delivery, quality and content of the app, until saturation was reached. Three iterations of the coding manual were made with three chief investigators of the Growing healthy team. After each iteration, the candidate met with the investigators who coded two transcripts prior to each meeting and discussed their feedback until the researchers were in agreement. Further, to minimise bias, another investigator involved in the Growing healthy program coded three interviews and discrepancies between the coding of this investigator and the candidate were resolved through discussion.

The inter-rater reliability of the transcripts coded by both the candidate and the investigator was measured using the Coding Comparison query function on NVivo 10® (QSR International Pty Ltd 2015). This generates a Kappa Coefficient score, the statistical measure of inter-rater reliability. A Kappa score >0.75 indicates "excellent" agreement between raters, Kappa 0.40 to <0.75 is "fair to good" and Kappa <0.40 is "poor" agreement (Viera & Garrett 2005). Inter-rater reliability ranged from "excellent" for *'initial engagement'* (Kappa 0.92) and the infant feeding behaviour '*age of solid introduction'* (Kappa 0.89) to "fair to good" for *'participant characteristics'* (Kappa 0.57), *'mode of delivery'* (Kappa 0.72) and *'quality'* (Kappa 0.41).

7.4 Results

7.4.1 Sample description

In total 25% of the participants of the Growing healthy app program (n= 225) indicated they would be willing to participate in the qualitative interview. From this sample of 56,

18 participants were selected based on their engagement scores and their characteristics to take part in the study. The final number of participants was decided upon data saturation, that is, the identification of re-occurring themes until no new themes arose. Participant characteristics are outlined in Table 7.2.

The participants' mean age at recruitment was around 30 years and their infants were approximately 8 months of age. Twelve of the participants were primiparous. Five participants reported education level of high school or lower, six had a certificate or trade qualification, six had tertiary qualifications and one did not report her education level. The majority of the participants in this study were recruited to the Growing healthy program via their health practitioner (n= 11). The remainder were recruited by face-to-face contact through their mothers group (n= 4), online via Facebook (n= 2) and by word of mouth through family and friends (n= 1). The mean duration of the interviews was around 41 minutes and ranged from 22 to 103 minutes.

The mean Engagement Index score of participants in this study was 36.3% and ranged from 15.6% to 52.5%. Eight participants were categorised in the high engagement group, seven were classified into the moderate engagement group and three into the poor engagement group.

Table 7.2 Characteristics of the qualitative interview participants (n= 18)

Participant #	Participant age (Years)[a]	Participant educational level[a]	Recruitment method[a]	Parity[a]	Infant age at baseline (Weeks)[a]	Age solids was introduced (Weeks)[b]	Engagement Index score (%)	Engagement Index level/group
1	33	Certificate/diploma	Online	Primiparous	8	24	32.4	Moderate
2	21	Year 10	Face to Face	Multiparous	9	24	41.7	High
3	26	Year 12	Online	Primiparous	13	26	50.8	High
4	36	Certificate/diploma	Face to Face	Primiparous	8	20	34.2	Moderate
5	30	Year 12	Practitioner	Primiparous	9	16	48.9	High
6	32	Certificate/diploma	Practitioner	Multiparous	3	26	31.9	Moderate
7	38	Certificate/diploma	Practitioner	Primiparous	6	18	31.5	Moderate
8	34	Certificate/diploma	Face to Face	Multiparous	8	20	20.1	Poor
9	35	Certificate/diploma	Practitioner	Multiparous	4	16	25.8	Moderate
10	24	University degree	Face to Face	Primiparous	10	24	44.1	High
11	25	-	Practitioner	Primiparous	2	16	52.5	High
12	33	Year 10	Practitioner	Primiparous	3	18	15.6	Poor
13	34	Higher university	Practitioner	Multiparous	2	21	32.2	Moderate
14	35	Higher university	Practitioner	Primiparous	11	21	33.2	Moderate
15	28	University degree	Practitioner	Primiparous	8	22	45.1	High
16	32	Higher university	Word of mouth	Primiparous	10	23	43.1	High
17	32	University degree	Practitioner	Multiparous	13	23	20.0	Poor
18	27	Year 10	Practitioner	Primiparous	9	24	50.0	High

Engagement Index cut-points for scores: poor engagement= <21.1, moderate engagement= 21.1-37.1, high engagement= >37.1

[a] Variables are based on data provided at baseline or T1 (age ≤3 months)

[b] data provided at six month or T2 (age 6 months)

7.4.2 Factors that influenced the participants' engagement with the Growing healthy program

A summary of the main findings is contained in Table 7.3. The following sections provide a description of the findings on those factors that influenced participant engagement with the program.

7.4.3 Initial engagement to join the Growing healthy program

The convenience associated with accessing an mHealth resource appeared to be an important reason for most participants' interest in joining the Growing healthy program. This was particularly the case for primiparous participants [*"all the information that was available; so obviously being a first time mum that gave me a little bit of information and help…"* Highly engaged participant 11].

Some participants also reported that they joined the program because they believed it was a trustworthy source of information about infant feeding. The university endorsement led participants to attribute high trustworthiness to the app [*"…it said something about Deakin University and I studied nutrition at Deakin University so I already had a high, what's the word, trust for what goes on there"* Highly engaged participant 15]. Further, participants who were referred to the program by their health practitioner also believed the app to be trustworthy [*"Yeah, and being that it was probably from a superior person, not like friends – because friends would have, they'd probably recommend like five different apps…"* Highly engaged participant 18].

7.4.4 Exploration of how participant characteristics, mode of delivery, quality and content affected Engagement Index levels

Participant Characteristics

Chapter Six indicated that all participants were initially engaged upon joining the program, although this study identified that differences in engagement between groups was partly attributed to their characteristics. In particular, parity, availability, knowledge on infant feeding, learning style and use of other sources all affected participant behaviour with the app.

Parity

Based on the findings from both Chapter Six and this study, majority of the primiparous participants were more highly engaged with the app compared with the multiparous participants. The primiparous participants used the Growing healthy program as their main resource to gain knowledge and skills on infant feeding practices ["I think as a first time mum especially it's really quite helpful, having everything in the one area instead of having to go to different sources for information… It was just all there for me." Highly engaged participant 5]. Meanwhile, multiparous participants, due to their previous experience, believed they had sufficient knowledge and skills with infant feeding practices. Further, they also felt limited in the time they had available to access the app as they needed to attend to their other parental duties [*"At first I did but just as (baby's name) got a bit bigger, I wasn't sitting around feeding as much to think "I'll have a look at that" if that makes sense. My hands are full with a two year old and a 9 month old. It's kind of, I only have time just to sit down…"* Moderately engaged participant 6].

Time/availability

Participants often saw time as a barrier that determined how frequently and when they were able to access the app due to being caught up with parenting duties. This was particularly an issue among multiparous participants. It was common that participants accessed the app while feeding or putting their baby to sleep [*"Mainly read it [the app] when she was younger and she was sleeping more."* Moderately engaged participant 14].

Knowledge on infant feeding

The participants' knowledge about infant feeding was a major influence determining how frequently the app was used. For example, participants with less knowledge on specific baby's age and stage of feeding [*"I started using it a lot more when it came to [baby name] started eating solids and what sort of finger foods and that kind of thing I could start to introduce to her."* Moderately engaged participant 7].

Participants with experience and knowledge from previous children tended to use the app less often [*"My baby that I did it with, she's actually my third baby. So I didn't really use it all that often to be honest."* Moderately engaged participant 13].

Some participants used the app to confirm their knowledge about infant feeding [*"When I need to double check things, like, starting with solids with my little one, like, I was told, you know, there's many mixed things as to when you can start them on solids."* Highly engaged participant 11].

Learning style

The participants' learning styles also varied. Some felt the need to read the information only once and others continuously referred back to the app throughout the different stages of feeding [*"... I read it from start to finish. So if I went to the bottle feeding section, I'd always read all of it and then go back."* Moderately engaged participant 1].

Use of other source of information

A number of participants used a combination of resources with the app [*"Between the Growing Healthy app and my mum and child health nurse, yeah, that sort of answered everything."* Highly engaged participant 11]. Participants often used other sources to compare information provided on the app and to obtain more detailed information [*"...I'd obviously, yeah, jump on the good old Google and look for a bit more information and if it sort of corresponded then I would, yeah, go with that information."* Poorly engaged participant 12]. Some participants were motivated to follow the latest recommendations despite the differing advice they received from other sources [*"Mostly I'd read a lot of articles on when to introduce solids and a lot of them said four months is okay but six months is better. My doctor also suggest six months would be better, so six months for me was..."* Highly engaged participant 3].

Mode of delivery

In addition to their' characteristics, participants' engagement level was also influenced by program elements including the various modes that the intervention was delivered. The participants' experiences with these elements impacted on their frequency of accessing the app. These elements are discussed in detail below.

Push notifications

The push notification was the most active form that enhanced participant engagement with the Growing healthy program. For example [*"When I was prompted by the text messages or the notifications I did it a little more often then, so yeah probably mostly*

then when I got the notifications" Highly engaged participant 10]. However, this was not the case for a small number of participants who felt overwhelmed when they received push notifications, particularly if they used other apps, hence this led to poorer engagement with the app. [*"I really don't like notifications to be honest. I feel like too many apps fill my phone with it and it sorts of stops me from what I'm meant to be doing."* Poorly engaged participant 8].

Participants' use of the push notifications was affected by how practical/easy it was for them to access relevant information on the app from the links provided in the message [*"…the best part about that was it said, you know, when they came up it said swipe and then it would take you straight there, which is really cool."* Highly engaged participant 11]. Participants also appreciated that messages were tailored and personalised according to their infant's age and stage of feeding [*"It didn't feel like a standard message to everyone. It felt like, "oh we realise that your child is now 3 months, have you looked at this?" I found it good because it was more of, someone was paying attention to you."* Highly engaged participant 18].

Another factor influencing use of push notifications was whether they were sent at a convenient time for the participant. Participants commonly mentioned they accessed push notifications and the app during feeding or while putting their infant to sleep. [*"Yes, I definitely read them and opened them and then, yeah, have a look right away unless I was busy, which I'd then go back to it."* Highly engaged participant 11].

The relevance of the content in the message to the participant further influenced its use [*"Yeah, I mean, look, again, as a third time mum, you know, that part of the reason why I didn't read them all. I think if I was a first time mum I would have read them all. There were just some things I just thought, 'Yes, I know what I'm doing here about this particular subject'."* Moderately engaged participant 13]. Lastly, technical issues such as push notifications disappearing before participants had the opportunity to access them limited their engagement with the app [*"You couldn't just push it to the side and come back to it. You either read it then when the notification came or it was gone"* Poorly engaged participant 17].

Overall, the majority of the participants were satisfied with the frequency of push notifications sent, regardless of their engagement level [*"…I reckon three (per week) is*

good because I think, like, because you get some notifications that are, you know, daily and I think that's too much..." Poorly engaged participant 12]. Most participants also preferred receiving messages on their phone [*"I think the push notifications are better because I – like they come up on my phone straight up and it's there."* Highly engaged participant 3]. Most of the participants reported that emails were the least preferred form for intervention delivery [*"Definitely push notifications or text messages, I always just delete e-mails."* Highly engaged participant 10].

Videos

Although very few participants utilised the videos, there was no distinct variation in engagement level among those who did compared with those who did not use the videos. The most commonly watched videos were on solid introduction including meal preparation and fussy eating, followed by videos on hunger and satiety cues, settling techniques and breastfeeding positions. Participants provided mostly positive feedback on the videos, believing that they provided practical advice and skills [*"They were fantastic. Like you can have so much information in front of you typed out but to actually see it is so much easier to work out what you're doing."* Moderately engaged participant 9]. Participants noted a range of reasons for not utilising the videos. Some reasons included believing they did not provide more value than the written information, the introductions were too long and they required using their phone internet data. For example, [*"I wouldn't say they were really good. Sometimes a few of them had slightly long introductions when you're meeting the mum … the information was useful, but that didn't add that much more than what was written."* Highly engaged participant 16].

Facebook

The majority of the participants joined the Growing healthy Facebook group. Similar to the videos, there was no clear association between participants' use of the Facebook group and their level of engagement. Participants felt that the group was a comfortable environment in which to express issues they experienced either with the app or with infant feeding practices. For example [*"...I didn't get the voucher for my questionnaire and I didn't do anything about it, but then I saw another mum say that she didn't get hers either, so I just posted on that one and then they sent it out."* Highly engaged participant 2]. Participants also preferred to use Facebook as a way to contact the team

to address issues experienced with the program or about infant feeding practices [*"But I loved that I was able to send a message and someone actually replied because I am way too shy to post publicly."* Highly engaged participant 15].

There was very little interaction between the participants on the Facebook group. Participants felt uncertain as to whether they were allowed to respond to posts from others on the group and some felt that the lack of communication between participants created a barrier [*"It was good. I don't think a lot of people use it, like posting questions or writing comments or things like that. It doesn't really seem like it hit off…."* Moderately engaged participant 1]. Others mentioned that they did not use the group as it did not provide them with novel information [*"I don't think I – I mean I went in there a couple of times but most of the information that everyone was talking about was already stuff that I was already talking about with everybody else."* Moderately engaged participant 7]. Further, a number of participants expressed that they would have liked to see more frequent posts with a variety of content [*"They could definitely put more information on there… there weren't a lot of articles or posts put on there…"* Highly engaged participant 3].

Interconnectivity: Sharing app based information

Consistent with the other features, there appeared to be no association between participants' use of the interconnectivity feature and their engagement. Very few participants used the interconnectivity feature of the app (that is, sharing information from the app through social media platforms). Participants who did use this feature found it beneficial, as they were able to reflect on information about infant feeding within their social group. This was expressed by a number of participants specifically recruited from the mothers' group. For example [*"I think it was in the mums group. It was that night and I came home and I was on the app and I saw something and I shared it with her on Time Share app… It was something that we would talk about through the day and then that information was right there so it was good."* Moderately engaged participant 1].

The main reason participants reported not using this feature was due to the unfamiliarity with the technological symbol used in the app to represent the sharing function [*"Yes I've seen that. I just never knew what it was for."* Highly engaged participant 18]. Many

participants commented that they would have used the function if they were aware of it [*"Yeah. I feel more comfortable sharing the information from Growing healthy with a wider range of people."* Highly engaged participant 15]. One participant still shared information from the app with others despite not knowing the existence of this function [*"It's funny because I've been wanting to share some of the info and I sometimes screen shot it and then post[ed] it."* Highly engaged participant 2].

App access to another carer

Very few participants signed up to provide access to another carer. Participants believed their partner would not benefit from the app or would not be interested in using it. The most common reason was that their partners' work took priority over infant feeding [*"No. It would have been my husband but he wouldn't do anything like that."* Moderately engaged participant 1]. Participants who did share the app with their partner noted the partner was disinterested in the app [*"Yes, I did and I gave it to my partner but he wasn't very interested. I do that with almost everything. I say, 'Read this and then you will understand' and he's more interested in his football forums."* Highly engaged participant 15]. One participant mentioned that the push notifications were sent at an inconvenient time for her partner, which led the partner to disengage with the app [*"He didn't like the notifications because they always came at an inconvenient time for him. It was usually when he was working."* Highly engaged participant 18]. No association was found between this feature and participant engagement.

Quality

Technological issues

Technological issues such as the smartphone system upgrades causing the app to become dysfunctional on many participants' phones, in turn impacted on participant engagement level. This experience caused some participants to feel frustrated and to disengage from the program altogether [*"I had the app. Then when I did the upgrade, it stopped working… and I think that's maybe why I stopped using it because I don't think it's been fixed since or it has and I just haven't needed to use it to check if it's fixed…"* Poorly engaged participant 17]**.** Another technological barrier was the need to request a unique code to access the app. This was an issue for participants who changed or upgraded their phone during the course of the program who needed to request a new

access code [*"Say if you have to reinstall the app, it's just like a technical glitch. I keep having to put in a code and I haven't used it because I've switched my phone again and I'm not sure if I would need another code to access it."* Highly engaged participant 15].

There were also reports of technical issues with the push notifications. In some instances, participants did not have the opportunity to tap on a push notification when it was sent as it disappeared from view [*"would get notifications pop up on my screen saying my daughter's age, and it might say she's nine months old. It had little helpful tips, and when I unlocked my phone I could never find where that tip went."* Moderately engaged participant 14].

Navigation and Design

The majority of the participants, regardless of their engagement level, felt that the design and layout of the app made it easy to navigate and to find the information they were interested in [*"you could find what you wanted fairly easily. It was pretty clear with the titles on the menu page."* Poorly engaged participant 17]. A few participants experienced difficulties and some struggled to identify how to change the page, search for specific information or to exit the app [*"I think I may have had a few troubles. It might have taken me a little extra time to get to the area that I was trying to get to but I could always find it…Is there a search function in there?"* Highly engaged participant 15].

Trustworthiness

All participants believed the app was a trustworthy source and most of them used the app as their 'go to' source. For example, [*"I just kind of tried different things but yeah. It was too confusing. Yeah. I actually recommended your app to a few different people just for the fact that it was a lot easier."* Moderately engaged participant 9].

Table 7.3 Themes and subthemes from interviews regarding the factors that influenced participants' engagement with the Growing healthy app program

Engagement Element	**Main theme**
Initial Engagement	• Primiparous parents were more likely to join the program • Parents joined the program because they wanted more support and information on infant feeding
Mode of delivery	
Smartphone application	• Participants felt it was a convenient and reliable resource on infant feeding • The program was mainly used to compare with other information they read about infant feeding practices • Participants who felt confident with infant feeding were less engaged with the program • The infants' age and stage of feeding determined how frequently participants used the app • Use of other resources (online, health practitioner, written sources) decreased engagement
Push notifications	• Participants opened push notifications according to their availability at the time they received it • Participants opened push notification according to the relevance of the message • Technical issues experienced, such as message disappearing before participants tapped on it or directing to incorrect locations on the app, impacted participants' use of push notifications • Repetitive messages led participants to disengage with the push notifications
Videos	• Videos provided practical skills about infant feeding • Concerns with internet data usage decreased engagement with videos • Some participants preferred written resources • Some participants felt the videos had long introductions
Facebook Group	• Some participants felt comfortable to express issues or questions on the group • Some participants wanted more frequent posts • Lack of variety in the content of the posts decreased engagement with the group
Interconnectivity	• A majority did not use this function as they were not familiar with the symbol used • Some participants believed this function was useful
Sharing app with another carer	• Partners were not engaged with the app • Infant feeding was not partners' main priority
Quality	
Design	• Participants believed the layout, colours and images used were appropriate
Usability	• App seemed counterintuitive during initial usage • Participants found it easy to use which increased engagement

Trust worthiness	• University endorsement of the app increased trustworthiness • Recommendation by health practitioner increased trustworthiness
Navigation	• Ease of finding the information increased engagement • Some participants were not aware of the search function
Technicality	• Experience with technical issues decreased engagement • Participants voiced frustration with push notifications disappearing
Content	• Primiparous participants wanted more detailed information • Participants wanted information on child development and play

7.4.5 Exploration of participant engagement with the app and the influence of precursors of solid introduction using the COM-B model

The second aim of this thesis was to explore whether participant engagement with the app influenced the uptake of the target behaviour (delaying solid introduction). The COM-B model was used to target the barriers associated with delaying solid introduction through the use of intervention functions and Behaviour Change Techniques (BCT), which were integrated in the mode of delivery and content of the Growing healthy program. Table 7.4 briefly describes the influence of the intervention functions and BCTs on the participants' behaviour.

Table 7.4 Impact of intervention functions and Behaviour Change Techniques on the outcome (delaying solid introduction)

COM-B elements	**Intervention functions**	**Strategies for change (BCT) to deliver intervention function**	**Summary findings from interviews**
Capability: Psychological & Physical	• Education • Training • Environmental restructuring	• Cognitive and interpersonal skills: instruction on how to perform a behaviour • Knowledge: information about health consequences	• The majority of participants were not aware of the guidelines on when to introduce solids before using the Growing healthy app • Information on when to introduce solids was obtained from a variety of sources
Opportunity: Physical	• Environmental context and resources (prompts/cues) • Enablement	• Adding objects to the environment	• Push notifications encouraged some participants to delay solids, but caused frustration for others who introduced solids earlier than six months • The videos helped some participants better understand the importance of delaying solids introduction • The app was used to ascertain participants' knowledge on when to introduce solids although it was not the main driver to their decision • Participants were more inclined to follow advice from their health practitioner if it was consistent with the program
Motivation: Reflective	• Persuasion • Education	• Belief about capabilities: verbal persuasion to boost self-efficacy • Belief about consequences: information about health consequences	• Some participants introduced solids earlier because of their infants' health such as reflux, sleep patterns and perceived insufficient consumption of milk • Participants acknowledged the importance of delaying solids introduction because of the health consequences such as development of the digestive system, impacting on stools and sufficient iron intake • Participants followed the most consistent advice provided to them whether it was to introduce at four months or to delay until six months

BCT: Behaviour Change Technique (described further in Chapter Two).

Intervention Function: means by which an intervention can change behaviour in each element of the COM-B model of the Behaviour Change Wheel (BCW)

7.4.6 Behaviour – Age of introducing solids

The age at which participants introduced solids to their infant ranged from 16 to 26 weeks (mean= 21.2 weeks). Of the 18 participants interviewed, two adhered to the Government issued infant feeding guidelines and introduced solids at around 26 weeks; 16 introduced between 17 and 25 weeks and three introduced at 16 weeks. As identified in Chapter Six there was no significant association between the participants' Engagement Index level and the age at which they introduced solids to their infant.

7.4.7 Influence of Capability on participants' behaviour – Education, Training, Environmental restructuring

The Growing healthy program targeted Capability, which included providing participants with information on the recommended age to introduce solids and the skills to identify whether their infant was ready for solids.

Overall, very few participants knew about the Government recommendations on the age at which to introduce solids prior to using the Growing healthy app. Multiparous participants were more aware of the recommendations compared to primiparous women [*"Yeah I always knew to wait and I have always waited in the past just to see – you know, let their tummies get what they need, things like that."* Poorly engaged participant 17]. Some participants' knowledge was based on advice they received from their previous children [*"Yeah, so [with] my daughter I was told not before six months; that was in 2010. My son in 2013, well, I suppose it was mid-2014 by the time he started eating, I believe, yeah, I was told from three months was fine and again with, (infant name) was the last, I'm pretty sure I was told the later the better, but you can from three months…"* Moderately engaged participant 13].

Some participants were informed about the recommendations prior to using the app by other sources such as their health practitioner, parenting courses, friends and mothers' groups (Opportunity). For example, [*"I did because I did a parenting course thing when my baby was seven weeks old. It was a new parents' class or something that the hospital offered."* Moderately engaged participant 1].

7.4.8 Influence of Opportunity and Motivation on participants' behaviour – Environmental context and Resources & Enablement

The factors that influenced participants' decisions to introduce solids earlier (four to five months) rather than later (five to six months) varied in this study. These factors included exposure to the Growing healthy app, the consistency of the advice they received from other sources such as health practitioners with the app, health consequences associated with early or delayed solid introduction and the perceived infants' cues of readiness.

Influence of the Growing healthy app

The majority of the participants used the information on solid introduction in the app along with other sources (Opportunity) to inform their knowledge (Capability) about the right age to introduce solids. The information provided by the app influenced participants in a range of ways. Some felt Motivated to delay until six months [*"It definitely got me to hold off to six months, because I wasn't going to."* Highly engaged participant 2]. Others interpreted the recommendation differently and were motivated to follow their infants' cues. [*"I was one of those mums that was like 'I am not starting until she is six months old', and I was adamant that that's when she will be starting. Then I think our app says to read from your child, and my daughter was interested in food at about five months...so I didn't wait until six months…"* Moderately engaged participant 14].

Consistency of advice received

Participants reported receiving advice about solid introduction from a variety of sources (Environmental - Opportunity) including their health practitioner, written source and the Growing healthy app. It was, however, the consistency between a range of information sources that gave participants confidence (Motivated) to choose when to introduce solids. For example, [*"Mostly I'd read a lot of articles on when to introduce solids and a lot of them said four months is okay but six months is better, my doctor also suggested six months would be better…I wasn't planning on introducing until six months at the latest..."* Highly engaged participant 3].

Health consequences

Health consequences associated with the timing of solid introduction influenced some participants to introduce solids earlier than the recommendations and encouraged others to follow the recommendations. Some of the reasons which led participants to introduce solids earlier included infant reflux [*"…he had reflux so, yeah, my health care provider suggested that, yeah, to start him early because that might help to sort of settle it down a little"*. Highly engaged participant 11]. Other factors included the infant not consuming sufficient milk [*"So at four months old I went to the health nurse appointments and the health nurse said to start introducing solids because at that stage she wasn't having much bottle…"* Highly engaged participant 5]. Some participants believed that introducing solids earlier would improve their infants' sleep patterns [*"My health nurse said when she was looking at food and those sorts of things and after viewing the app…it gave me a little bit more encouragement that she would need it in the mornings or in the evening to make her sleep better…"* Moderately engaged participant 8].

Conversely, some participants considered the importance of delaying solid introduction and following the recommendations because of the negative impact that early introduction might have on their infants' health. The reasons participants decided to delay included the impact on infants' digestive health, infants receiving sufficient iron from milk feeding until six months, and experience from previous infants suffering from constipation. For example, [*"The main reason was because it's recommended for their iron stores. Yeah, it's recommended to start them at 6 months. A paediatrician did recommend to start a little bit earlier on rice cereal and puréed fruit. That was at five months but I did still wait a little longer until around the sort of six-month mark."* Highly engaged participants 15].

Infants' cues

Infants' cues also influenced some of the participants' decisions on the age at which they introduced solids to their infants [*"Because she was starting to copy us when we were eating, like making mouthing movements and that kind of thing and so we just started giving her little tastes of what we were eating just to see how she went with it."* Moderately engaged participant 7]. Some participants who had planned to introduce solids earlier than six months, then delayed on observing infant cues suggesting the

infant was not yet ready to begin solids [*"We noticed that she wasn't ready so she was avoiding it, avoiding the spoon so we're like 'we're not going to push her to do it'. So she probably didn't actually really start proper solids or meals until she was about six months old."* Highly engaged participant 5].

7.5 Discussion

There were two aims explored in this study. The first aim was to explore the participants' experiences and engagement with the Growing healthy app. The findings showed a wide range of reasons that influenced participant engagement with the app including the app quality, modes of delivery, content and participant characteristics. For instance, participants who utilised the push notifications were more likely to access the app frequently and had a higher engagement level, while those who experienced technological issues had poorer engagement with the app. Further, the majority of primiparous participants had a higher engagement level compared with multiparous participants.

The second aim was to identify the factors associated with the participants' decisions on the age at which they introduced solids. The results showed that the COM-B elements of Environmental Opportunity and Reflective Motivation influenced participants' decisions. Specifically, consistency in the advice participants were exposed to (Opportunity) was the main driver (Motivation) of their decision on the age at which they introduced solids. This influenced participants regardless of their engagement level with the app.

7.5.1 Factors associated with engagement in mHealth interventions

Understanding the factors that influence engagement not only impacts participants' use of the program, but it is also important for developing the required knowledge and skills for the uptake of the target behaviour. There are three common phases that occur in mHealth interventions or programs: initial engagement, engagement and disengagement (O'Brien & Toms 2008). As expected, the factors identified in the conceptual model (Figure 7.1) including quality, mode of delivery, content and participant characteristics all influenced each phase of engagement with the Growing healthy program.

One of the main determinants of initial engagement was the convenience of accessing infant feeding information via an app. This finding supports the results arising from the qualitative interviews described in Chapter Four and another study (Willcox, van der Pligt, et al. 2015), where mothers were enthusiastic about obtaining health information via a range of technologies. It confirms that parents have accepted and adapted to online social phenomena and suggests that mHealth is an appropriate medium for conducting interventions with this demographic.

7.5.2 The impact of app quality on participant engagement

One of the elements associated with the app quality that affected initial engagement was perceived trustworthiness. Participants believed the app was a trustworthy source of information on infant feeding due to the university endorsement advertised on the app. The findings in Chapter Three identified that few online infant feeding sources provide details about the qualifications of the developers. Previous research has demonstrated that consumers' perception of the credibility of online information plays a key role in determining the usefulness of websites (Jung, Walsh-Childers & Kim 2016; Lim & Van Der Heide 2015). However, a common finding is that individuals often use information sources of dubious quality in part because they do not feel well equipped to interpret and evaluate content quality (Cash et al. 2015; Dart, Gallois & Yellowlees 2008). These findings highlight the importance of utilising a reputable endorsement that would enable users to easily determine trustworthiness (Metzger, Flanagin & Zwarun 2003; O'Key & Hugh-Jones 2010; Taki et al. 2015). Perceptions of trustworthiness were enhanced when participants were referred to the program by their health practitioners. This supports the notion that participants perceive the advice from their health practitioner as superior to other sources (e.g. friends or family, online sources or pamphlets) (Gildea, Sloan & Stewart 2009). Although recruitment to the Growing healthy study was slower and more expensive through health practitioners than with online recruitment (Laws, Litterbach, et al. 2016), there were benefits to this approach in that it enhanced perceptions of the trustworthiness of the program and therefore participants were more likely to adopt health behaviours promoted in the app.

The participants were also satisfied with the aesthetics of the app including the design and layout and felt confident to navigate around the app. Although design and ease of navigation contribute to a good quality app, they were not particularly associated with

higher engagement, as poorly engaged participants also expressed their satisfaction with these features. A number of participants provided feedback on the lack of symbols utilised by the app, such as turning the page, and the majority were unaware of the interconnectivity feature.

To ensure that apps are intuitive for the target demographic, products are often beta tested (testing the quality of the app or website) before release to the public (Naeem et al. 2015). In previous mHealth interventions, the participants were involved in beta testing the program for quality by utilising an app quality assessment tool (Pocuca et al. 2016) Another study used qualitative methods to obtain feedback on the usability, navigation and aesthetics of the app and made adjustments before conducting the intervention (Breakey et al. 2013). Given time constraints in the present study, the researchers beta tested the app, which may potentially reduce the likelihood of identifying technological or navigational issues making the app less intuitive to use. To address this issue, a more objective assessment could have been achieved by beta testing with an external group from the target audience before implementing the program.

Another aspect of app quality, technological issues proved the main barrier that prevented participants accessing the app or led them to disengage with the app. However, this was not the case for highly engaged participants. Disengagement due to technological issues is a factor known to influence participant interaction with digital technology (O'Brien & Toms 2008). The main technological issue that occurred in the program was app dysfunction due to an unexpected upgrade in the operating systems for both the iOS and android smartphones. The Growing healthy app was built on a native app so that it was accessible to participants with both iOS and android phones, and so that it could effectively function without internet access. Native apps rely on the phone's operating system and must adhere to their design requirements of the operating systems (Apple 2016; Google 2016a). The app therefore became dysfunctional when participants upgraded the software on their phone. In future studies, not only is it important to select the most suitable platform (i.e. hybrid, native or cross platform) (Serrano, Hernantes & Gallardo 2013) for the intervention but also to understand the processes involved with using these technologies. It is essential that the researchers work closely with the program developers to understand what these processes involve

and to develop strategic plans on how to deal with possible occurrences such as operating system upgrades. Most importantly, researchers need to consider and incorporate the additional costs involved in the maintenance of technology within their funding budget. One potential method which can be implemented to strategically manage issues that may arise within projects includes applying the Project Management Body of Knowledge (PMBOK) guide (Karaman & Kurt 2015). This involves identifying possible barriers and potential solutions to avoid compromising the user's experience.

Overall, it is evident that the quality of mHealth interventions contributes significantly to how participants engage with the intervention. Specifically, in this study technological issues were a major influence in decreasing participant engagement. Conversely, the ease of use, including the design and layout, encouraged participants to use the app.

Previous mHealth interventions highlighted the importance of utilising various modes of delivering the intervention (e.g. articles, games, quizzes, message boards, photo galleries, videos) to increase engagement levels (Baltierra et al. 2016) and to encourage health behaviour change (Webb et al. 2010). In this study the unidirectional push notifications were the main influence on engagement. One aspect that engaged participants to use the push notifications was the fact they were tailored and personalised to suit their infant's age and stage of feeding. Similar findings were reported in a systematic analysis which focused on mHealth interventions for weight loss and identified that tailored materials led to significantly higher engagement in the intervention outcomes measured (Raaijmakers et al. 2015).

Consistent with other findings (McCarroll et al. 2015; Pellegrini et al. 2015), participants were likely to engage with the app through the push notifications when these were perceived as relevant and if they were sent at a convenient time. One of the disadvantages of using push notifications is the inability to view them at the user's own leisure (Danaher et al. 2015). Although push notifications can be pre-programmed and scheduled for delivery at predefined times to suit the demographic (Danaher et al. 2015), parental duties scheduled around the infant's needs (Shieh, Broome & Stump 2010) makes it challenging to determine a schedule that would suit all participants. During the course of the program, participants were sent weekly emails due to the identification of low usage of push notifications. The findings in Chapter Six illustrated that a large number of participants (71.1%) opened the emails at least once during the program, and were significantly more likely to attain a higher Engagement Index score compared with participants who only used the app. However, the participants in this study reported that they generally ignored or deleted emails, suggesting a stronger preference for push notifications. For future studies, app developers might consider creating a message bank such as the android or iOS Notifications Center, which stores unopened notifications (Google 2016c; iMore 2016) delivered via the app to give participants the opportunity to access push notifications at their own convenience.

Other studies have also presented participants with videos embedded in the app to provide content and encourage the uptake of healthy behaviours (Danaher et al. 2015; O'Brien & Toms 2008). In this study videos provided participants with practical skills on how to practise infant feeding and settling techniques. Yet because internet data was required to access the YouTube videos, very few participants utilised this feature. The

cost of the data required to access the videos was therefore a barrier to participants' engagement. However, videos are considered an effective mode for delivering well targeted health promotion messages and in turn for modifying health behaviours (Tuong, Larsen & Armstrong 2014), also evident in this study. It would therefore be important to consider other ways to include videos that would not require participants to use phone internet data.

Further, social norms and prompts from peers, health professionals and family members are known to influence mothers' infant feeding (Russell, Taki, Azadi, et al. 2016). Specifically, there is evidence that fathers play a major role in influencing infant feeding behaviours including breastfeeding initiation (Wolfberg et al. 2004) and the age at which solids are introduced (Hauck & Irurita 2003; Swanson & Power 2005). To address this influential factor, participants were offered the opportunity to provide app access to another carer. However, very few participants signed up to obtain app access for their partners. Those who did reported that partners lacked engagement with the app. To engage other carers, different strategies are required to appeal to the demographic (Baltierra et al. 2016). One study which has considered the importance of engaging other carers is the Parent Infant Feeding Initiative (PIFI) (Maycock et al. 2015). Embedded in this larger intervention is a study, Milk Man, a smartphone app targeted at fathers through gamification and focused on increasing breastfeeding duration and decreasing the early introduction of solids (White et al. 2016). It would be beneficial to observe the outcomes of this study to identify whether this technique was in fact effective in engaging fathers and improving target outcomes for future interventions.

The program also incorporated interconnectivity to encourage participants to share information from the app with their wider social network. Yet very few participants used this feature as they were not aware of the availability of this function. It thus had no influence on participant engagement. This finding illustrates the importance of using universal symbols, which are applied in commonly used apps, which participants would automatically recognise to identify certain functions utilised in the digital field. Given the inherently ever-changing nature of smartphone apps and features that can be offered, designing such programs has become an important challenge to ensure they are interoperable and enhance users' experience (Folkmann 2012). Beta testing is essential to explore how participants use an app program to identify any features or elements that

are not recognised. Further, an introductory video which illustrates the functions available on the app may also be useful.

Social networking behaviours within the Growing healthy Facebook group did not appear to be related to engagement level, as there was rarely any interaction. Social networking sites have been identified as a useful outlet to engage and retain participants in interventions, particularly because sites such as Facebook report that 61% of their users log in daily (Kaushal 2013). Social networking sites including Facebook groups and forums that support participants have been shown to positively impact on maternal mental health (McDaniel, Coyne & Holmes 2012; Meadows 2010). In this study, the majority of the participants joined the group although there was minimal interaction between the participants as they were part of other more established groups. This finding is similar to other interventions that do not involve face-to-face interaction with their participants and have established closed groups to encourage social connectivity (Maher et al. 2014; Willcox, Campbell, et al. 2015). Despite the low interaction on the Facebook group in this program, the Growing healthy Facebook group appeared to be an important outlet that some participants felt comfortable in using to express issues experienced with the program such as reporting unreceived gift vouchers after completion of surveys or being unable to access the app or push notifications. Further, some participants used this group to ask specific questions regarding infant feeding practices.

7.5.4 The influence of participant characteristics on engagement

Another aim of this study was to describe how participants' characteristics, namely parity, ability to access the app, knowledge of infant feeding, learning style and use of other sources, affected engagement levels. Results indicated that the participants' knowledge of infant feeding and experience with the app determined how frequently they accessed the app throughout the nine-month program. The app use decreased once confidence with infant feeding practices was established. This finding is in line with studies aimed at the management of chronic diseases where use attrition occurred once participants gained confidence in managing the condition (Guertler et al. 2015). However, unlike many health apps which have been developed to monitor and manage chronic diseases (Free et al. 2013) or to track physical activity (Kirwan et al. 2012) which is usually an ongoing behaviour, this app was designed to be a "just in time"

resource (Danaher et al. 2015; US Department of Health & Services 2015). This program supported participants with advice on infant feeding practices only up to nine months of the infant's age. The analysis of the app data presented in Chapter Six illustrated that engagement among the majority of participants decreased after their infant reached five to six months. This was further supported in the interviews as participants mentioned their use decreased after attaining the knowledge about solid introduction. A number of mHealth studies have identified that to maintain user engagement, it is necessary to capture their attention through novel information so that the app remains relevant to them (Baltierra et al. 2016; O'Brien & Toms 2008). These findings need to be considered in any re-formulation of the Growing healthy app.

Finally, primiparous participants in the current study reported being relatively more engaged with the app than multiparous participants. This appeared to be explained by the fact that multiparous participants felt they already had the knowledge and skills for feeding their infants from previous experience. This explains why these participants attained a lower engagement score with the app. Interestingly, this finding further supports the results reported in Chapter Four where multiparous participants showed less interest in the development of an mHealth intervention. However, with ongoing change in the infant feeding guidelines, it is still crucial to draw these participants' attention to the latest evidence around best practice in infant feeding. Similar to the Milk Man study, which developed an app which used gamification to engage fathers in supporting mothers to prolong breastfeeding and delay solids, different strategies need to be considered to tailor interventions that target multiparous parents (Bai, Fong & Tarrant 2015; Kieffer et al. 1997).

7.5.5 Facilitating the uptake of healthy infant feeding behaviours in the Growing healthy program using the COM-B model

A new paradigm, the Behaviour Change Wheel (Michie, van Stralen & West 2011) was integrated in the Growing healthy program to enhance the uptake of healthy infant feeding behaviours. As indicated in Chapter Four, much of the literature has only described applying the BCW model to develop and implement behaviour change interventions (Alexander, Brijnath & Mazza 2014; Atkins & Michie 2015; Russell, Taki, Azadi, et al. 2016). There are no published studies identified by the candidate that

present the outcomes of interventions which applied this model. This limits the comparability of evidence on the application of this model.

Nonetheless, the findings of this study have identified that the some of the intervention functions and BCTs that have been selected to impact on the participants' behaviour with regards to delaying solid introduction were more effective than others. However, despite the knowledge (Capability) they had on the infant feeding recommendations, Social and Environmental Opportunity and Reflective Motivation were the main drivers that influenced the participants' decisions on the age at which they introduced solids.

The participants' lack of knowledge (Capability) about the recommendations, identified in Chapter Four, was addressed in the Growing healthy program through the intervention functions 'Education', 'Training' and 'Environmental Restructure'. In addition the BCTs 'Cognitive and Interpersonal Skills' and 'Knowledge' were also used. Even though ample information was provided about the recommendations and the importance of delaying solid introduction, it is inevitable that participants' receive information from other external sources (Social and Environmental Opportunity) that may potentially be inconsistent with the app (Arden 2010; Clayton et al. 2013). Similar to previous interventions, these sources include advice from health practitioners, online sources and social groups (Russell, Taki, Azadi, et al. 2016; Shieh, Broome & Stump 2010). Therefore, the participants' Reflective Motivation, specifically beliefs about the consequences of solid introduction remains the strongest driver influencing their decision. Participants who delayed solids were influenced by belief that their infant's digestive system was not yet developed, impact on infant's bowel movements and belief that the infant was receiving sufficient iron from milk feeding. Conversely, those who introduced solids earlier believed it would improve their infant's reflux, sleep patterns or nutritional intake.

This thesis hypothesised that increasing participants' engagement with the app would continuously expose them to information regarding delaying solid introduction and thus encourage the uptake of the target/desired behaviour. The utilisation of this method was derived from exploring other behaviour change mHealth interventions which effectively influenced the uptake of healthy behaviours (Davies et al. 2012; Webb et al. 2010). However, Chapter Six demonstrated that there was no significant relationship between participants' engagement with the program and the age at which they introduced solids.

This suggests that an mHealth program alone may not influence participants' infant feeding decisions. Rather there are other contributing factors. Further exploration of the study findings provides a clearer understanding of the analysis in Chapter Six. Participants who were exposed to advice from external sources that were consistent with that provided by the app were likely to delay solid introduction. There are two main barriers associated with the uptake of healthy behaviours in this intervention. One of the barriers is the assumption that all participants comprehend (Psychological-Capability) the advice and recommendations intended by the researchers. The second barrier includes the inconsistent advice provided by health practitioners (Environmental-Opportunity) and limited accordance with the recommendations, which is a consistent finding in other studies (Clayton et al. 2013; Hamilton et al. 2011).This is a particular concern as participants have demonstrated that they view health practitioners as a superior and plausible source (Shieh, Broome & Stump 2010).

It is important to restate that the aim of the intervention was to encourage participants to follow the government recommendations, which was to introduce solids at around six months but not before four months (National Health and Medical Research Council 2012). The findings support data reported in Chapter Six that the majority of participants adhered to the guidelines of introducing between four and six months, although most did so before six months. These findings are in line with the latest data on the average age of solid introduction in Australia which is at 4.7 months (Australian Institute of Health and Welfare 2010). Future recommendations should focus attention on addressing the reasons why participants introduced solids before six months of age. Clearly, infants should be introduced to solids when they are developmentally ready. The findings of this study showed that although participants had the necessary knowledge and were aware of the recommendations (Capability), their decisions appeared to be affected by their Reflective Motivation (e.g. beliefs about consequences of delaying solid introduction), which is a consistent finding with other studies (Moore, Milligan & Goff 2014; Russell, Taki, Azadi, et al. 2016). As motivation is often the barrier to the uptake of most health interventions, further research needs to be conducted to identify effective ways to influence motivation about infant feeding. As participant knowledge is not measured in this intervention, there is a possibility that participants' interpretation of the advice provided led them to that behaviour. It would be beneficial to consider measuring this in future studies. A previous study

demonstrated ways of measuring participant knowledge in mHealth interventions through quizzes and activities built in the app (Baltierra et al. 2016).

The misinterpretation of the infant feeding recommendations is not limited to parents, but also health practitioners (Moore, Milligan & Goff 2014). This finding was evident in this qualitative study and the qualitative interviews described in Chapter Four (Russell, Taki, Azadi, et al. 2016) which identified that some parents were encouraged by health practitioners to introduce solids early. Health practitioners suggested introducing solids to resolve reflux, insufficient milk feeding or poor sleep patterns, none of which fit with concepts of readiness (Clayton et al. 2013; Tarrant et al. 2010). As practitioners are an influential source of information, engaging them in interventions targeted at the prevention of childhood obesity has been effective in previous interventions (Cameron, Spence, et al. 2015; Wen et al. 2011). Coupled with the findings from these programs, this study emphasises the necessity of educating health practitioners involved in antenatal and postnatal care about healthy infant feeding behaviours, including the concept of readiness for solid introduction.

7.5.6 Strengths and limitations

The strengths of this mixed methods study included qualitatively exploring participants' experience with an mHealth program based on their engagement, which very few studies have done (Dennison et al. 2013). Further, to the candidate's knowledge this is the first study to explore participants' experience with an mHealth program based on their Engagement Index score. Utilising the Engagement Index to measure how participants used the program provided the opportunity to identify variations in participant behaviour based on their socio-demographic characteristics. Further, exploring these variations qualitatively provided a greater understanding on the factors that influenced engagement. While this study aimed to interview participants of various engagement levels, as the completion of the nine month survey was an inclusion criteria for this study, more highly engaged participants were more likely to be retained and participate in the survey.

Another strength of this study was the use of telephone interviews to gather in-depth information about the participants' experiences with the program. This made participation more convenient for this demographic. However, a limitation included the

timeframe at which the interviews were conducted (≥9 months of the infants age) as several participants struggled to recall their experiences with using the app. To overcome this barrier various strategies were put into place: emailing the participants (when sending the consent and study information forms) two broad questions that encouraged them to reflect on their usage of the app throughout the program; asking participants to open the app or the website; guiding the participants to each app element as discussed during the interview.

This study used the Behaviour Change Wheel, specifically the COM-B model, to explore the impact that the Growing healthy program had on the participants' behaviour with solid introduction. Using this model has helped identify the barriers faced by participants who achieved low engagement scores. This qualitative information will be useful to consider in the enhancement of the next version of Growing healthy, but also for future interventions developing an mHealth program.

A limitation emerged in this analysis: the discrepancy between participants' reported age of solids introduction in the qualitative study (Section 7.4.5.) and that reported in the survey (Chapter Six). This was partly related to the inaccurate conversion of months into weeks, identified in previous interventions that discussed outcomes of infant feeding practices (Wardle, De Domenico & Wen 2014). To reduce this limitation in future interventions, developers could include an age conversion calculator on the app similar to that available on Google (Google 2016a) or provide a description of accurate conversion within the program.

7.6 Conclusion

This study found that a number of factors influenced the participants' behaviour and engagement with the Growing healthy app. The participants' engagement with the app was determined by their confidence about their knowledge on infant feeding practices. The participants who utilised the push notifications accessed the app more frequently, while technological issues was the main barrier preventing participants from accessing it resulting in disengagement for some participants. There was evidence that the Growing healthy program influenced the participants' decision on solid introduction as they mainly used the app to acquire their knowledge. However, the consistency of the

advice they were exposed to, particularly if it was from their health practitioners, most influenced their decision.

These findings imply that mHealth interventions are not only a convenient source of information for participants, but they may also have potential to influence healthy infant feeding behaviours if consistent messages are provided. This study therefore emphasises two key messages: it is important to address modifiable barriers such as technological barriers; and it is important to utilise health practitioners as the referral pathway to apps in this domain.

Chapter 8: Conclusions

This chapter summarises the thesis findings (Section 8.1). Strengths and limitations of the current research are discussed as well as future research implications and intervention development (Section 8.2).

8.1 Overview of findings

The components of this thesis are detailed below. In overview, this thesis has presented a group of studies conducted to inform and evaluate aspects of a novel mHealth program that aimed to support a range of healthy infant feeding behaviours. The primary outcome focus for this thesis was the age of solid introduction. The sample involved in the program, and the assessment of participant engagement with the program was described utilising a purpose-designed tool. This Engagement Index was utilised to understand how participants interacted with the Growing healthy app program and to describe intervention impact on the uptake of healthy infant feeding behaviours. Finally, the thesis described a qualitative study detailing the variety of influences on participants' behaviour using the app and influences on their decision about the age they introduced solids to their infants. The findings presented in this thesis are relevant in a global setting as they demonstrate a potential strategy to target the high prevalence of child overweight and obesity through encouraging the uptake of healthy infant feeding behaviours.

This thesis began with the description of a literature review on mHealth interventions targeting childhood obesity prevention through encouraging healthy infant feeding behaviours (Chapter Two). At the time, that review identified only one intervention using text messages which aimed to encourage mothers to prolong exclusive breastfeeding and delay the age of solid introduction (Jiang et al. 2014). The outcomes of that study supported the proposition that mHealth interventions targeting mothers have the potential to influence the uptake of healthy infant feeding behaviours. However, the evidence base was scant, indicating a deficiency in the literature on interventions using digital technologies to support the development of a mobile app program. This program was tested with mothers of infants three months or younger to

support them with infant feeding. The process involved in developing the program is described in Chapter Five.

This thesis hypothesised that enhancing participant engagement with the mHealth program would increase intervention exposure and thus influence the uptake of healthy behaviours promoted in the program. Support for this premise was explored in the literature, including factors that influence participant engagement in mHealth interventions and methods used to measure participant engagement (Chapter Two). The literature identified three factors important in enhancing participant engagement: the quality of the mHealth program; the mode of delivery used; and the integration of a theoretical model to influence the uptake of behaviour. These elements were considered in the conceptual framework (Section 2.7) developed for this thesis.

Despite the scarcity of interventions found using an mHealth approach, the internet has increasingly been used as a source for seeking health-related information (Eysenbach et al. 2002). Parents, in particular, have been turning to the internet to seek information that supports them with feeding across the child's life stages (Bernhardt & Felter 2004; Buultjens, Robinson & Milgrom 2012). It was therefore necessary to explore the quality of the existing apps and websites to identify whether an online resource was necessary (published manuscript presented in Chapter Three). Despite the proliferation of online infant feeding sources, the study found very few good quality websites and no apps that comprehensively addressed healthy infant feeding practices following the national guidelines (National Health and Medical Research Council 2012). Chapter Three identified factors that contributed to a good quality app such as providing information about the developer, design and layout, navigation, interactivity, content and accessibility, security and connectivity. These were considered during the development of the Growing healthy app program.

Further a qualitative study was conducted (presented in Chapter 4) to determine whether mothers from a relatively disadvantaged background (as indicated by low educational attainment) were interested in an mHealth program and to explore the modes of delivery that would engage them to use an mHealth program focussed on infant feeding. The mothers were interested in a number of features including receiving personalised and tailored messages, information on infant age and stage of feeding, videos, social

networking groups and recipes. These features were incorporated into the subsequent design of the Growing healthy program.

Participant engagement with this program was then analysed using an Engagement Index that was purpose designed for the Growing healthy program (Chapter Six). This index used app data and the results of the satisfaction survey included in the nine-month survey (Appendix 5F, Question D1). The participants of this study were categorised as either poorly, moderately or highly engaged. Participants were likely to attain a higher Engagement Index score if they were first-time parents, recruited through a health practitioner, used both the app and emails and joined the program when their infant was younger than three months of age. These findings were further explored in a qualitative study presented in Chapter Seven. Based on the findings of Chapter Seven, participants' characteristics, the modes used to deliver the program and the quality of the app influenced the participants' engagement with the program. Of the various features that were included in the program, the push notifications were the main feature that triggered participants to use the app. Conversely, the quality of the app, specifically the technological issues, led participants to disengage. Ultimately, participant engagement related to parents' confidence in their knowledge and skills with infant feeding practices. Chapter Six indicated that a majority of the primiparous participants attained higher scores, and constantly referred to the app throughout the stages of feeding their infant. The majority of the multiparous participants interviewed reported feeling confident with infant feeding from their previous experience and used the app less frequently.

This thesis focused on the age of solid introduction as the selected behaviour to test the hypothesis that participant engagement with the program was associated with the uptake of healthy behaviours. The current national guidelines recommend that solids should be introduced 'at around six months but not before four months of age' (National Health and Medical Research Council 2012). The research described in the literature review identifies that early solid introduction has been associated with increased risk of childhood overweight and obesity. Early solid introduction is particularly prevalent among disadvantaged populations including mothers with a lower educational attainment. To understand the barriers to uptake of the recommendations among these parents, the qualitative study described in Chapter Four also explored their behaviour

using the Behaviour Change Wheel, COM-B system (Capability, Opportunity, Motivation –Behaviour) (Michie, van Stralen & West 2011). A number of mothers reported receiving inconsistent advice (Opportunity) on the recommendations for solid introduction, causing confusion. However, the main driver of their decision was the mothers' Motivation associated with their beliefs about the consequences of early solid introduction. To address these barriers, the Growing healthy app program implemented Behaviour Change Techniques (BCT) (Chapter Five).

Findings of this thesis indicated that the intervention (Growing healthy) was successful in engaging participants to use it resourcefully. However, no significant relationship was identified between participants' Engagement Index level and the age that they introduced solids. Regardless, the majority of participants introduced solids following the national guidelines (between 17 and 26 weeks) (Chapter Six). The participants' decisions about the age of solid introduction were explored in the qualitative study described in Chapter Seven. The COM-B elements of Environmental Opportunity and Reflective Motivation influenced participants' decisions. Specifically, the consistency in the advice participants were exposed to (Opportunity) was the main driver (Motivation) to their decision. This was a common finding across the interviewed participants regardless of their engagement level with the app.

8.2 Strengths and limitations of this thesis, and implications for future research and practice

The findings from this thesis have provided important information for future research and practice, specifically within the fields of childhood obesity prevention and mHealth interventions. Firstly, the Growing healthy program delivered via an mHealth app provides an example of a low participant burden health behaviour intervention. This is an important consideration for interventions that target parents with young infants who need to attend to their ongoing parental duties (Shieh, Broome & Stump 2010). Further, this intervention was low cost and has the potential for very broad reach. As such, this intervention is likely to be scalable, having the potential to be implemented in real-world settings.

Prior to dissemination, however, further translational research is required in order to provide evidence to policy-makers on the efficacy of implementing a program like Growing healthy. A recently published study, which explored factors that influence translation of childhood obesity interventions into routine practice, emphasised the importance of collaboration between policy-makers, researchers and practitioners (Laws, Hesketh, et al. 2016). Although translation was not a focal point of this thesis, the findings illustrated that health practitioners play a key role not only with parents' decision on infant feeding practices but also their engagement with the intervention. This conclusion is supported as participants recruited through practitioners attained higher Engagement Index scores. This finding was further explored and in qualitative interviews found that advice from health practitioners had a strong influence on participants' decisions. Participants' uptake of the recommendations in the app was more likely if they received consistent advice. These results have important implications for the potential translation of this app, highlighting the fundamental importance of health practitioners in influencing the uptake of healthy infant feeding behaviours.

One strength of this study was the engagement of participants with a range of education exposures, suggesting recruitment across a wide range of socio-economic backgrounds. There were no statistically significant differences in participants' engagement between those from different education background, illustrating that the program was effective in engaging disadvantaged population. The findings of this study therefore support the evidence which suggests that mobile phones have the potential not only to bridge gaps in health disparities but also to engage hard-to-reach demographics (Fjeldsoe, Marshall & Miller 2009). Among the disadvantaged participants in the Growing healthy program, the majority were recruited by health practitioners working in low SES locations (Laws, Litterbach, et al. 2016).

An important strength of this thesis is the utilisation of both quantitative and qualitative methods to explore and understand how participants engaged and interacted with the Growing healthy app program. The quantitative data collected for this thesis included the app data measuring participants' behaviour using the app and three quantitative surveys conducted throughout the nine month program. These surveys collected demographic information and infant feeding covariates as well as a satisfaction survey to measure participants' experience with the program. These data were then utilised to

develop an Engagement Index, an additional methodological strength of this thesis. This was a novel approach to assessing engagement in an mHealth intervention, as very few researchers have comprehensively analysed participant engagement (Baltierra et al. 2016; Guertler et al. 2015). Particularly with the growth in information technology and the opportunity to apply several engagement techniques in an mHealth program, engagement has become a multidimensional construct (Curtis, Lahiri & Brown 2015; O'Brien & Toms 2010). It was therefore necessary to develop an index that measured user engagement to provide insight into which aspects are important for capturing participants' attention and encouraging sustained use of the app. Another benefit of this index was to explore the variation in participant engagement level based on their characteristics. Lastly and most importantly, the ultimate aim of any mHealth intervention is to enhance the uptake of healthy behaviours; thus the index helped to explore the association between participants' engagement and their behaviour about introducing solids.

However, it is important to acknowledge that the index measuring participant engagement was not specifically validated. Future research should focus on refining this index so that it can be used consistently to promote comparability, particularly for assessment on engagement in infant feeding interventions. As outlined in section 8.1, there is a growth of mHealth interventions targeting infant feeding behaviours for the prevention of childhood obesity, and it is expected that the research in this field will continue to grow. It is therefore recommended that researchers plan to assess engagement thoroughly, potentially via the use of an index such as this. These findings can contribute to the development of more effective interventions with the aim of translating them to implement in a real-world setting.

A further strength of this thesis was the qualitative study described in Chapter Seven, which enabled the candidate to gain a deeper understanding on participants' engagement scores and their experience with the Growing healthy program. It strengthened understanding of factors that impacted on participant engagement and of features that were likely to enhance interaction with the Growing healthy program. Qualitative data also allowed exploration of the impact the program had on participants' decisions about infant feeding, specifically the timing of solid introduction. The information collected regarding influences on participant engagement should be

considered and incorporated in the design and delivery of future mHealth programs targeting infant feeding behaviours.

An additional benefit of mHealth interventions is the ability to personalise and tailor them to suit the individual's needs, which is a limiting factor in group-based interventions. Previous literature has emphasised the importance of tailoring programs to increase participant engagement by involving the end-user during the development of the program (Curtis, Lahiri & Brown 2015; Klasnja & Pratt 2014; Riley et al. 2011). One of the strengths of the Growing healthy app program is the inclusion of qualitative studies with parents in the target demographic to explore their thoughts on features that would enhance their engagement with the mHealth program. The qualitative studies described in Chapter Four and the focus groups described in Chapter Five, Section 5.4.2, emphasised on the importance of tailoring messages according to participants' infant feeding behaviour. The findings presented in Chapter Seven highlighted that the tailored push notifications appealed to participants' interests as they provided relevant information based on their infants' age and stage of feeding.

One limitation of the Growing healthy program was limited tailoring of the program to engage multiparous participants and carers who were invited to access the app. As a result both groups showed less engagement compared with primiparous participants. Other studies have suggested that health practitioners consider adjusting advice on infant feeding behaviours according to parity (Bai, Fong & Tarrant 2015; Kieffer et al. 1997), as first-time mothers have different knowledge, attitudes and experience related to infant feeding and care from those who already have children. A majority of the interventions developed to support infant feeding behaviours for prevention of childhood obesity have specifically targeted first time mothers (Campbell et al. 2008; Daniels et al. 2009; Taylor et al. 2011; Wen et al. 2007). There is a need to consider the development of specific interventions tailored to support multiparous mothers with infant feeding.

Similarly, different strategies are required to engage fathers in an mHealth program to support mothers with infant feeding behaviours. Unlike the limited research with multiparous mothers, there is a growth in the literature on programs that have been

developed focusing on supporting fathers of infants (Fletcher et al. 2016; Maycock et al. 2015; Roberts 2016; White et al. 2016).

Another limitation is the self-report of anthropometric measures in the self-administered questionnaire. This has potential to limit the accuracy and reliability of the results associated with infants' weight or age of solid introduction, despite being commonly used in large observational studies. These self-reported measures were presented as continuous variables rather than categorical variables, which further increased the risk of incorrect imputation of data. For example, a few participants reported extreme values for the age they introduced solids, the weight of the baby or the infant's date of birth.

Overall the results from the Growing healthy app program are not comparable with the outcomes of previous childhood obesity prevention interventions (Campbell et al. 2016; Daniels, Mallan, Nicholson, et al. 2015; Wen et al. 2015). However, this thesis provides complementary evidence on the importance of providing ongoing support. For example, participant engagement with the Growing healthy app program decreased over the course of the nine-month program. The qualitative study described in Chapter Seven identified that one reason for participant disengagement was a sense of confidence with infant feeding. Many participants expressed an interest in receiving ongoing support with feeding throughout the child's development stages. Additional future research is therefore necessary to complement the findings of these studies. This includes exploring to what extent these interventions are capable of fostering skills in mothers to help them practise healthy behaviours with their children or whether they merely increase participants' reliance on external forms of support.

Ultimately, the Growing healthy program, aimed to provide evidence to enable policy makers and health care professionals to identify ways of promoting healthy behaviours from early life to overcome the current obesity epidemic. The evidence goes beyond the uptake of the healthy behaviours and the impact on BMI; it also includes sustainability of desired outcomes, and the design, cost effectiveness and scalability of future interventions (Campbell et al. 2016). This thesis demonstrates that the Growing healthy program has the potential to be implemented into healthcare practice, although it would be beneficial to conduct this study longitudinally and on a larger scale.

It is evident that research into childhood obesity prevention will continue to grow. Accordingly, it is expected that mHealth interventions will also grow. Researchers currently involved in existing interventions are identifying strategies to maximise the effectiveness of their program. In particular, there is a mutual aim across these interventions to enhance the evidence base regarding cost effective, scalable interventions that promote healthy infant feeding behaviours to improve child weight and health.

8.3 Conclusion

This thesis has highlighted the importance of considering the quality, mode of delivery and integration of a theoretical model to enhance participant engagement in an mHealth intervention. Specifically, it emphasised the importance of involving the target demographic as well as health care practitioners in the development of programs to ensure that the intervention is tailored to their needs. This thesis has shown that an intervention, such as the Growing healthy app program, is a practical approach to delivering information to support parents' infant feeding behaviours. The findings highlighted that families most at risk can be reached using an mHealth approach which has implications for informing policy-makers, health practitioners and researchers in public health.

This thesis also provides important information for researchers within the prevention of childhood obesity and mHealth fields. It provides a basis for future interventions to build upon, highlighting factors that should be considered when developing an mHealth program, specifically targeting participant engagement with the uptake of healthy infant feeding behaviours. In addition, this thesis provides a novel contribution to the evidence base regarding a comprehensive approach to analysing participant engagement in mHealth programs. It highlights the benefits and considerations for future mHealth programs to measure the association between participant engagement and targeted behaviour outcomes. Although no association was identified in the findings of this thesis between participant engagement and the age of solid introduction, it is important that researchers do not draw conclusions of the intervention effect based on this outcome. Rather, it is recommended that researchers refer to the analysis of the larger research program in which this thesis was embedded to compare infant feeding

outcomes between the Growing healthy program participants and the control group, which was not focused on in this thesis.

The findings of this thesis also have important broader implications for future research. The issues highlighted include the need to validate the Engagement Index and for concurrent programs focused on infant feeding to utilise this index for a consistent measure of user experiences and the correlates of infant feeding practices. Other issues include the need to consider technological advances to improve the functionality of the program, to tailor interventions to suit multiparous participants and fathers, to enhance engagement in health practitioners to influence participant uptake of healthy behaviours, and to conduct longitudinal studies.

Research regarding mHealth interventions targeting the uptake of infant feeding behaviours is in its infancy. This thesis provides a catalyst by providing insights to the factors that influence app engagement within the field of early childhood feeding and the prevention of childhood obesity.

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