



HabEat

Determining factors and critical periods in food habit formation and breaking
in early childhood: a multidisciplinary approach

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1. Summary of findings and recommendations

This document presents the findings and evidence-based recommendations from HabEat, based on the analysis of data from birth cohort studies and experimental work among infants, toddlers and children up to 6 years of age. HabEat aimed to develop strategies to promote healthy food habits in infants and young children. These include interventions to facilitate habit breaking while taking into account individual differences in child eating behaviour and parental feeding strategies. These recommendations can be used to guide parents towards the promotion of healthy eating habits in their children, particularly focusing on vegetable and fruit consumption. A booklet aimed at informing parents has been prepared based on this work and evidence from previous literature. HabEat has developed recommendation for both policy makers and stakeholders, which promote the formation of healthy eating habits. The summary of such recommendations is presented below in three sections: i) breastfeeding and complementary feeding; ii) feeding young children; iii) food intake regulation and parental feeding practices.

Breastfeeding and complementary feeding

Breast milk is the best food for infants. Among its many advantages, HabEat found evidence that it may facilitate the consumption of vegetables and fruit and a greater variety of healthy foods in later childhood. This may be the result of exposure to flavours from the mother's diet changing the taste of the breast milk.

Recommendation: Continued efforts should be made to encourage breastfeeding.

The complementary feeding period is a 'window of opportunity' when an infant is particularly receptive to a variety of foods with different flavours and textures. It is important that infants are introduced to a variety of different vegetables in the complementary feeding period as HabEat found some evidence that this increases later acceptance of novel foods. Familiarity with many different vegetables is likely to lead to the consumption of a greater variety of vegetables and fruit, as the child grows.

HabEat has shown that introducing a variety of plain vegetables to infants can increase acceptance of a novel vegetable. HabEat has also shown that repeating the exposure to the same vegetable can increase acceptance of that vegetable. If it is refused at first it should be offered again after a few days. The number of tastings needed will depend on the age and eating temperament of the individual child and on the particular vegetable. As many as 8 exposures may be necessary and can be carried out in both home and childcare settings.

HabEat found that infants and younger children accept novel vegetables more readily than older children (2-6 years).

HabEat has shown that children (aged 4 to 36 months) who are less enthusiastic eaters needed more exposures to accept a novel vegetable. These children consumed less of the vegetable at the beginning but their intake increased with exposure.

Recommendation: Introduce plain vegetables as first foods in the complementary feeding period and use repeated exposure to a variety of vegetables to increase acceptance of vegetables.

Feeding young children (2-6 years of age)

Children are more likely to become neophobic and picky (refuse novel but also familiar foods) between the ages of 2 and 6 years and at this stage it is more difficult to achieve acceptance of a novel vegetable. HabEat has shown that repeated exposure to a plain novel vegetable increases intake in children of this age.

Offering several different serving styles (sticks, grated, squares etc.) of vegetables may be effective in increasing intake, as this influenced liking and intake among young children in HabEat.

HabEat found that offering children more than one vegetable to choose may increase their intake of vegetables. Other HabEat studies have shown that offering the same (relatively familiar) vegetable twice per week may lead to boredom and diminish intake of that vegetable.

HabEat did not find evidence that, for children aged 4 to 6 years, helping to prepare vegetables on one occasion in a restaurant setting was effective in increasing their intake of a relatively familiar vegetable. Neither the child's teacher nor a cartoon character acting as a role model was effective in increasing intake of a relatively familiar vegetable in a classroom setting.

Recommendation: Use repeated exposure to a novel vegetable to help a child learn to enjoy the taste of that vegetable. When possible offer children a choice of two or more vegetables.

Children described by their parents as 'difficult eaters' were found by HabEat to eat less vegetables and fruit and a less varied diet at 4-5 years of age than children who were not described as difficult.

Recommendation: Parents should persist in offering children who are 'difficult eaters' a variety of tastes and textures to help them learn to like a range of foods.

Food intake regulation and parental feeding practices

HabEat found that parents who used 'Food as a reward' were more likely to have children (aged 3-6 years) who ate in the absence of hunger than parents who did not use this feeding strategy.

Recommendation: Foods should be offered to a child in response to their feelings of hunger, and not used as reward for a good behaviour or for any other reason

HabEat found that when children (aged 3 to 6 years) ate a preload of energy-dense food less than one hour before a meal, they ate less during the meal. However, at the meal, children

adjusted their food intake only partially for the energy ingested from the preload. Therefore their overall average energy intake was higher with the preload than when only the meal was eaten.

HabEat found that when energy-dense foods were available freely after a meal, most children (aged 3 to 6 years) ate in the absence of hunger and consumed extra energy.

Recommendation: Avoid offering energy-dense snacks before or after meals. If children are hungry before a meal, vegetables could be offered as a snack/appetizer.

2. HabEat background

HabEat has brought together researchers from 11 groups¹ from 6 European countries and has applied a multidisciplinary approach (psychology, epidemiology, behavioural science, nutrition, sensory science) to investigate how key food habits are formed in infants and young children. Further work has investigated different strategies which may be useful in changing bad food habits that are already present. A combination of epidemiological studies, based on existing birth cohorts from 4 countries, and experimental work in 6 countries has been carried out with the aim of identifying:

- The critical periods in the formation/breaking of food habits;
- The key learning mechanisms, their relative impact in the short, mid and long term and their importance according to the different critical periods;
- The most effective strategies for breaking habits, i.e. for changing from poor to healthy habits;
- Individual reactions to the learning mechanisms and individual susceptibility to changes.

The project has worked hand-in-hand with stakeholder advisors (including industry and health professionals) to produce recommendations that childcare professionals, policy makers and parents from different target groups (especially those most at risk) in different EU regions will find helpful. Feed-back from stakeholders has been obtained via presentations and discussion groups held in the UK, Portugal, Poland, and in France during the final symposium.

¹ INRA: Institut National de la Recherche Agronomique
FBR-DLO: Food & Biobased Research (WUR) - Stichting DLO, the Netherlands
Inserm: Institut National de la Santé et de la Recherche Médicale, France
ULeeds: University of Leeds, UK
WUR: Wageningen University, the Netherlands
UCPH: Københavns Universitet, Denmark
UCL: University College London, UK
U.Porto: University of Porto, Portugal
HUA: Harokopio University, Greece
UNIBRIS: University of Bristol, UK
IT: INRA Transfert SA

3. Study descriptions and findings from HabEat

3.1. Development of assessment tools

Many tools had been already developed and validated to assess parental feeding practices and eating behaviours from birth to 5 years of age. However, there was a need to systematically identify gaps in the measurement of these and other related sub-dimensions, and to further develop new tools.

3.1.1 Review of methods to assess parental feeding practices and preschool children's eating behaviour

We conducted a systematic review aimed to identify gaps in tools used in the literature to measure parental feeding practices and eating behaviour, food intake and food preferences in children aged 0 to 5 years (de Lauzon-Guillain et al., 2012). Two electronic literature databases (Medline and Psycinfo) were used to search for both observational and experimental human studies. The articles selected for review were those presenting tools with data on internal consistency and/or test–retest reliability and/or construct validity. A total of 3,445 articles were retrieved, and further searching of reference lists and contact with experts produced an additional 18 articles.

Most of the tools on parental feeding practices assessed authoritarian practices, such as pressure to eat or restriction of eating, known to be related to the likelihood of a child eating in the absence of hunger. However, few of the tools focused specifically on parental attention to a child's hunger and satiety cues throughout infancy and early childhood. Moreover, the degree of control given to children in feeding events was not assessed among children younger than 2 years. Food preference tests based on sensory aspects rather than nutritional quality may be worth investigating. We identified a need for further evaluation of quality, especially test–retest reliability and construct validity, for most tools developed for use in children aged 0 to 5 years.

3.1.2 Design and validation of new tools to measure parental feeding practices and child's self-regulation

For obesity prevention, the ability to respect physiological cues (hunger and satiation) during feeding events must be considered. Most infants and young children are able to regulate food intake by these internal cues, but this ability decreases with age. Based on the identified gaps from the systematic review, we developed a new tool to measure parental feeding practices and a child's self-regulation of food intake in children from 1 to 5 years. This was developed in order to establish potential relationships between these dimensions. We then validated the tool in three different country settings (France, Portugal and Greece).

The first version of the questionnaire included 62 items, and was piloted in France among 793 participants. Analysis of the data allowed us to identify irrelevant items which were then withdrawn and to validate the internal consistency of each dimension. A shorter version of the questionnaire (48 items) was then translated into English with a back-translation method to verify the translation. It was then translated and adapted into Greek and Portuguese. Other dimensions concerning parental feeding practices (Overt Control, Covert Control dimensions from Ogden et al, and Restriction and Pressure-to-eat dimensions from Birch et al) were added. The final version included 9 dimensions assessing parental feeding practices, and 4 dimensions concerning child's self-regulation. Parents of 1 to 5-year-old children were recruited in schools and nurseries in the three countries to complete a questionnaire about their feeding practices, the child's capacity to regulate his/her food consumption, and the child's height and weight. A subsample of parents was asked to complete the questionnaire twice with a 3-week delay to assess test-retest repeatability.

Using Structural Equation Modelling, we were able to validate the consistency of most of the dimensions of the questionnaire. The test-retest analysis confirmed the repeatability of the questionnaire. Therefore, we have developed a questionnaire which could be used in studies aiming to examine the links between parental feeding practices and child's regulation of food intake and how this relates to weight status. This questionnaire could be part of epidemiological cohorts and/or longitudinal studies in the three European countries in which it was tested (Monnery-Patris et al, paper under preparation).

3.1.3 Development of a tool to measure child's food preferences

A tool to facilitate direct interviews with children about their food preferences was developed, using foods with different sensory properties. First a list of familiar foods was established for each of the countries: France, Greece and Portugal. This food list covered a large range of foods: fruits, vegetables, meats, fish, eggs, cheese, sweets, salted foods and drinks. Although the list was not exactly the same across countries (due to cultural differences), the different categories were, as much as possible, equally balanced and diversified. The foods were represented with pictures with a presentation likely to be familiar to a child. The test of the tool was performed via kindergartens in each country, where 5-year-old children were interviewed individually. They were asked to rate how much they liked a large range of foods presented in picture form. In France and Greece a subsample of children performed the test twice with a 3 week delay in order to assess test-retest repeatability of the results. A subsample of parents was asked to answer a questionnaire, indicating how much they thought their child liked each food presented during the test to assess the convergence between the child's answers and the parents' answers.

Using Structural Equation Modelling and test-retest analysis we confirmed the content validity of some food dimensions of the tool for liking of foods and its repeatability. The food liking tool could be used to establish food profiles in young children, and then to relate these specific profiles (e.g., picky eaters, those who dislike cheese) to a child's intake of different foods and to a child's weight status.

This tool highlights the importance of interviewing a child directly, since the results suggest that parental responses do not systematically predict their child's preferences.

3.2. Cohort studies - Identification of critical periods and factors in the formation of food habits from birth to 5 years-old

3.2.1 The cohorts

Cohort studies are ideal settings for assessing the effect of exposures across the life span. By using data from four European birth cohorts, we provide cross-cultural evidence on how perinatal and postnatal exposures, such as early parental feeding practices, influence fruit and vegetables intake, food variety and eating behaviours of infants and pre-school children, and how they could impact a child's growth and adiposity. Data were available from child cohorts followed from birth or before birth in four European countries. Analyses were always performed in parallel with the same statistical methods using similar data collected in the separate cohorts.

- From the UK: The Avon Longitudinal Study of Parents and Children (ALSPAC) is a longitudinal birth cohort study, which recruited 14,541 pregnant women resident in a geographically defined area in the South West of England with an expected delivery date between April 1991 and December 1992. Questionnaires completed during pregnancy provided data on socio-demographic factors, maternal diet (evaluated by a food frequency questionnaire) and tobacco use. Birth data were collected from medical records. Growth (weight and length) during infancy was available from routinely collected measurements performed by health professionals as part of the UK infant health surveillance programme and data were extracted from the local child health database. Breastfeeding duration and age at introduction to various foods was obtained from questionnaires completed by parents when the child was 6 and 15 months of age. Parent-completed FFQ about the child's diet and eating behaviours were collected at 2, 3, 4, 7, 9 and 13 years of age. Website - <http://www.bristol.ac.uk/alspac/>.

- From France: the EDEN mother-child cohort is a longitudinal study, which recruited 2,002 pregnant women between February 2003 and January 2006 in two French university

hospitals, in Nancy and Poitiers, before 24 weeks of amenorrhea (on average at 15 weeks). A questionnaire completed during pregnancy provided data on socio demographic factors, maternal diet (food frequency questionnaire) and tobacco use. Birth data were collected from medical records. Individual equations were used to calculate each child's weight and length from data measured routinely by health-care providers and weight and length measured during clinical examinations at 1, 3 and 5 years. When the child was 4, 8 and 12 months, mothers completed mailed questionnaires with details of feeding methods and age of introduction to several food groups. Parent-completed FFQ about the child's diet at 2, 3 and 5 years of age was recorded. Website: <https://eden.vjf.inserm.fr/> and <http://birthcohorts.net/>

- From Portugal: Generation XXI is a prospective population-based birth cohort established in a defined geographic area in the north of Portugal (Porto) by recruiting women in all public maternity units from Porto between April 2005 and August 2006. A total of 8,647 children and 8,495 mothers were enrolled at baseline. Of the invited mothers, 91.6% agreed to participate in the interviews. Data on demographic and social conditions, lifestyles, medical history, and prenatal care were collected by trained interviewers during the first 24 to 72 hours after delivery. Weight and height measured during routine medical appointments were retrieved from the booklet of data which accompanies every child. At 6 and 15 months, intermediate follow ups were conducted in subsamples and information was collected on breastfeeding and complementary feeding (available for a sub-sample of 1,040). At 4 years, the entire cohort was re-evaluated (86% of participation) and each child's diet was recorded by interviewer-completed food frequency questionnaire covering the last 6 months. Website: <http://www.geracao21.com/> and <http://birthcohorts.net/>.

- From Greece: The Greek EuroPrevall cohort study is a longitudinal study which recruited 1084 new-born infants between October 2005 and October 2007 in two different clinics in Athens. Standardized questionnaires were used to collect baseline data from each mother regarding her pregnancy, the child's birth, child's dietary intake (focusing mainly on foods related to allergies) and quality of life. Socio-demographic data, such as parental education level, parental age, occupational status and family income were collected at birth. Follow ups, using similar questionnaires, were conducted when children were 1, 2 and 2½ years old by telephone and 4 months during face-to-face interviews. During these face to face interviews data on breastfeeding and complementary feeding practices were also collected. Data on each child's food intake was collected at 2 and 4 years using an 80-item FFQ covering the last 3 months. Furthermore, during the 4-year follow-up anthropometric (i.e. weight, height) and body composition (i.e. fat mass levels) assessment measurements were conducted using standard procedures and equipment.

3.2.2 Summary of findings

Our main objective was to examine whether early feeding practices, such as breastfeeding duration and timing of complementary feeding, influence later fruit and vegetables intake, and if they are related with dietary variety of preschool children. In many countries, fruit and vegetables intake and dietary variety in children remain below recommendations, and the long-term effects of early parental feeding practices are not clearly understood.

Fruit and vegetables intake in early childhood (assessed by food frequency questionnaires) varied across the 4 cohorts with an average intake of less than one vegetable per day in the EuroPrevall and more than three vegetables per day in the Generation XXI cohort. There were also differences in early feeding practices across the four cohorts. Longer breastfeeding duration (i.e. ≥ 6 months) was found in Generation XXI (more than 50%) compared to ALSPAC (around 35%), EDEN (25%) and EuroPrevall (30%). Timing of complementary feeding (foods other than milk) varied also across the cohorts: in ALSPAC, complementary foods were introduced mainly between 3 and 4 months of age, in Generation XXI at around 4 months, in EuroPrevall at around 5 months, and in EDEN there was no peak age for introduction to complementary foods. Although there were discrepancies on early feeding practices across the four European cohorts, longer breastfeeding duration was quite consistently related to higher fruit and vegetables intake (>1 serving/day for fruit and >1 serving/day for vegetables, except in Generation XXI in which due to a high vegetable intake we had to use >3 serving/day) in young children. The associations with age of introduction to fruit and vegetables were weaker and less consistent across the cohorts. Results were adjusted for infant's age and gender, and maternal age, education level, smoking during pregnancy and in Eden and ALSPAC for maternal own fruit and vegetables intake (de Lauzon-Guillain et al., 2013).

Additionally, we calculated the healthy plate variety score (HPVS) to assess variety of healthy foods within and across main food groups based on the number of servings recommended for each group in healthy eating guidelines (maximum score of 5). The mean scores for each of the cohorts ranged from 2.3 (in ALSPAC at 2 years) to 3.8 (in Generation XXI at 4 years), suggesting that preschool children are not consuming as wide a variety of healthy foods as is recommended and that variety increases with age. Our results suggest that never or short breastfeeding duration (equal or less than 3 months) is associated with lower variety of healthy foods in preschool children. The association with the age of introduction to fruit and vegetables was weaker and less consistent across the cohorts. However, in UK children (ALSPAC) later introduction to vegetables (6 months or more) was associated with a lower variety score at 2, 3 and 4 years compared to introduction to vegetables between 4 and 5 months (Jones L et al, submitted paper).

In a further study we aimed to investigate whether weight at birth, as a surrogate measure of the intrauterine environment, influenced the occurrence of problematic eating

behaviours in the child. These problematic eating behaviours, assessed based on caregiver's perception, could in turn be mediators to a worse health profile. From our data, parents of children born small for gestational age reported eating difficulties more often, including poor eating patterns (eating small quantities each meal or needing to be stimulated to eat) at early ages (4-6 months), but this effect was weakened at older ages (15, 24 and 48-60 months) (Oliveira A et al, submitted paper). In subsequent analyses, children with eating difficulties (poor eating, food refusal, unable to get into a routine) as described by parents were likely to have lower fruit and vegetables intake, as well as a lower variety score at 4-5 years of age than those with no difficulty in Generation XXI, ALSPAC and EDEN cohorts. This suggests that the presence of eating difficulties could be an early indicator of a worse dietary profile later in life (Oliveira A et al, paper under preparation).

We also aimed to evaluate the effect of early feeding practices on a child's growth and obesity development. No clear associations between breastfeeding and/or complementary feeding practices and childhood adiposity were found across the cohorts (Manios Y. et al, paper under preparation).

3.3. Experimental studies

Several experimental studies were conducted in HabEat aiming to explore two main objectives: (i) to compare different strategies based on learning by experience in children from the start of complementary feeding and up to 3 years; (ii) to study, beyond 3 years and up to 6 years, new strategies for breaking habits, i.e. for changing from poor to healthy eating habits. These experimental studies focused on vegetable intake. One study focused on the quantitative dimension of eating habits by studying food intake regulation in children beyond 3 years and up to 6 years.

3.3.1. Comparing different strategies based on learning by experience

Children quite often do not like to eat vegetables and this may be due to their taste, texture or appearance. Interestingly, most young infants are willing to taste and eat vegetables; however, this willingness decreases as the child ages. A randomized controlled trial named 'TASTE' specifically investigated vegetable intake in newly weaned infants to determine whether exposure to a wide variety of vegetables early in life would prevent the observed decline in liking and intake at a later age. The task has been completed by partners from the UK (UCL), Greece (HUA) and Portugal (U.Porto). In the UK (n=98), Greece (n=101) and Portugal (n=92) parents of 4-6 month old infants were recruited and randomized to receive either (i) guidance on introducing a variety of vegetables as first weaning foods or (ii) usual care. The intervention was delivered shortly before mothers planned to start

complementary feeding and the focus was on encouraging parents to offer a variety of vegetables that are culturally appropriate to the family and easily available in the area and country in which they live. Infants in the intervention groups showed increased consumption and liking of an unfamiliar vegetable in the short term, but only in countries where single vegetables are not already amongst the common first foods offered to infants (UK and Greece). Beneficial effects of the intervention were not maintained at the 6 or 9 months follow-up, although results from the Greek sample suggest that there may be a positive effect of the intervention on vegetable variety and general vegetable acceptance.

Learning to like vegetables can be achieved in a variety of ways in an experimental setting. The first way is via repeated exposure (RE) to an unmodified target vegetable, the second is via flavour-flavour learning (FFL) where the vegetable taste is paired with a previously liked taste such as sweet. The third is flavour-nutrient learning (FNL) where the target vegetable is paired with a flavourless energy-dense ingredient such as oil. In HabEat, we aimed to compare these learning strategies in a between-subjects design, with an age range from 4 to 36 months. The task has been completed by UCPH, Denmark, with children in the age range 12-36 months, by ULeeds, UK, with infants from 9 to 38 months and by the INRA, France, with infants at the beginning of the introduction of semi-solids foods. The same unfamiliar vegetable (artichoke) used across the three sites was chosen after a preliminary survey (Ahern et al., 2013). In another sub-task conducted by WUR, the Netherlands a cross-over design was conducted with two soups, one with high energy content, the other one with low energy content. Finally, we assessed the effect of sensory manipulation on learning to like the taste of vegetables. Results of all studies support the view that repeated exposure is the most effective technique for promoting the intake of a vegetable in pre-school children compared to FFL and FNL. This is important since RE does not require the addition of any other ingredients (such as sugar, salt, oil or maltodextrin), it requires only regular preparation techniques and is probably the method most easily endorsed within public health messages. Also, it appears that fewer than 10 exposures are effective for increasing intake. The results suggest that the weaning period and the following 12 months might be the optimal time for the introduction of a wide variety of vegetables into the habitual diet. The work showed that introducing novel foods such as vegetables is a more difficult task after the age of 2 years.

3.3.2. Exploring new strategies for breaking habits

By the age of 3 years, some 'poor' food habits have been established in some children. These 'poor' food habits may be manifest as eating beyond needs and/or a low variety of healthy food in the diet, especially low intakes of fruits and vegetables. In HabEat, we aimed to develop new strategies for relearning or breaking food habits and to determine their sustainability.

We aimed to explore child's food intake regulation and to measure two behaviours of overeating that have previously been shown to relate to childhood adiposity: (i) caloric compensation, evaluated by serving a preload before a meal and (ii) eating in the absence of hunger, measured by energy intake from foods served after a meal. Measurements were conducted in France at three time points: before an intervention programme (T0), just after the intervention programme (T1=T0+3 months) and one year after the intervention programme (T2=T1+ 1 year). Children were 3 to 6 years old.

The first behaviour measurement at T0 showed that, on average, preschool children compensated partially ($52\% \pm 4$) for energy consumed in a preload eaten 30 minutes before their lunch. The second behaviour measurement at T0 showed that, on average, preschool children ate 25% extra energy on top of the previous meal (in the absence of hunger). To explore if it is possible to decrease overconsumption in such situations an intervention programme, aimed at helping children to focus on their internal cues of hunger and fullness to better control their food intake was developed. The programme consisted of 8 education sessions just before and/or after the lunch time at school. This intervention was completed with children with problems in regulating their intake, i.e. with a low score of caloric compensation or/and high score of eating in the absence of hunger. The intervention programme did not improve the ability of children to compensate their energy intake during successive eating occasions and did not limit their eating in the absence of hunger. Furthermore, caloric compensation and eating in the absence of hunger were not correlated with each other, suggesting that they correspond to two different mechanisms.

In another experiment, we studied the effect of repeated exposure on the intake of originally neutrally liked foods, in a real life class room approach, in which all children received the same vegetables and their intake was measured. We also investigated the role of variations in serving style of the offered vegetables. In the Netherlands, 4 to 6 years old children were offered two shapes (slices and sticks) of raw carrots for 10 sessions. In Denmark, 3 to 5 years old children were offered a novel vegetable Chinese radish. Serving style was investigated by defining three experimental groups that received a different serving style of vegetable during the 7 exposure sessions: sticks, triangles and grated. The Danish children assessed Chinese radish as neutrally liked, whereas the Dutch parents reported that their child's liking for raw carrots was between neutral and moderately liked. The results obtained in the Netherlands showed that repeated exposure, as a way to increase familiar vegetable intake, was not successful in 4 to 6 years old children in a Dutch school situation. The Danish children in all three groups increased their intake after repeated exposure to Chinese radish. The difference in familiarity of the vegetable, the slight liking differences as well as cultural and situational differences may explain the different outcomes. Both studies indicated that serving style influenced liking and intake. Two non-exclusive hypotheses could be proposed: firstly it may be easier to modify behaviour in younger children and the Dutch children aged 4 to 6 years were too old to be

influenced in this way and secondly it may be easier to induce increased intake of a novel vegetable rather than of a relatively familiar one, as was used in the Dutch study.

Finally, we explored the effect of different social learning strategies: idol or teacher imitation (testing the strategies convivial eating and positive restriction), freedom of choice and participation in food preparation on the intake of vegetables in 2 to 6 years old children from Denmark, Greece and the Netherlands. Concerning the imitation studies conducted among 3 to 6 years old children, no increase in vegetable intake was found during the intervention period in both the two Greek studies (HUA) and the two Dutch studies (DLO-FBR). In the Greek idol imitation study, there was a difference in vegetable intake between the three conditions, right after the positive restriction period. Carrot intake was highest in the positive-restriction group and the lowest in the control group. This may indicate a positive role for positive restriction, but a difference in baseline consumption – which was not assessed - cannot be ruled out and the other three studies within this task did not find this result. Initially, the long-term effects were promising for the Dutch idol intervention: an increase in intake was seen in both intervention groups, whereas the control group did not show an increase in intake. However, when the results of all four studies were combined, it seemed more likely that the increase in intake over the long-term was due to an age effect. Cultural and situational differences may have had a major impact on these results.

Additionally, the effect of freedom of choice with regard to vegetables on vegetable intake was investigated in Denmark (UCPH), Greece (HUA) and the Netherlands (WUR). Taking the results together, the studies indicate that freedom of choice can contribute to a higher consumption of vegetables compared to no choice. The results suggest that some children may benefit more from choice being offered more than others since the Dutch study indicated that the age of the child and the child's level of vegetable liking may be moderators of the effect.

The effect of participating in vegetable preparation was studied in the Netherlands (DLO-FBR) at the 'Restaurant of the Future' among children aged 4 to 6 years. Results showed no increase in vegetable intake, due to participation, and measures at 1 and 3 months after the intervention also showed no long-term effect of the intervention. This might be due to the large within-subject variability that was observed, the age group that was studied, or the fact that parent-child conversations after the meal were partly controlled in the study. It is hypothesized that it may not be the participation in vegetable preparation itself that may affect intake but the positive comments and interaction with parents during vegetable preparation and this should be examined in future studies.

3.3.3. Impact of child and maternal characteristics and maternal practices

Short term learning studies conducted to promote the acceptance of new foods such as vegetables may be more or less successful. We aimed to understand how child characteristics and child experiences shaped by the family, including parenting decisions, may influence the initial acceptance of an unknown/unfamiliar vegetable and the evolution of intake of an unknown/unfamiliar vegetable after several exposures to this vegetable. Thus, we have assessed features of the child such as age, previous experience of feeding (breastfeeding, age of weaning), eating traits (e.g. satiety responsiveness, food fussiness), and maternal characteristics such as education and neophobia, and maternal diet such as how often fruits and vegetables are consumed at home. We have modelled various influences which might determine both how much of a new food is consumed and how successful learning is in response to different learning strategies among children aged 4 to 46 months. From these analyses, it was found that food avoidance - a construct integrating satiety responsiveness² and food fussiness³ - was higher for older children and was the best predictor of both initial intake and learning velocity. The effect was negative for the initial vegetable intake: the higher the avoidance, the lower the initial intake of a novel vegetable. On the contrary, the effect was positive on learning velocity: children who scored high in food avoidance showed bigger increase in intake during the intervention. Thus, children who are fussy eaters may demonstrate 'learning' since they gradually increase intake of vegetables with time, even though this remains lower than in other groups of children. Moreover, children resistant to learning were fussier and tended to be older than learners (Caton et al., 2014). Therefore, although age is a powerful predictor of intake, this is moderated by child eating traits such as food fussiness and satiety responsiveness.

Younger children were more likely to be plate-clearers than older children and children with higher food fussiness scores were more likely to be non-eaters. For children aged 2 to 6 years, food fussiness and neophobia were negatively correlated to the child's initial vegetable intake, whereas liking for the vegetable(s) used in the study or for raw or boiled vegetables in general was positively related to the child's initial vegetable intake.

In conclusion, the formation of eating habits can be shaped by feeding practices including repeated exposure, however, strategies to enhance vegetable liking and intake need to

² Satiety responsiveness corresponds to assessment of cues of fullness and was measured through five items of the Child Eating Behaviour Questionnaire (Wardle J et al. (2001). *J Child Psychol Psychiatry*, 42, 963-70), completed by parents. Four referring to the development of satiety over the course of the meal ('My child has a big appetite' (reversed), 'My child gets full up easily', 'My child gets full before his/her meal is finished', 'My child leaves food on his/her plate or jar at the end of a meal' and one referring to the fact that food intake is reduced to compensate for a prior snack.

³ The term 'food fussiness' covers two eating traits, the reluctance to eat or the avoidance of novel foods, defined as food neophobia, and a high selectivity about the range of foods that are accepted. It was measured through six items of the Child Eating Behaviour Questionnaire, three referring to neophobia ('My child decides that s/he doesn't like a food, even without tasting it', 'My child enjoys tasting new foods'(reversed), 'My child is interested in tasting food s/he hasn't tasted before (reversed)') and three related to the selectivity ('My child is difficult to please with meals', 'My child enjoys a wide variety of foods' (reversed), 'My child refuses to eat certain types of food (e.g. vegetables, meat)').

consider both the age of the child and their eating traits, in order to optimize effects on vegetable consumption.

4. Recommendations

4.1. Current national recommendations – finding the gaps

Current national guidelines for each of the 6 countries participating in the HabEat project were analysed and are summarized in Supplemental file 1.

Exclusive breastfeeding is recommended until 6 months of age and at least for 4 months in France, Greece, Portugal, Denmark and the Netherlands. In the UK the recommendation is specific for the first 6 months.

Portugal, Greece, France, Denmark and the Netherlands base their recommendation for the introduction of complementary foods on the commentary of European Society for Paediatric Gastroenterology, Hepatology, and Nutrition: preferably, it should start around the 6th month of age; not before 17 weeks, nor beyond 26 weeks¹. In the UK, the recommendation is to introduce complementary foods when the child is around 6 months of age. As the first foods, Portugal recommends a vegetable broth or soup, enriched with olive oil; the UK suggests simple and easily digested foods e.g. rice, fruit or vegetables, meat, yoghurt, cheese and custard simply pureed or mashed with no added salt or sugar. The UK provides a list of foods to avoid if parents have decided to start complementary feeding prior to 6 months. In the Netherlands, in general, there is no specific recommendation for first foods, unless complementary feeding starts before 6 months: in this case, soft fruit and vegetables with a sweet taste are recommended e.g. pear, banana, melon, peach, apple, courgette, carrots, cauliflower, French beans and broccoli. In Denmark cooked vegetables, soft fruits, spreads, soft bread and porridge from different types of flour are recommended. There are no specific recommendations of first foods in France and Greece.

In Greece, feeding a variety of first foods is recommended to ensure that nutrient needs are met. In Portugal, variety is only mentioned for vegetables, to improve acceptance. In Denmark a high variety is recommended: foods have been divided into four groups and parents are recommended to feed their children mostly with foods from groups containing, fruit, vegetables and various carbohydrates and giving less meat, milk, cheese, eggs and fish and only small amounts of fats.

A general recommendation to improve acceptance by repeated exposure is made in France and the UK. In Portugal there is a specific mention of 11 attempts of exposure and in the Netherlands to 10 attempts, and variety is mentioned in this context: “repeated exposure is not restricted to subsequent days, but can be varied, for example by alternating 5 different

tastes, each day one taste, and then for 50 days (10 times per taste)". Mere exposure is mentioned by Portugal (only for fruit), France and the Netherlands.

The age recommended to introduce lumpy foods is around 10 months of age in Portugal and in The Netherlands and 8 months in France, although there is no a specific national guideline for lumpy foods in this last country. There is no mention of repeated and mere exposure in Denmark's recommendations.

The two countries with specific recommendations for toddlers are France and the Netherlands. The UK gives specific recommendations for children over 12 months of age and discusses the age at which semi-skimmed milk can be introduced.

During the HabEat project we held a stakeholder's workshop in Warsaw, Poland. One of the participants in the meeting, Aleksandra Rekosz, translated the recently up-dated Polish feeding recommendations so that we could compare them with the consortium countries. The recommendations on breastfeeding and timing of complementary foods introduction are the same as the majority of consortium countries however, specific first foods are mentioned: purred fruits or baby fruit juice (up to 150 g) and pureed vegetables, baby cereal; choose fruit over juice. There is no mention of variety or repeat exposure. It is indicated that new foods should be introduced in small amounts one at a time and given for several days. Lumps should be introduced between 7 and 8 months and be of a texture that encourages chewing. The Polish recommendations for toddlers are much more detailed than most of the other countries with information about the numbers of meals and snacks, the amount of protein and energy to be included, the number of portions from each food group and an explanation of what a portion of food might consist of. There are specific instructions to parents on how, when and where to feed their toddlers with variety and repetition (up to 20 times) mentioned. These are quite detailed and useful recommendations which conform partly to HabEat findings. There is a need to improve guidelines for these age groups in many European countries. Increasing the level of knowledge about current practices of complementary feeding and toddler's food habits would be beneficial. Integrated recommendations across Europe, which take into account country-specific culture, are needed.

4.2. Recommendations for paediatricians, nutritionists, day care professionals, policy makers and the baby food industry based on HabEat findings

Recommendation 1: Continued efforts should be made to encourage breastfeeding.

Recommendation 2: Introduce plain vegetables as first foods in the complementary feeding period and use repeated exposure to a variety of vegetables to increase acceptance of vegetables.

Recommendation 3: Use repeated exposure to a novel vegetable to help a child learn to enjoy the taste of that vegetable. When possible offer children a choice of two or more vegetables.

Recommendation 4: Parents should persist in offering children who are ‘difficult eaters’ a variety of tastes and textures to help them learn to like a range of foods.

Recommendation 5: Foods should be offered to a child in response to their feelings of hunger, and not used as reward for a good behavior or for any other reason.

Recommendation 6: Avoid offering energy-dense snacks before or after meals. If children are hungry before a meal, vegetables could be offered as a snack/appetizer.

In the Supplemental file 2 we provide an overview of the HabEat findings, grouped by common topics, which lead to the recommendations. In the stakeholders brochure we have listed these recommendations and provided suggestions for future research (see Supplemental file 3).

4.3. Ethical issues and barriers to implementation

We discuss here the ethical issues and barriers that were raised during our stakeholder workshops. We have considered some of these suggestions when designing our guidelines for parents (see section 4.4).

Breastfeeding is the best way to feed infants, but it may not be possible for reasons independent of maternal will, therefore it is important to include advice for parents of infants who are not breastfed (for whatever reason). This could include the wording ‘infant formula is a safe and healthy alternative to breast milk and, if used, should be continued until at least 12 months of age’.

At the beginning of complementary feeding, it is important to introduce a variety of vegetables to encourage a diversity of tastes. In fact, it is easier for infants to accept vegetables if introduced at the beginning of complementary feeding but there may be some

conflict with recommendations to avoid foods with high fibre content or a perceived risk of allergy.

Parents may also be reluctant to offer a food to their child that has been refused previously or that the parent believes the child dislikes. We should emphasize that repeated exposure is effective. However, we need to be careful in our recommendations to define what 'repeated exposure' actually means (e.g. how many times, at what sort of frequency, what constitutes 'exposure', repeat but not pressurize, no reward with a 'liked food' if a 'new food' eaten etc.) .

Health professionals who advise parents (e.g. Paediatricians) need to be aware of these recommendations so that they are able to communicate them to parents.

A further possible problem; families may be on a low income and find it difficult to afford a variety of vegetables. We should offer country specific advice on how to buy and use vegetables most effectively (e.g. seasonal purchase, storage, use of left-overs). We should also include the advice that frozen and canned vegetables and fruit can be a good alternative to fresh ones.

Another barrier to intake; parents with little or no knowledge of cooking may find it difficult to follow advice to involve their child in food preparation and cooking.

We advise not to give energy-dense snacks before a meal time but parents may find it difficult to refuse giving food if the child seems to be hungry. We could include advice to 'distract the child with other activities or to give low energy foods such as raw vegetables'. It may also be that the child is thirsty therefore offering a drink of water may satisfy the child.

How best to help parents to recognize that it is important to follow health professional's advice remains to be answered, but it is a strong barrier to implementation of these guidelines.

4.4. Development of guidelines for parents incorporating HabEat findings

HabEat findings in combination with previous research have been used to develop guidelines for parents that aim to help them promote healthy eating in their children starting in infancy. We have particularly focused on vegetables and fruit consumption because in most Western countries, large population groups, including children and adolescents, eat far less than the recommended amount (Currie et al., 2004). It is likely that promoting the adequate intake of vegetables and fruit early in life is particularly important in helping to reverse this low intake, because health behaviours learned in childhood tend to track into adolescence and adulthood (Mikkila et al., 2005; Northstone & Emmett, 2008).

Variety, repetition and persistence are the key messages emerging from HabEat research, these have been incorporated into the guidelines for parents. The title page is “VEGETABLES AND FRUIT, Help your child to like them... promoting variety, repetition and persistence” (see Supplemental file 4). Here we present a referenced description of the HabEat findings and the previous research upon which the guidelines are based.

Research has shown that infants are born with a liking for sweet tastes and a dislike of sour or bitter ones (Steiner, 1974). Therefore they are more likely to accept sweet foods like milk than sour foods like some fruits and bitter tasting vegetables. Infants need to learn to accept these more difficult tastes so parents need to help them.

There are several reasons to teach children to like vegetables and fruit. They are important sources of a wide range of micronutrients and there is an international consensus that vegetables and fruit consumption can help to prevent a number of chronic diseases including cardiovascular disease and some cancers. There is evidence that diets lacking in fruits and vegetables are associated with the development of obesity (World Health Organization, 2003; Boeing et al., 2012). Furthermore they add flavours and rich colours, contributing to a higher sensory variety in the meals.

A critical factor that can encourage later acceptance of a variety of foods is breastfeeding. Breast milk takes up flavours from a mother’s food (Hausner et al., 2010) and may encourage infants to accept vegetables and fruit and healthy food more easily. In HabEat children who were breastfed for only a short period or not at all were less likely to eat vegetables (de Lauzon-Guillain et al., 2013) and a balanced diet when they grew older (Jones et al., submitted). Breastfeeding benefits the health of both mothers and infants and it is best to continue it beyond the introduction of complementary foods, for 6 months or longer (Agostoni et al., 2008).

Introducing a vegetable as a first food when starting complementary feeding may be beneficial. It has been shown that it is easier to introduce novel vegetables into a child’s diet at the stage of complementary feeding than when they are older (Coulthard et al., 2010). The introduction of single vegetables as first foods was tested in the TASTE randomized trial from HabEat and was shown to increase liking and acceptance of an unfamiliar vegetable in the short-term (Fildes et al. paper under preparation). Furthermore another HabEat study showed that the more types of vegetables that a child had been offered prior to exposure to the novel vegetable the more the child ate at first exposure (Remy et al., 2013). The stage of complementary feeding is a ‘window of opportunity’ when an infant is particularly receptive to a variety of foods with different flavours and textures. Promoting vegetables and fruit as part of usual eating early in a child’s life encourages them to eat a balanced diet. The guidelines advise that parents should offer infants something different each day over several days but not to forget to repeat foods that have been refused at first.

Several other studies have shown that exposure to a variety of flavours is really important when feeding infants, because this leads to greater acceptance of new and different foods immediately and in later years (Gerrish & Mennella, 2001; Skinner et al., 2002; Maier et al., 2008; Nicklaus, 2011; Schwartz et al., 2011) and allows a greater variety in the nutritive content of foods and an increased likelihood that a well-balanced diet will be consumed (Gerrish & Mennella, 2001; Skinner et al., 2002). Some studies have shown that the number of exposures required for a new food to become accepted decreases as the diet becomes more varied (Williams et al., 2008; Schwartz et al., 2011), and the child is less likely to become bored by over exposure to familiar foods (Rohlf's Domínguez P et al., 2013).

The guidelines warn parents that it is likely that when an infant first tries a new taste, they will show some odd facial expressions. It suggests that this does not necessarily mean the child does not like the taste, sometimes this reaction happens simply because the child is surprised by an unfamiliar taste. As reported above, infants are born with a liking for sweet tastes and need to learn to like sour or bitter ones. Therefore, the guidelines advise that parents persist beyond 3 to 5 tries to encourage their child to accept a novel food. For younger children the number of exposures needed might be fewer than 8 but for older children a food should be offered at least 8-10 times before deciding that child does not like it. We suggest that in this case the food can be offered again at a later date.

Experience through mere or repeated exposure is the most efficient and simple learning mechanism for children (Hausner et al., 2010; Caton et al., 2013; de Wild et al., 2013; Remy et al., 2013). Infants who ate only small amounts of a vegetable the first time they were offered it, usually ate more in subsequent meals (Currie et al., 2004). Repeated exposure to different types of vegetables and fruit is relatively easy to implement at home or at day care-centres, as supported by the HabEat findings reported above.

How many exposures are necessary may vary from one child to another, according to a child's age, and may depend on the particular vegetable being offered. Children are not all the same; therefore there is not a single strategy for complementary feeding. In particular, children who do not enjoy eating needed more exposures and had a lower increase of a new vegetable intake after a learning period (Caton et al., 2014). In the HabEat cohort analysis we have shown that picky/fussy (difficult to feed) children are more likely not to eat vegetables at age 4/5 years (Oliveira et al. paper submitted); we suggest that encouraging infants to taste vegetables in the first steps of complementary feeding may help to avoid this. The guidelines advise parents of children with eating difficulties in early life to persevere with offering them a variety of tastes and textures to prevent a too restricted food repertoire later in life. HabEat research has shown that even fussy eaters increased their intake of a vegetable with repeated exposure (Caton et al., 2014).

A technique that is commonly used to improve the acceptance of vegetables is to add a familiar liked food to vegetables that are disliked or unfamiliar. However, HabEat has shown

that repeated exposure of a plain vegetable is an effective method for increasing intake of the vegetable and that adding a different flavour or an energy source did not increase intake any further (Hausner et al., 2010; Caton et al., 2013; de Wild et al., 2013; Remy et al., 2013; de Wild et al., 2014). The guidelines advise that offering a plain vegetable on several occasions will nearly always be enough to increase acceptance.

By around 7-8 months of age, infants should be given finger foods that they can hold themselves to help them learn about foods. Soft cooked sticks or pieces of vegetable and slices of soft fruit work well as first finger foods. Progressively an infant will be able to eat more solid chewable foods with lumps in larger portions and will learn to feed themselves. Not giving chewy/lumpy foods during this period has been shown to be associated with later feeding difficulties and lower fruit and vegetable consumption (Northstone et al., 2001; Coulthard et al., 2009). The infant will need at least two meals a day that include solid foods from this age, and parents are advised to offer a vegetable and/or fruit at each meal; mashed rather than pureed vegetables or fruit.

As the child grows creating positive conditions will improve acceptance of vegetables and fruit. In particular what the caregiver eats plays an important role in determining what the child eats, whether breastfeed or not, so it is important for the parents to follow a healthy diet. Studies have shown that mothers who consume specific vegetable flavours during pregnancy and or lactation transmit these flavours to their infant via the amniotic fluid and breast milk (Hausner et al., 2009). Furthermore, mother's fruit and vegetable intake was one of the strongest determinants of child intake in food records kept for 7 year old children (Jones et al. 2010). It is also known that mothers are less likely to make available those foods that they themselves dislike or do not eat (Birch & Davison, 2001), therefore reducing the chances of their children being exposed to these foods. The guidelines suggest that if a vegetable is unfamiliar to the parents, they could try it themselves and learn to like it by repeat exposure and then make it part of the normal family diet.

Parents can facilitate positive eating environments to promote a healthy relationship with food. The attitudes and actions of parents in the process of feeding their child influence the child's food intake and preferences. Different forms of pressuring can be used by parents or caregivers: verbal prompts, praise, reward or coercive practices. These practices may reduce a child's ability to self-regulate their intake and are associated with higher levels of pickiness (Williams et al., 2008). Serving foods as a reward or comforter can make them seem desirable and increases preferences for these foods (Fisher & Birch, 1999). The problem is that healthy foods are not often offered as a reward, instead adults offer non-healthy already very much liked foods as reward. HabEat found that mothers who used 'Food as a reward' were more likely to have children (aged 3 to 6 years) who ate in the absence of hunger than mothers who did not use this feeding practice (Remy et al, paper under preparation). It is important to respect the child's internal cues of hunger or satiety in order to improve their self-regulation of food intake. Therefore, the guidelines suggest that

parents should respond to their child's hunger cues while avoiding the use of food as a reward for good behaviour, the use of pressure or bribery to try to make a child eat. There is evidence that refusing a child access to specific foods or restricting them too much could have an adverse effect as the "forbidden" food becomes more attractive (Fisher & Birch, 1999).

The food environment is a crucial influence on food preferences and intake. It is normal for children to need a small snack between meals. Fruits and vegetables prepared in finger sized portions are ideal snacks for children. Some foods often used as snacks are high in fat, salt and/or sugar e.g. biscuits, chocolates, sweets, cakes, potato crisps, corn crisps (Johnson et al., 2008). Links have been found between high intakes of these foods and the development of obesity especially when intakes of fruits and vegetables are low (Boeing et al., 2012). These foods are energy-dense and micronutrient-poor therefore have only a very limited place in providing a balanced diet.

The food industry could innovate by providing new healthier snacks or reformulate existing snacks in order to reduce fat, salt and/or sugar content.

HabEat research has shown that overeating is likely if energy-dense snacks are offered to children either before or after a meal. If offered before the meal the children ate less of the meal but did not fully compensate for the energy intake from the snack. If offered after the meal the children ate even though they had already eaten a normal amount of the meal thus consuming extra energy (Remy et al. paper under preparation). The guidelines suggest to parents that it is better not to offer energy dense foods that are high in fat, salt and/or sugar just before a meal or outside a meal time because it may dull a child's appetite thus leading to lower consumption of more nutritious main meals and excess energy intake. Furthermore if children are allowed free access to foods high in fat, salt and sugar after eating a normal main meal they are very likely to eat them even when they are not hungry.

The guidelines advise that making foods such as fruits and vegetables more easily available is a good way of increasing children's intake. HabEat research suggests that offering children two different vegetables during a meal and giving them the opportunity to choose one or eat both may increase intake (de Wild et al, submitted paper). This may avoid the possibility of boredom occurring with particular foods. Different ways of preparing the vegetables, e.g. cooked vs. raw, different cooking types or cut into different shapes are likely to lead to increased intake. Including vegetables as a snack during the school day provides an additional vegetable eating moment (Zeinstra et al., 2010). These vegetables can be taken in a snack box by children going to school. Activities that encourage contact with foods can help a child to become familiar with them.

Children often show signs of neophobia at around 2-3 years of age (Rigal et al., 2012) and many children go through a phase where they are unwilling to try new foods or even reject

foods they have eaten before. These eating difficulties were associated with a lower vegetables and fruit intake and less variety in 4-5 years old children from the cohorts participating in HabEat (Oliveira et al, paper submitted). The guidelines make parents aware of the possibility of children being difficult eaters and suggest that parents attend to signs of food refusal and fussiness with patience and that most children will grow out of this phase. The guidelines advise that it is better not to offer a completely different meal to a picky child as usually they will gradually start to eat what the rest of family eats. Parents are advised not to pressurize the child because it is not necessary to include particular foods in a child's diet since a balanced diet can be made up from a combination of many different foods. However, we advise that if the child's eating does begin to worry the parent they should speak to a health professional about it.

To deal with barriers to following advice raised during the stakeholders feed-back we have included advice to formula feeders and about how to keep the cost of providing vegetables and fruit down. For formula feeders the booklet emphasises the importance of not changing to cows' milk as a replacement before 12 months. This has been shown to increase the likelihood of anaemia in infants (Hopkins et al., 2007). The guidelines advise the parents that introducing a variety of vegetables at the start of complementary feeding is even more important for formula-fed infants. For keeping the cost down the guidelines suggest the use of seasonal produce and tinned or frozen vegetables and fruit, preferably without added salt or sugar. They also suggest ways of using surplus vegetables and fruit.

4.5. Recommendations for future research

From the cohort studies conducted, longer breastfeeding appeared to be related to higher diet quality in early childhood. This is consistent with the hypothesis that early sensory exposure through breastfeeding enhances later acceptance of foods like fruit and vegetables. It would be of great interest to confirm this result in cohorts from low and middle income countries where breastfeeding duration is longer in disadvantaged rather than in advantaged families. This would ensure that our result is not due to unmeasured residual confounding related to socio-economic status which was associated with both breastfeeding duration and fruit and vegetables intake in the HabEat cohorts.

Moreover, results from the UK cohort indicated that the association of longer breastfeeding with better diet could persist throughout childhood, but again it would be important to perform similar analyses in cohorts with follow-up extending to adult life. Furthermore, none of the cohorts involved in this project collected data on maternal diet during breastfeeding. According to the sensory hypothesis, variety in diet during breastfeeding could be of great importance to enhance acceptance of foods in infants. Although there is

likely to be continuity between maternal diet in pregnancy and diet while breastfeeding, further cohorts need to collect data on maternal diet during breastfeeding in order to reach safer conclusions.

The relationship between complementary feeding and better diet in childhood was not consistent across the cohorts and highlighted the need to go beyond the timing of complementary feeding. Previous results suggested that other aspects of complementary feeding should be taken into account, such as food variety during the complementary feeding period, and use of home-prepared vs. ready-prepared baby foods.

Child eating difficulties were frequently reported by parents in all the participating cohorts. The determinants of these difficulties, how the parents adapt child feeding in response to these difficulties, and how these adaptations shape the future food habits of the child should be a topic for future research. Validated tools in different languages to assess infant and child eating behaviours should be used to facilitate international comparisons. The HabEat experimental work has identified a group of children who do not respond to repeated exposure by increasing intake of a food, further investigation of why and how this happens would be important.

The intervention at the start of complementary feeding concluded that repeated exposure to a variety of single vegetables results in short term increases in acceptance (intake and liking) of an unfamiliar vegetable in the UK sample (highly educated), but not in the samples in Portugal and Greece. These interventions should be replicated in larger population samples with different cultural food habits and socio-economic status. Additionally, no clear effect of the intervention was found at later follow-up. Therefore, the longer term impact of the intervention should be studied and its effectiveness should be tested at follow-ups extended beyond 9 months post-intervention.

When exploring new strategies for breaking habits, repeated exposure was shown to be very efficient for increasing the child's intake of a novel vegetable and increases in intake differed with different serving styles. Future research should focus on what are the optimal serving size and the optimal frequency of exposure in this type of repeated exposure study.

On the other hand, increasing vegetable intake of a relatively familiar vegetable seems more difficult to achieve, and repeated exposure may not be sufficient. Future research should focus on effective strategies to increase children's intakes of relatively familiar vegetables. In addition, future research should focus on testing the repeated exposure mechanism with four types of vegetables: unfamiliar-liked, unfamiliar-disliked, familiar-liked and familiar-disliked, although these combinations may be difficult to find in practice.

There is little research currently about the effect of positive restriction on intake of healthy foods such as vegetables. The studies conducted in HabEat have touched on this area, but future research should investigate this strategy with more sensitive measures. Future

research should focus on the conditions that support a positive effect of modelling and the conditions that undermine a positive effect of modelling in complex settings such as a classroom. Home experiments could also be useful for testing positive restriction and modelling.

Future studies should test whether children compensate (diminish) their vegetable intake during dinner when an additional vegetable eating moment at school is created, which was the case in different HabEat experiments.

From our results, it is plausible that offering a choice of vegetables to toddlers may be an effective strategy to increase their vegetable consumption. However, this finding warrants further investigation. Similar studies with larger numbers of children involved and focusing on different age groups are needed. It might also be worthwhile to explore the freedom of choice and variety condition, using less liked or disliked or unknown vegetables, and to understand if this strategy is applicable to these situations especially for non-vegetable likers/low-vegetable likers. We also need to further investigate whether children helping with vegetable preparation repeatedly (rather than just once as tested in HabEat), or in the home-setting, or in children over 6 years has a beneficial effect on vegetable intake.

In the HabEat project, the Comprehensive Parental Feeding Practices questionnaire (Musher-Eizenman & Holub, 2007) was used in various experiments. Because internal consistency was not satisfactory for all dimensions, this questionnaire needs to be validated in further research.

Finally, research on other health-promoting foods often rejected by children, such as fish and whole-grain cereals, are needed.

Supplemental file 1

CURRENT NATIONAL GUIDELINES – finding the gaps?

	PORTUGAL	FRANCE	UNITED KINGDOM	GREECE	DENMARK	THE NETHERLANDS	POLAND
BREAST-FEEDING							
Duration of exclusive breast-feeding	For the first 6 months ¹ .	Until 6 months of age, and at least for 4 months to have health benefit ² .	For the first 6 months ³ .	For the first 6 months ^{4,5} .	Up to 6 months of age ⁷ .	For around 4-6 months ⁸ .	For the first 6 months ¹² .
COMPLEMENTARY FEEDING							
Timing	Preferably, about the 6th month. Never before 17 weeks and beyond 26 weeks ¹ .	From 6 months onwards and in any case in any case not before the beginning of the 5th month ² .	Around 6 months Introducing solid foods before 6 months: if after checking with your health visitor/doctor, you decide to introduce solid foods before 6 months, you should avoid giving certain foods as they may cause food allergies or make your baby ill. These include foods that contain wheat, gluten, nuts, peanuts, peanut products, seeds, liver, eggs, fish, shellfish, cows' milk and soft or unpasteurised cheese.	Preferably, about the 6th month. Never before 17 weeks and beyond 26 weeks ^{4,5} .	Preferably, about the 6th month. Never before 17 weeks and beyond 26 weeks ⁷ .	Preferably, about the 6th month. Never before 17 weeks and beyond 26 weeks ⁸ .	Preferably about the 6th month. Never before 17 weeks and beyond 26 weeks ¹² .
First foods	A vegetable broth or soup, enriched with olive oil ¹ .	--	Simple and easily digested foods such as rice, fruit or vegetables, meat, yogurt, cheese and custard simply pureed or mashed with no added salt or sugar or mixed with breast or formula milk.	--	Cooked vegetables, soft fruits, spreads and soft bread, porridge from different types of flour ⁷ .	No specific foods are recommended as first foods but if starting before 6 months, then soft fruit and vegetables with sweet taste are recommended: pear, banana, melon, peach, apple, courgette, carrots, cauliflower, French beans, broccoli ^{8,9} .	Purred fruits or baby fruit juice (up to 150 g) and purred vegetables, baby cereal. Choose fruit over juice ¹² .

<p>Variety</p>	<p>"For vegetables, it is also important to promote variety, to improve acceptance"¹.</p>	<p>--</p>	<p>Your baby's diet should consist of a variety of the following types of food: fruit and vegetables; bread, rice, pasta, potatoes and other starchy foods; meat, fish, eggs, beans and other non-dairy sources of protein and milk and dairy products.</p>	<p>"Feed a variety of foods to ensure that nutrient needs are met"⁴.</p>	<p>High variety is recommended. Foods have been divided into 4 groups and parents are recommended to feed their children most foods from groups containing, fruit, vegetables and various carbohydrates and less meat, milk, cheese, eggs and fish and (only) small amounts of fats⁷.</p>	<p>"Once a taste is accepted, new ones can be introduced as well as combined fruits/vegetables/other foods to improve "variety"⁸.</p>	<p>--</p>
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CURRENT NATIONAL GUIDELINES – finding the gaps?

	PORTUGAL	FRANCE	UNITED KINGDOM	GREECE	DENMARK	THE NETHERLANDS	POLAND
COMPLEMENTARY FEEDING (cont.)							
Repeated exposure	“In introduction of foods 11 attempts are often needed to succeed” ¹ .	“Not insist in case of refusal, propose again later” ² .	“Offer small amounts lots of times” ³ .	--	--	“Repeated exposure (approx. 10 times) is recommended for new tastes as it facilitates acceptance” ⁸ .	--
Mere exposure	“Each fruit should be introduced isolated, to let them discover the taste” ¹ .	“1 taste or texture at a time” ² .	--	--	--	“Each new food should preferably be introduced isolated, to let them discover the taste” ⁸ .	Offer new products one at a time (for several days) in small amounts ¹² .
Lumpy foods	Around 10 months of age ¹ .	From 8 months ² .	From 6 months - soft cooked meat such as chicken, mashed fish pasta, noodles, toast, pieces of chapatti, lentils, rice and mashed hard boiled eggs.	--	At the end of complementary feeding ⁷ .	Around 10 months of age ⁸ .	Around 7-8 months ¹² .

<p>Texture</p>	<p>“From the 8-9th month the texture of foods should be progressively less homogeneous”¹.</p>	<p>--</p>	<p>“Infants can eat pureed, mashed and semi-solid foods beginning at six months. By 8 months most infants can also eat "finger foods". By 12 months, most children can eat the same types of foods as consumed by the rest of the family”</p>	<p>Gradually increase food consistency and variety as the infant gets older, adapting to the infant’s requirements and abilities. Infants can eat pureed, mashed and semi-solid foods beginning at six months. By 8 months most infants can also eat "finger foods" (snacks that can be eaten by children alone). By 12 months, most children can eat the same types of foods as consumed by the rest of the family⁴.</p>	<p>--</p>	<p>“From the 8-9th month the texture of foods should be progressively less homogeneous”⁸.</p>	<p>The texture of foods should stimulate chewing¹².</p>
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CURRENT NATIONAL GUIDELINES – finding the gaps?

	PORTUGAL	FRANCE	UNITED KINGDOM	GREECE	DENMARK	THE NETHERLANDS	POLAND
	TODDLERS						
Meals	--	4 meals a day: breakfast, lunch, afternoon snack (only one), dinner ² .	3 meals a day, chopped if required, plus breast milk or whole cows' milk and healthier snacks like fruit, vegetable sticks, toast and rice cakes.	Children should be encouraged to eat breakfast every day and given the apparent inverse association between number of daily meals and obesity development, it is appropriate that children older than 2 years of age eat at least 4 meals per day ⁵ .	--	Offer 3 principal meals and not more than 4 snacks in between meals a day ^{8,10,11} .	4-5 meals a day: 3 principal meals, and up to 2 snacks; serve meals in 3-4 hour intervals ¹² .
Recommended portions	--	<p>Fruit and vegetables: at least 5 a day</p> <p>Starchy products: at every meal</p> <p>Dairy products: 3 per day (or 4 depending on portion size and calcium content)</p> <p>Meat/Fish/Eggs: 1 or 2 per day, alternately</p> <p>Added fat: moderately</p> <p>Sweet products: sometimes, in limited portions</p> <p>Beverages: priority to water as much as child want</p> <p>Salt: to be limited².</p>	<p>3 to 4 servings a day of starchy food such as potatoes, bread and rice</p> <p>3 to 4 servings a day of fruit and vegetables</p> <p>2 servings a day of meat, fish, eggs, dhal or other pulses (beans and lentils)</p> <p>Use full-fat dairy products Children under 2 need the extra fat and vitamins found in them. From 2 years old if they are a good eater and growing well they can have semi-skimmed milk. From 5 years old 1% fat and skimmed milk is OK.</p>	The relevant guidelines are mainly based on the "American Recommendations for Children and Adolescents" (table 3 of the reference paper) ⁶ .	--	<p>Total energy kcal/day 1-3 years old: less active life style, boys 1100, girls 1000; more active life style, boys 1200, girls 1100. Daily recommended amounts 1-3 years old: 150 g fruit, 50-100 g vegetables, 50-100 g potatoes/rice/pasta or legumes, 70-105 gr bread (=2-3 slices), 10 gr cheese, 300 ml milk or milk products, 50-60 g meat/fish/chicken/egg or meat replacers, 15 g oil/fry-and bake products, 10-15 g halvarine, 750 ml drinks (including milk), 10 microgram extra vitamin D every day until 4 year^{10,11}.</p>	<p>Total energy kcal/day: 83 kcal/kg body weight.</p> <p>Less than 1g protein/kg body weight and no more than 15% of total kcal intake. Up to 30-40% of fats. 55-60% of carbohydrates and no more than 10% of added sugars. 15 micrograms of vitamin D (either with food or supplements)</p> <p>Dairy: 3 portions; It is recommended to give a child 2 portions of milk and 1 portion of other dairy products. 1 portion = glass of milk, 1/2 cup of yoghurt, slice of cheese</p> <p>Meat, fish, eggs: 1-2 portions; 1 portion = 1/2 egg, 1/2 chicken breast</p> <p>Grains: 5 portions; 1 portion = slice of bread, 1/2 cup of cereals, 2-3 Tbs of rice/pasta, 1 pancake</p> <p>Vegetables: 5 portions; 1 portion = 2 Tbs of sweet corn, 1 potato, cup of cooked zucchini</p> <p>Fruits: 4 portions; 1 portion = 1/2 banana, small peach, 1/2 glass of fruit juice</p> <p>Oils: 1-2 portions; 1 portion = 1 tsp of olive oil, 1 tsp of high quality butter</p>

	PORTUGAL	FRANCE	UNITED KINGDOM	GREECE	DENMARK	THE NETHERLANDS	POLAND
	TODDLERS						
							Water between meals. Sweets and beverages in limited amounts. 12
Parental feeding practices	--	<p>Parents have to decide what is offered to the child:</p> <ul style="list-style-type: none"> - only one meal for the whole family - be firm but not rigid <p>Children have to decide the quantity².</p>	<p>Keep offering healthy snacks/finger foods such as vegetables, bread or pieces of pasta, potato, meat or fish to encourage them to be independent eaters. Avoid offering snacks with lots of added sugar.</p>	--	<p>Parents are recommended to let children use fingers when eating and at 18 months of age, manual control is developed sufficiently to ensure that the child can use a spoon by itself⁷.</p>	<p>Advice to parents: choose fixed time for meals and snacks; take care of your child not being too tired to eat; eat as often as possible with the whole family; keep mealtimes at 15-30 minutes to prevent boredom/fatigue, create pleasant atmosphere; do not eat in front of the TV, be a good example for your child; allow your child to choose for example between two kinds of bread spreads or two kinds of vegetables; parents determine when and what to eat, the child how much it wants to eat; it is not necessary to finish your plate, however, second plate is also allowed; when your child is not eating enough, do not give any snacks in between meals; do not reward your child when eating vegetables; do not punish your child if not eating; be positive. Don't offer plates that are very full; offer small portions; encourage child to taste from everything on its plate; Don't follow the child with food when it is walking around ^{10,11}</p>	<p>Advice to parents: gradually and consistently introduce new foods in small amounts several times (up to 20); be a good example to your child and stay positive during meal-time; be patient and determine rules regarding eating: eating at the dinner table, meal should take no more than 30 minutes, the meal should not take place in front of TV; parent decides what a child will eat and how the meal is served, the child decides whether the meal is eaten or not; pay attention to variety; encourage your child to be independent while eating; do not play with a child at the dinner table; do not force-feed the child; do not give snacks between meals¹².</p>

	PORTUGAL	FRANCE	UNITED KINGDOM	GREECE	DENMARK	THE NETHERLANDS	POLAND
	TODDLERS						
Others	--	How to develop food liking? - Children have to learn new tastes - Use variety within a same food group or for cooking foods - Introduce your child to several fruits and vegetables (buying them together...) - Cooking together - Eat slowly ² .	Cups: introduce a cup from around 6 months and offer sips of water with meals. Using an open cup or a free flow cup without a valve will help your baby learn to sip and is better for your baby's teeth.	--	--	Taste: to get used to a new taste, it can take up to 10 times exposure to get familiar to this taste. Please supply tap water to your child, good for child, environment and saving money. After first anniversary please get rid of the feeding-bottle, introduce a normal cup for drinking. It is indicated that from about 1 year, children need less energy, so may eat less ^{10,11} .	--

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11. Public health infant and child care centre, municipality of Renkum; the Netherlands will follow guidelines of Dutch "Voedingscentrum" (see Ref 10) (in Dutch: Consultatiebureau gemeente Renkum: <http://www.stmg.nl/index.php?id=1915>)
12. Aleksandra Rekosz. Polish recommendations for infant and toddler feeding. Personal communication.

Supplemental file 2

Overview of HabEat findings and recommendations

BREASTFEEDING AND COMPLEMENTARY FEEDING			
STUDY, PARTNERS INVOLVED	FINDING	SUGGESTED RECOMMENDATION	HABEAT REFERENCES
Cohort Inserm, U.Bristol, U.Porto, HUA	Studies in several European countries have shown that children who are breastfed for longer periods are more likely to eat fruit and vegetables and have a higher variety of healthy food in their diet in later childhood.	Maternal milk is the best food for young babies. Among its many advantages, it may influence their acceptance of a greater variety of healthy foods in later childhood. Even after starting with complementary foods, breast milk should continue.	(de Lauzon-Guillain et al., 2013) (Louise J et al, paper submitted)
Experimental ULeeds, UCPH, INRA	Children (4-36 months) who do not enjoy eating or those who are fussy eaters still increase their intake after repeated exposure to a new vegetable, though intake is still relatively low.	Children (4-36 months) who do not enjoy eating need more exposures to learn to eat a new vegetable. Children who are fussy eaters need some encouragement and to taste a new vegetable as a first step.	(Caton et al., 2014)
Experimental UCL HUA U.PORTO	In the UK repeated exposure to a variety of single vegetables at the start of complementary feeding results in short term increases in acceptance (intake and liking) of an unfamiliar vegetable. No clear effect of the intervention was found at later follow-up and the longer term impact of the intervention remains unclear.	The weaning period is a 'window of opportunity' when an infant is open to accept a variety of foods with different textures and flavours. It's really important that babies are fed with a variety of different vegetables as first foods as this seems to increase acceptance due to familiarity and consequently consumption of a greater variety of vegetables and fruits. Recommend introducing a variety of single vegetables early in weaning and advise mothers on the importance of repeated, persistent and varied exposure to vegetables.	(Fildes A et al, paper submitted)
Experimental ULeeds, UCPH, INRA	It is easier to introduce new vegetables in a child's diet at the stage of complementary feeding than when they are older, in particular when they are more than 2 years old.	Introduce a variety of vegetables from the beginning of complementary feeding before neophobia sets in.	(Caton et al., 2014)
Experimental INRA	Repeated exposure to a basic vegetable purée is an effective and simple way to increase intake and liking not only in the short term but at least until three months after exposure in infants at the beginning of complementary feeding. Moreover, at the beginning of complementary feeding, it is not necessary to add an ingredient with a liked taste or an energy-dense ingredient to induce learning for a novel vegetable.	Whatever the reaction expressed by the child on the first trial of a food, a food should be offered at least 8 times before deciding that child does not like it. It is not necessary to add an ingredient with a liked taste or an energy-dense ingredient to enhance acceptance of the food.	(Remy et al., 2013)
Experimental University of Copenhagen	Mere exposure is the most effective method for increasing intake of a new vegetable, compared to adding sweetness or adding energy in 1-3 years-old children.	Apply mere exposure when feeding children; in childcare settings and in the home.	(Hausner et al., 2012)

FOOD INTAKE REGULATION/ PARENTAL FEEDING PRACTICES			
STUDY, PARTNERS INVOLVED	FINDING	SUGGESTED RECOMMENDATION	HABEAT REFERENCES
Cohort Inserm, UNIBRIS, U.Porto	Child eating difficulties (poor eating, food refusal, unable to get into a routine) as described by parents were associated with lower fruit and vegetable intake and lower dietary variety in 4-5 years old in three European countries.	Parents of children with eating difficulties in early life should persevere offering them a variety of foods, textures to prevent a too restricted food repertoire later in life!	Oliveira et al., papers submitted
Experimental studies HUA, UCPH, FBR-DLO	Children aged 2 to 6 years who are fussier or more neophobic, ate less of the vegetables during the first study session, whereas children who like vegetables more, ate more vegetables during the first study session.	Special attention should be given to children who are fussier, more neophobic and have a low vegetable liking, because they are at risk for low vegetable consumption. This group of children might need other interventions to encourage liking and intake of vegetables.	-
Experimental studies INRA	When children aged 3 to 6 years ate a preload less than one hour before a meal, they ate less during the meal. However, at the meal children adjusted only partially for the energy brought by the preload (~50%).	Avoid offering foods before a meal to children to avoid overeating.	Remy et al., in preparation
Experimental studies INRA	When palatable foods are available after a meal, most of children aged 3-6 years eat in the absence of hunger.	Outside the meal, children should not have access to energy-dense foods.	Remy et al., in preparation
Experimental studies INRA	Parents, who used the parental practice 'Food as reward' more often, had children (3-6 years) who ate more in the absence of hunger.	Foods should be offered to a child in response to his/her hunger feeling, and not as reward for a good behaviour.	Remy et al., in preparation

FEEDING CHILDREN 2-6 YEARS			
STUDY, PARTNERS INVOLVED	FINDING	SUGGESTED RECOMMENDATION	HABEAT REFERENCES
Experimental UCPH	Mere exposure is very efficient for increasing intake of a novel vegetable (Chinese radish) among children aged 3 to 5 years, and increases in intake differed with different serving styles.	Parents should offer children ready to eat vegetables, and continue to offer them even if children initially refuse novel vegetables.	Olsen et al., in preparation
Experimental studies FBR-DLO	Repeated exposure to two vegetable shapes (raw carrots) in a school situation did not significantly increase intake. Mean intake over session 1, 5 and 10 was 32 grams in intervention and 47 grams in control group. Slices were preferred over sticks for six out of ten sessions.	Offer children ready-to-eat vegetables as a snack during the school day, but not too frequent the same vegetable, since boredom may occur. Vary with vegetable shapes and serving style.	Zeinstra et al, in preparation
Experimental studies HUA and FBR-DLO	In a school setting, vegetable intake (raw carrot sticks) remained stable over a period of eight convivial eating sessions where the children ate carrots together with an enthusiastic role model. This role model was 1) a TV/ child idol via movie and 2) the child's own teacher. In the Greek idol imitation study, carrot intake was highest in the positive-restriction group right after the positive restriction period and the lowest in the control group. This can indicate a positive role for positive restriction, but a difference in baseline consumption – which was not assessed prior to the study - cannot be ruled out. During the choice tests, where children could choose one out of four vegetables, their vegetable intake was 2 to 3 times higher compared to the convivial eating sessions. In the Greek choice test, the preference for carrot gradually decreased by the children. It is likely that 8 exposures in 6 weeks are too many and the Greek children got overexposed to the vegetable and subsequently became possibly bored.	Offer children ready-to-eat vegetables as a snack during the school day, but not too frequent the same vegetable, since boredom may occur. Offer children a range of vegetables of which they choose what to eat.	Zeinstra et al., submitted Costarelli, in preparation
Experimental studies UCPH,WUR, HUA	Evidence from the three HabEat studies together with the evidence from some recent other studies, it seems that offering choice can be a promising strategy for encouraging vegetable consumption for some children and for some situations.	It may be useful to offer children a choice among two or three vegetables. Especially for children who have difficulties in eating vegetables, it may be worth trying whether choice-offering helps them to eat their vegetables.	(de Wild et al., 2014) Olsen et al, in preparation Manios et al, in preparation
Experimental studies FBR-DLO	Assisting once in vegetable preparation under supervision of a chef-cook did not increase vegetable consumption in 4-6-year old children. There was a slight tendency that children in the intervention	Let children participate in vegetable preparation (although the evidence from our study was weak and did not come from increased vegetable intake, but from effects on choice and general meal involvement).	Zeinstra et al, in preparation

FEEDING CHILDREN 2-6 YEARS

STUDY, PARTNERS INVOLVED	FINDING	SUGGESTED RECOMMENDATION	HABEAT REFERENCES
	<p>group were more likely to choose carrots in comparison with children in the control group, which may indicate that their interest in carrots was maintained after preparing carrots. In addition, 'involvement in meal preparation' of the children that participated in the cooking session remained stable three months later, whereas this declined in the control group.</p>		
<p>Experimental studies WUR</p>	<p>Mere exposure and possibly flavour-nutrient learning (FNL) can be effective learning strategies to increase the intake and acceptance of novel green vegetable soups in preschool children. The positive effects on intake remained stable for at least 6 months after conditioning. Repeated exposure and flavour-flavour learning are effective mechanisms to increase vegetable intake and acceptance in young children.</p>	<p>Mere exposure is a powerful and relatively simple technique to stimulate vegetables in young children and relatively easy to implement in daily life, at home or at day care-centres.</p>	<p>(de Wild et al., 2013)</p>

Supplemental file 3 Stakeholders brochure

http://www.habeat.eu/media/file/Brochure_stakeholders.pdf

Supplemental file 4 Parents Guide

http://www.habeat.eu/media/file/BookletHabEat_Electronic%20version.pdf

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