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Temperament as a predictor of eating behavior in middle childhood – A fixed effects approach

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ABSTRACT

Background: Individual differences in temperament are believed to influence the development of children's eating behavior. This hypothesis has predominantly been tested in cross-sectional designs and important confounders such as genetics and stable parenting factors have not been accounted for. The present study aims to establish more clearly than previous studies if temperament is involved in the etiology of eating behavior in middle childhood.

Methods: A community sample of Norwegian children (n = 997) were followed biennially from age 4 to age 10. Temperamental negative affectivity, effortful control, and surgency were measured by The Child Behavior Questionnaire (CBQ). The Children's Eating Behavior Questionnaire (CEBQ) captured four 'food approach' behaviors ('food responsiveness', 'enjoyment of food', 'emotional overeating', 'desire to drink') and four 'food avoidant' behaviors ('emotional undereating', 'satiety responsiveness', 'food fussiness', 'slowness in eating'). The prospective relationships between temperament and eating behavior were tested with fixed, random and hybrid effect models, which adjust for all unmeasured time-invariant factors (e.g. genetics, common methods over time)

Results: Over and above unmeasured time-invariant confounders, higher negative affectivity predicted more 'food approach' and 'food avoidant' behavior, as did low effortful control, although less consistently so. Greater surgency was prospectively related to more 'food approach' and less 'food avoidant' behavior, but only at some ages and with the exception of emotional over- and under-eating.

Conclusions: Our findings indicate that temperament is involved in the etiology of children's eating behavior. Negative affectivity, in particular, may affect both 'food approach' and 'food avoidant' behavior. Because children prone to react with negative affect are at increased risk of obesogenic and disordered eating behaviors, their parents should be particularly aware of how to support healthy eating.

1. Introduction

Children's eating behaviors (i.e., their interest in and preferences for food, triggers of eating, and frequency and amount of intake) are associated with their later weight development (French, Epstein, Jeffery, Blundell, & Wardle, 2012; Steinsbekk & Wichstrom, 2015) and possibly also later eating pathology such as bulimia nervosa and binge eating (Pearson, Riley, Davis, & Smith, 2014). Guided by ecological models, researchers have therefore delineated how factors at the level of the individual, the family and the community can explain individual differences in development of eating behavior. Eating behavior evolves through a complex interplay between biological tendencies and environmental influences (Ventura & Worobey, 2013), and temperament is an individual factor that has received considerable attention (Anzman-Frasca, Stifter, & Birch, 2012). According to Rothbart's psychobiological model (Rothbart, Derryberry, & Posner, 1994), three overarching temperamental dimensions exist: (1) *Negative affectivity*, characterized by mood instability, angry reactivity and dysregulated negative emotions; (2) *Effortful control*, defined as the ability to inhibit a dominant response (e.g., eat some chocolate) to perform a less salient response (e.g., avoid eating the chocolate) (Rothbart & Bates, 2006) (i.e., a self-regulatory- or control process); (3) *Surgency*, which concerns the child's approach and activity level (i.e., 'outgoing' children) (Rothbart et al., 1994). Each of these temperamental dimensions have been linked to various types of eating in childhood (Bergmeier, Skouteris, Horwood, Hooley, & Richardson, 2014; Hafstad, Abebe,

Abbreviations: The Child Behavior Questionnaire, CBQ; Children's Eating Behavior Questionnaire, CEBQ -; Trondheim Early Secure Study, TESS

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Torgersen, & von Soest, 2013; Leung et al., 2016; Steinsbekk, Bonneville-Roussy, Fildes, Llewellyn, & Wichstrom, 2017); behaviors that can be categorized as either 'food approach' or 'food avoidant'. *Food responsiveness* (i.e., the tendency to eat in response to food cues such as sight and smell of food), *enjoyment of food* (i.e., a more general interest in food and greater subjective reward experienced from eating) *emotional overeating* (i.e., the tendency to eat more in response to negative emotions), and *desire to drink* are behaviors positively associated with food/beverage intake and weight (Carnell & Wardle, 2008; Jansen et al., 2012; Tan, Walczak, Roach, Lumeng, & Miller, 2018) and are therefore defined as '*food-approach'* behaviors. '*Food avoidant'* behaviors, on the other hand are negatively associated with food intake and weight (Carnell & Wardle, 2008; Haycraft, Farrow, Meyer, Powell, & Blissett, 2011; Jansen et al., 2012), and include *satiety responsiveness* (i.e., the ability to adjust eating in response to internal feelings of hunger and fullness), *emotional undereating* (i.e., eat less in response to negative emotions), *food fussiness* (i.e., picky or fussy eating), and *slowness in eating* (i.e. eating at a slow pace).

Although exceptions do exist, studies on infants, toddlers, and preschoolers often report temperament—eating behavior links. For example, highly negative affective children are more likely to use food to appease their feelings (i.e., emotional overeating) (Haycraft et al., 2011; Messerli-Burgy et al., 2018; Steinsbekk, Barker, Llewellyn, Fildes, & Wichstrøm, 2017), and show higher levels of picky or fussy eating (Hafstad et al., 2013). Children displaying high levels of effortful control are less food-responsive (Leung et al., 2014), and effortful control is positively associated with self-regulated eating in adolescents (Godefroy, Trinchera, Romo, & Rigal, 2016). A study of preschoolers reports that surgency positively correlated with enjoyment of food and food responsiveness (Leung et al., 2016), but findings are mixed (Haycraft et al., 2011). Furthermore, only a handful of longitudinal studies exists (Bergmeier et al., 2014; Hafstad et al., 2013; Leung et al., 2016; Steinsbekk, Bonneville-Roussy, et al., 2017) and the present study is the first to examine the prospective associations between different temperamental characteristics and eating behavior dimensions in middle childhood. Of even more importance is the extent to which observed associations can be interpreted as temperament *causing* eating behavior. One may question the validity of etiological conclusions drawn from observational data. Firstly, there is genetic covariance between temperament and eating behavior (Racine et al., 2013), and twin studies of adults have shown that the observed association between personality (i.e., temperament in childhood) and eating disturbances may stem from common genes (Koren et al., 2014). Secondly, although temperament is generally conceived of as a stable construct, research has also reported substantial change (Roberts & DelVecchio, 2000). These changes may result from variations in both parenting (Micalizzi, Wang, & Saudino, 2017) and the home environment (Kiff, Lengua, & Zalewski, 2011; Matheny & Phillips, 2001). Parenting factors are also hypothesized to cause changes in eating behavior (Savage, Fisher, & Birch, 2007), and characteristics of the home environment are associated with children's eating (Fulkerson, Larson, Horning, & Neumark-Sztainer, 2014). Hence, both parenting and other environmental characteristics may affect both temperament and eating, creating a spurious association between the two. Third, because both temperament and eating behavior are usually assessed through parent-report, a common methods effect (e.g. common rater bias) may explain the association between them. One statistical method, the fixed effect regression/dynamic panel modelling approach is able to overcome some of the unmeasured confounding problems by being able to adjust for all unmeasured *time-invariant* factors (i.e., variables that do not change their value e.g., genetics (although their impact may change)) (Allison, 2009; Bollen & Brand, 2010; Firebaugh, Warner, & Massoglia, 2013), and will therefore be applied here to examine the relationships between temperamental dimensions and later eating behaviors, net of the potential effect of all unmeasured time-invariant confounders.

More specifically, children high in negative affectivity may experience more negative emotions and have more problems with downregulating these emotions than less reactive children; these children are also more likely to use maladaptive emotion regulation strategies (Santucci et al., 2008) (such as emotional eating). We therefore hypothesize that greater negative affectivity will be prospectively associated with more emotional overeating. Although emotional distress may trigger eating, the most natural response to distress is to eat less because gut activity decreases in the presence of emotional arousal, normally suppressing hunger and eating (Heatherton, Herman, & Polivy, 1991). Thus, although highly negative affective children might be at risk for emotional overeating, they might be just as likely to display more emotional *under*eating than less reactive children. We therefore hypothesize that greater negative affectivity will also be prospectively associated with more emotional undereating. Additionally, because fear, shyness and discomfort characterize negative affectivity and fear makes humans more reluctant to try new foods (Pliner, Pelchat, & Grabski, 1993) and possibly more likely to eat at a slower pace, we hypothesize that greater negative affectivity will be prospectively associated with more food fussiness and slowness in eating. As regards effortful control, which can be seen as a top-down self-regulatory- or control process (Bridgett, Burt, Edwards, & Deater-Deckard, 2015), we hypothesize that higher effortful control will predict lower food responsiveness, less emotional overeating, higher satiety responsiveness and slowness in eating over time (i.e., better self-regulation of eating). Put simply; in today's western 'obesogenic' environment where food is easily accessible, we often have to decide actively whether, what and how much to eat – and those who have well-developed self-regulation abilities (i.e., high levels of effortful control) are probably more adept at regulating their intake according to their needs. The third temperamental dimension, surgency, concerns the child's approach and activity level (i.e., 'outgoing' children). Because highly surgent children are generally approach oriented and externally focused it is likely they will also behave in such a manner with regard to their eating, i.e., being 'food approaching' as opposed to 'food avoidant': Display interest in food, have more desire to drink, be willing to try new food, be easily triggered by external food cues and eat at a faster pace. We therefore hypothesize that children high in surgency will demonstrate more 'food approach' behavior (i.e., greater enjoyment of food, food responsiveness, emotional overeating and desire to drink), whereas children low in surgency will become more 'food avoidant' (i.e., more food fussy, eating at a slower pace) over time.

2. Materials and methods

2.1. Participants and procedure

The 2003 and 2004 birth cohorts (N = 3,456) living in Trondheim, Norway, and their parents, were invited to participate in the Trondheim Early Secure Study (TESS) (Steinsbekk & Wichstrom, 2018), which the present study is built on. Because the primary aim of TESS was to assess mental health, parents also received the Strengths and Difficulties Questionnaire (SDQ) (Goodman, 1997) version 4–16, a brief measure of emotional and behavioral problems, in addition to the invitation letter. Parents brought the completed SDQ when they attended the well-child clinic for the routine health check at age 4 years, and the health nurse obtained the parents' written consent to participate (5.2% of eligible parents were missed being asked) (n = 2,475). Procedure and flow of participants are presented in Fig. 1, and additional details can be found in Steinsbekk and Wichstrom (2018). Because almost all children in the two cohorts appeared at the city's well-child clinic (97.2%) for the health check-up (age 4), the sample is effectively a community sample. To increase sample variability, children with higher SDQ scores (i.e., more problems) were oversampled. In doing so, children were allocated to four strata according to their SDQ scores (cut-offs: 0–4, 5–8, 9–11, and 12–40), and the probability of selection increased with increasing SDQ scores (0.37, 0.48, 0.70, and 0.89 in the four strata, respectively).

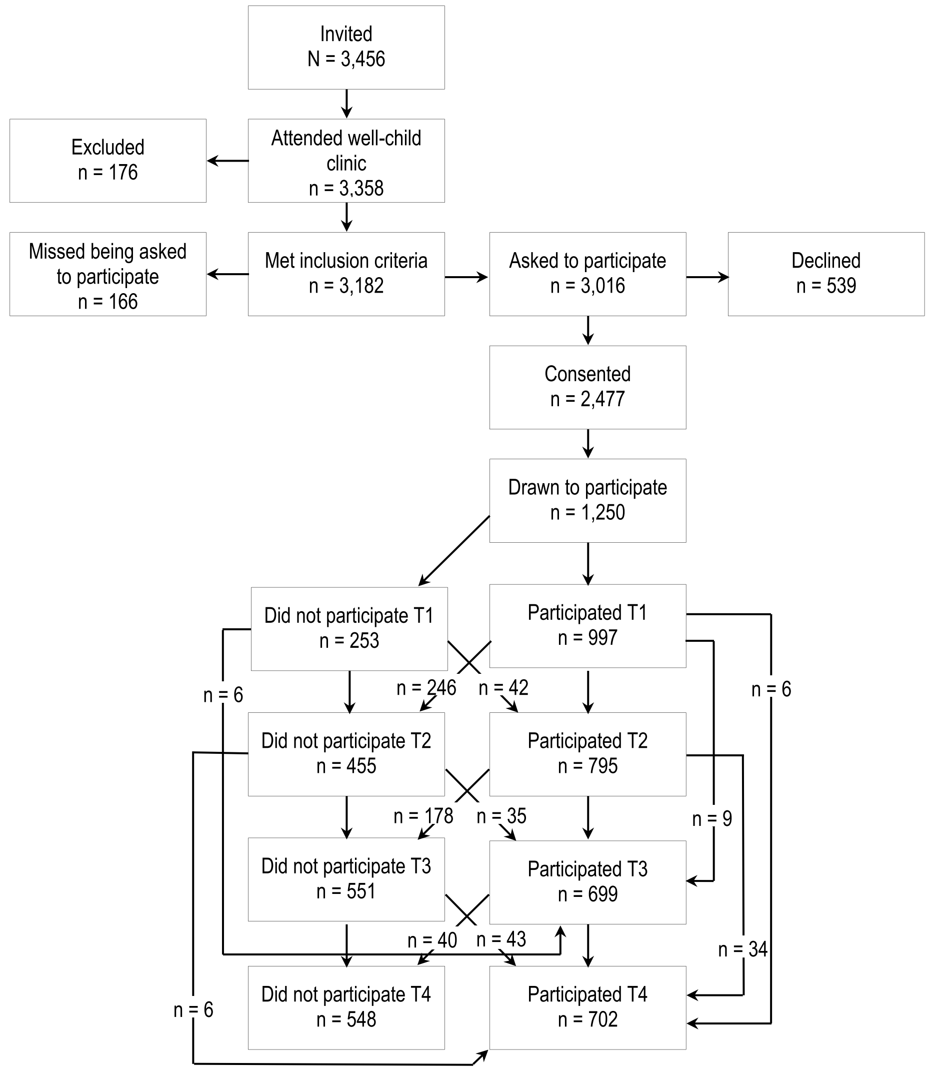

Fig. 1. Procedure and flow of participants.

To produce appropriate population estimates, we accounted for this oversampling in the statistical analyses applied (see Results). As can be seen in Figs. 1 and 997 children participated at Time 1 (T1) (50.9% female, 49.1% male) and their mean age was 4.7 years (SD =.30). The corresponding numbers for the following data collections were: Time 2 (T2): n = 795; M_{age} = 6.7 years, SD=.17; Time 3 (T3): n = 699; M_{age} = 8.8 years, SD =.24; Time 4 (T4): n = 702; M_{age} = 10.51 years, SD =.17. Baseline (T1) characteristics revealed that the majority of participating parent informants were ethnic Norwegians (93.0%) or of Western origin (5.6%), married or cohabitants (89.1%), and mostly mothers (84.4%). At T1, 5.7% of the informants were leaders; 25.7% were higher level professionals, whereas 39% were lower level professionals; 26% were formally skilled workers; 0.5% were farmers/fishermen and 3.1% were unskilled workers. Differences in rates of occupations between the present sample and the Norwegian parent population were negligible, and never exceeded 3.6% (Statistics Norway). The sample was also comparable with the Norwegian parent population with regard to the parents' level of education (Statistics Norway, 2012) and children's BMI (Juliusson et al., 2013). All procedures were approved by the Regional Committee for Medical and Health Research Ethics, Mid Norway.

2.2. Measures

Eating behavior was measured using the Norwegian version of the Children's Eating Behaviour Questionnaire (CEBQ) (2001) at ages 6, 8 and 10, and all subscales were included: Food Responsiveness (range of internal consistency for age 6 to10: α = .65- 0.71; 5 items, e.g., "Even if my child is full, she/he finds room to eat her/his favorite food"); Enjoyment of Food (α = .81-0.83; 4 items, e.g., "My child enjoys eating"); Emotional Overeating (α = .75-0.77; 4 items, e.g., "My child eats more when worried"); Emotional undereating (α = .75-0.78; 5 items, e.g., "My child eats less when upset"); Satiety Responsiveness (α = .70-0.74; 5 items, e.g., "My child gets full easily"); Food Fussiness (α = .89-0.90; 6 items, e.g., "My child is difficult to please with meals"); Slowness in Eating (α = .70-0.72; 4 items, e.g., "My child eats slowly"); and Desire for Drinks (α = .65-0.71; 3 items, e.g., "My child is always asking for a drink"). The CEBQ has been validated using objective measures of eating behavior (Carnell & Wardle, 2007), and it has been shown to have good test-retest reliability (Wardle, Guthrie, Sanderson, & Rapoport, 2001).

Temperament was assessed by the Norwegian version of the parent-reported Children's Behavior Questionnaire (CBQ) (Rothbart, Ahadi, Hershey, & Fisher, 2001). The 195 items are rated on a 7-point Likert scale (1 = "Extremely untrue of your child"; 7 = "Extremely true of your child"). The three overarching dimensions of the CBQ were used: (1) Negative affectivity, which consists of the subscales Anger/Frustration, Discomfort, Fear, Sadness and Soothability; (2) Surgency, containing the subscales Impulsivity, High Pleasure, Activity Level, Shyness; (3) Effortful control which includes the subscales Attentional

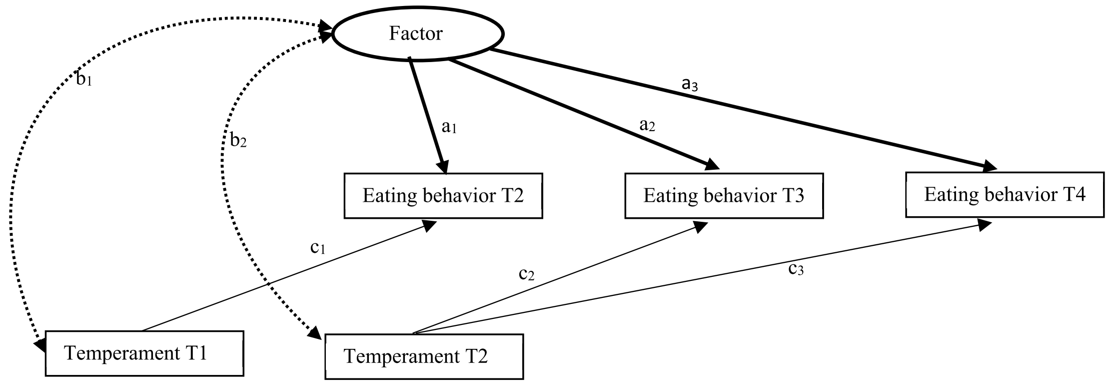

Fig. 2. The hybrid fixed/random effects model: Cross-lagged part (normal font) and time-invariant factor part (in bold)
Note: Presentation of the analytical model tested. T1: Age 4; T2: Age 6; T3: Age 8; T4: Age 10. Note that the model is abbreviated for illustrative purposes. Due to the high number of parameters to be estimated relative to the number of children, a model for each of the eating behaviors in question was created (i.e., 6 models). Each model consists of 1 time-invariant factor, 1 eating behavior (measured at T2, T3, T4) and 3 temperamental traits (Measured at T1,T2) (Results: see Table 2). The "latent factor" is a time-invariant factor that loads on the respective factor, e.g., on 'Food responsiveness'. In random effects models, the correlations between temperament (i.e., predictors) and the time-invariant factor are fixed to zero, whereas in fixed models these correlations are freely estimated. In a hybrid model, the temperamental dimensions shown to be uncorrelated with the time-invariant factor are fixed, whereas those who are associated with the latent factor are freely estimated. Time-invariant factor part (a) and fixed (b)/random; (c) cross-lagged paths. In all models, temperamental factors (i.e., negative affectivity, surgency, and effortful control) are allowed to correlate with each other and with eating behavior (not shown).

Focusing, Attentional Shifting, Inhibitory Control, Low Pleasure and Perceptual Sensitivity. At age 6, the short version of the CBQ (SF-CBQ) (Putnam & Rothbart, 2006) was used. Internal consistency was high at both time points (Negative affectivity: Age 4: $\alpha = .88$; Age 6: $\alpha = .81$) (Effortful control: Age 4: $\alpha = .84$; Age 6: $\alpha = .75$) (Surgency: Age 4: $\alpha = .92$; Age 6: $\alpha = .83$).

2.3. Statistical analyses

To adjust for all potential unmeasured confounding variables, we conducted a fixed effects regression analyses within a structural equation modelling (SEM) framework (Allison, 2009; Bollen & Brand, 2010; Firebaugh et al., 2013) (for a more detailed description of this method see supplementary material). SEM has the advantage of offering flexibility in specifying the relationship between model parameters to arrive at a best-fitting model, while effectively handling missing data. Fig. 2 illustrates the fixed effects model tested (details of the model fitting procedure is displayed in supplemental material). Due to the high number of parameters to be estimated relative to the number of children, not all eating behaviors could be analyzed in one model. Separate models for each of the eight eating behaviors were therefore created. In each model, eating behavior (e.g., Food Responsiveness) at ages 8 and 10 was regressed on temperament (i.e., negative affectivity, effortful control and surgency) at age 6, whereas eating behavior at age 6 was regressed on temperament at age 4. To include unmeasured time-invariant effects and thus adjust for them, a fixed effects part was added to each model by constructing a latent variable loading on the eating behavior in question. This latent time-invariant variable was allowed to correlate with temperament at age 6, whereas the correlations with temperament at age 4 were set to zero (because these must be considered exogenous variables given that eating behavior (i.e., outcome variable) was measured from age 6 onwards). Temperament variables at all time points were allowed to correlate and age-6 temperament was allowed to correlate with concurrent eating behavior. In addition, because we hypothesized that the influence of temperament on eating behavior would increase with age, Satorra-Bentler qhi-square tests (Satorra & Bentler, 2001) were used to examine such age differences by comparing the paths from temperament at age 4 to eating behavior at age 6 with the corresponding age 6 to 8 paths.

When modeling the hypothesized paths from temperament to eating behavior, we examined whether random or fixed effects fit the data best. Because of their exclusive reliance on within-person variance, fixed effects models have limited statistical power. In contrast, a random effects model utilizes between-person variance as well and is thus statistically more powerful but presupposes that the predictors are uncorrelated with the latent time-invariant factor – which may not necessarily be true. We therefore compared the random effects models to the fixed effects models, testing differences in χ^2. However, because differences in χ^2 do not follow a χ^2 distribution when a robust maximum likelihood estimator is applied, Satorra-Bentler's scaled χ^2 was used (Satorra & Bentler, 2001); which thus becomes a functional equivalent to the Hausmann test (Allison, 2009). Furthermore, hybrid models (i.e., models where insignificant correlations between predictors and the fixed latent variable are set to zero) retain the fixed effects advantage while preserving statistical power (Allison, 2009; Firebaugh et al., 2013), and we therefore tested whether a hybrid model would deteriorate model fit compared to fixed or random effects models. Furthermore, the importance of time-invariant factors (e.g. genetics) can change with development (Roberson-Nay et al., 2015), thus we tested whether a model allowing the effects of time-invariant factors to vary over time is better fitted to the data than a more parsimonious model where factor loadings are identical over time points.

Parental socioeconomic status was neither associated with temperament nor eating behavior and was therefore not included as a confounder in the analysis.

3. Results

Descriptives are displayed in Tables 1 and 2, whereas bivariate correlations between all study variables are presented in supplemental material (Table S1). The results of the model fitting procedure (Table 3) (Description of the procedure in supplemental material) revealed that for 'Enjoyment of food', 'Satiety responsiveness' and 'Food fussiness' a random effects model (M2) should be preferred, whereas a hybrid

Table 1
Estimated means and confidence intervals of temperament variables (n = 802).

	Age 4		Age 6	
Temperament	Mean	95% CI	Mean	95% CI
Negative affectivity	3.63	3.59, 3.67	3.73	3.68, 3.77
Effortful control	4.91	4.88, 4.94	5.18	5.15, 5.22
Surgency	4.54	4.49, 4.58	4.31	4.27 4.36

Table 2
Estimated means and confidence intervals of eating behavior variables (n = 802).

	Age 6		Age 8		Age 10	
Eating behavior	Mean	95% CI	Mean	95% CI	Mean	95% CI
Food responsiveness	1.90	1.86, 1.93	1.87	1.82, 1.90	1.89	1.84, 1.93
Enjoyment of food	3.45	3.40, 3.48	3.50	3.44, 3.53	3.58	3.52, 3.62
Emotional overeating	1.33	1.29, 1.36	1.32	1.28, 1.35	1.34	1.30, 1.38
Desire to Drink	2.38	2.33, 2.43	2.19	2.14, 2.24	2.09	2.03, 2.13
Emotional undereating	2.63	2.58, 2.70	2.48	2.43, 2.55	2.39	2.32, 2.45
Satiety responsiveness	2.92	2.88, 2.96	2.80	2.77, 2.86	2.75	2.70, 2.79
Food fussiness	2.76	2.70, 2.82	2.67	2.63, 2.75	2.59	2.53, 2.66
Slowness in Eating	2.55	2.50, 2.60	2.41	2.36, 2.47	2.36	2.31, 2.41

model showed the best fit for 'Food responsiveness', 'Emotional overeating', 'Emotional undereating', 'Slowness in eating' and 'Desire to Drink'.

The parameter estimates from temperament to eating behaviors in each of the preferred models are shown in Table 4 (food approach behaviors) and Table 5 (food avoidant behaviors). At all time points examined, negative affectivity significantly predicted higher levels of food responsiveness, emotional overeating, emotional undereating, satiety responsiveness, food fussiness, slowness in eating and desire to drink, even when all unmeasured time-invariant confounders were accounted for. Enjoyment of food was the only eating behavior prospectively unrelated to negative affectivity, but this eating behavior was

Table 3
Results of model fitting procedure.

	χ^2	df	p-value	$\Delta\chi^2$	df (diff.)	p-value	RMSEA[b] (90% CI)	SRMR[c]	CFI[d]	TLI[e]
Food responsiveness										
M1: Baseline model[a]	752.640	21	≤.000							
M2: Random effects	22.986	8	.003				.05 (.03, .07)	.04	.980	.946
M3: Fixed effects	13.999	5	.016	9.214	3	.027	.05 (.02, .08)	.04	.988	.948
M4: Hybrid model	**16.543**	**6**	**.011**	**2.450**	**1**	**.117**	**.05 (.02, .07)**	**.04**	**.986**	**.950**
Enjoyment of food										
M1: Baseline model[a]	774.165	21	≤.000							
M2: Random effects	**6.019**	**8**	**.645**				**.000 (.00, .03)**	**.03**	**.1.000**	**1.007**
M3: Fixed effects	4.701	5	.454	1.052	3	.789	.000 (.00, .05)	.03	1.000	1.002
Emotional overeating										
M1: Baseline model[a]										
M2: Random effects	23.872	8	.003				.05 (.03., 07)	.03	.968	.916
M3: Fixed effects	13.069	5	.023	11.421	3	.010	.05 (.02, .08)	.03	.984	.931
M4: Hybrid model	**16.252**	**6**	**.013**	**3.323**	**1**	**.068**	**.05 (.02, .07)**	**.03**	**.979**	**.927**
Desire to drink										
M1: Baseline model[a]	469.19	21	≤.000							
M2: Random effects	26.417	8	.001				.05 (.03, .08)	.03	.959	.892
M3: Fixed effects	17.273	5	.004	9.115	3	.028	.05 (.03, .09)	.03	.973	.885
M4: Hybrid model	**18.447**	**7**	**.010**	**1.413**	**2**	**.493**	**.05 (.02, .07)**	**.03**	**.974**	**.923**
Emotional undereating										
M1: Baseline model[a]										
M2: Random effects	24.780	8	.002				.05 (.03, .08)	.03	.966	.910
M3: Fixed effects	8.956	5	.111	17.271	3	.001	.03 (.00, .06)	.02	.992	.966
M4: Hybrid model	**12.177**	**7**	**.095**	**3.160**	**2**	**.206**	**.03 (.00, .06)**	**.03**	**.989**	**.968**
Satiety responsiveness										
M1: Baseline model[a]	668.555	21	≤.000							
M2: Random effects	**26.545**	**8**	**≤.000**				**.05 (.03, .08)**	**.05**	**.971**	**.925**
M3: Fixed effects	19.073	5	.002	5.787	3	.122	.06 (.03, .09)	.05	.978	.909
Food fussiness										
M1: Baseline model[a]										
M2: Random effects	**26.954**	**8**	**≤.000**				**.05 (.03, .08)**	**.03**	**.982**	**.953**
M3: Fixed effects	21.707	5	≤.000	2.799	3	.424	.07 (.04, .09)	.03	.984	.934
Slowness in eating										
M1: Baseline model[a]	662.93	21	≤.000							
M2: Random effects	24.660	8	.002				.05 (.03, .07)	.04	.974	.932
M3: Fixed effects	15.262	5	.009	9.466	3	.023	.05 (.02, .08)	.03	.984	.933
M4: Hybrid model	**16.951**	**7**	**.018**	**0.554**	**2**	**.758**	**.04 (.02, .07)**	**.03**	**.984**	**.953**

Note. All models are nested and compared with the next model (i.e., random models are compared with fixed models, fixed models are compared with hybrid models); $\Delta\chi^2$ is corrected according to Satorra-Bentler's procedure; preferred model in bold. [a] The baseline model is an unstructured model (null model/null hypothesis) assuming zero covariation between the observed variables; [b] Root mean square error of approximation; [c] Standardized root mean square residual; [d] Comparative fit index; [e] Tucker Lewis index.

Table 4
The paths from temperament to eating behaviors – ‘food approach’ subscales.

	Food responsiveness				Enjoyment of food				Emotional overeating				Desire to drink			
Temp.	*B*	95% CI	*β*	*p*	*B*	95% CI	*β*	*p*	*B*	95% CI	*β*	*p*	*B*	95% CI	*β*	*p*
								Age 6								
Negative affectivity age 4	**.10**	**.03, .17**	**.10**	**.008**	-.08	-.16, .01	-.06	.088	**.09**	**.02, .16**	**.09**	**.014**	**.13**	**.01, .24**	**.09**	**.034**
Effortful control age 4	**-.10**	**-.18, -.01**	**-.08**	**.027**	**.20**	**.11, .30**	**.15**	**≤.001**	-.05	-.13, .02	-.05	.164	-.05	-.18, .08	-.03	.414
Surgency age 4	.01	-.05, .07	.02	.652	.02	-.05, .09	.02	.565	-.02	-.08, .03	-.03	.411	-.00	-.09, .08	-.00	.936
								Age 8								
Negative affectivity age 6	**.19**	**.12, .27**	**.23**	**≤.001**	-.05	-.13, .30	-.05	.217	**.19**	**.12, .26**	**.24**	**≤.001**	**.15**	**.06, .24**	**.14**	**.002**
Effortful control age 6	-.08	-.16, .01	-.08	.074	**.19**	**.10, .29**	**.17**	**≤.001**	**-.11**	**-.20, -.03**	**-.13**	**.012**	**-.18**	**-.31, -.04**	**-.15**	**.010**
Surgency age 6	**.09**	**.03, .15**	**.12**	**.002**	**.08**	**.01, .15**	**.09**	**.018**	.00	-.06, .06	.00	.970	.05	-.04, .14	.05	.277
								Age 10								
Negative affectivity age 6	**.21**	**.13, .29**	**.23**	**≤.001**	-.05	-.14, .03	-.05	.218	**.22**	**.14, .29**	**.27**	**≤.001**	**.16**	**.07, .25**	**.14**	**≤.001**
Effortful control age 6	-.06	-.16, .03	.06	.179	**.22**	**.13, .31**	**.18**	**≤.001**	-.09	-.18, .00	-.10	.062	-.11	-.23, .02	-.08	.102
Surgency age 6	.06	-.01, .13	.07	.073	.05	-.02, .12	.05	.185	.02	-.05, .08	.02	.620	**.09**	**.01, .17**	**.09**	**.034**

Note. For ‘Food responsiveness’, ‘Emotional overeating’, and ‘Desire to drink’, results from the preferred hybrid model (M4) (Table S1) are displayed, whereas for ‘Enjoyment of food’, the results of the preferred random model (M2) is presented. *B* = unstandardized beta coefficients; *β* = standardized beta coefficients.

Table 5
The paths from temperament to eating behaviors – ‘food avoidant’ subscales.

	Emotional undereating				Satiety responsiveness				Food fussiness				Slowness in eating			
Temperament	*B*	95% CI	*β*	*p*	*B*	95% CI	*β*	*p*	*B*	95% CI	*β*	*p*	*B*	95% CI	*β*	*p*
								Age 6								
Negative affectivity age 4	**.32**	**.19, .46**	**.20**	**≤.001**	**.13**	**.05, .21**	**.12**	**.001**	**.19**	**.08, .30**	**.12**	**.001**	**.11**	**.00, .22**	**.08**	**.045**
Effortful control age 4	.02	-.12, .16	.01	.764	-.02	-.11, .11	-.01	.755	**-.13**	**-.26, .00**	**-.07**	**.050**	.03	-.08, .14	.02	.577
Surgency age 4	-.08	-.17, .02	-.06	.139	-.04	-.10, .03	-.04	.242	-.07	-.16, .02	-.06	.108	**-.13**	**-.21, -.05**	**-.12**	**.001**
								Age 8								
Negative affectivity age 6	**.39**	**.25 .53**	**.30**	**≤.001**	**.12**	**.05, .20**	**.13**	**.001**	**.21**	**.11, .32**	**.16**	**≤.001**	**.22**	**.11. .32**	**.20**	**≤.001**
Effortful control age 6	.06	-.08, .19	.04	.408	-.01	-.10, .08	-.01	.805	**-.19**	**-.31, -.07**	**-.13**	**.002**	**.14**	**.04, .25**	**.12**	**.007**
Surgency age 6	.06	-.04, .19	.05	.256	**-.08**	**-.15, -.01**	-.10	**.023**	**-.13**	**-.22, -.04**	**-.11**	**.003**	-.04	-.12, .03	-.04	.285
								Age 10								
Negative affectivity age 6	**.43**	**.30, .56**	**.31**	**≤.001**	**.09**	**.01, .17**	**.09**	**.023**	**.22**	**.12, .33**	**.16**	**≤.001**	**.24**	**.13, .34**	**.21**	**≤.001**
Effortful control age 6	.08	-.06, .26	.05	.256	-.02	-.11, .08	-.01	.730	**-.26**	**-.38, -.13**	**-.16**	**≤.001**	**.14**	**.04, .24**	**.11**	**.005**
Surgency age 6	.07	-.03, .16	.05	.168	**-.08**	**-.15, -.01**	**-.09**	**.035**	**-.10**	**-.20, -.01**	**-.08**	**.034**	**-.12**	**-.19, -.04**	**-.12**	**.001**

Note. For ‘Emotional undereating’ and ‘Slowness in eating’, results from the preferred hybrid model (M4) (Table S1) are displayed, whereas for ‘Satiety responsiveness’ and ‘Food fussiness’, the results of the preferred random model (M2) is presented. *B* = unstandardized beta coefficients; *β* = standardized beta coefficients.

significantly predicted by higher levels of effortful control, as was slowness in eating (ages 6 to 8 and 8–10 years). Lower effortful control, on the other hand, predicted more food fussiness at all time points, as well as greater food responsiveness from ages 4 to 6, emotional overeating and desire to drink from ages 6 to 8. Children higher on surgency at age 6 were more likely to enjoy food more and be more food responsive but displaying less satiety responsiveness and less food fussiness at age 8. The diminished satiety responsiveness and food fussiness were also still evident at age 10 (Table 5). Surgent children also displayed more rapid eating over time, apart from the age 6–8 years lag (Table 5).

Age-differences in the associations (age 4–6 years compared to age 6–8 years) were also observed: The prospective relationships between negative affectivity and food responsiveness and emotional overeating became stronger over time (Food responsiveness: $\Delta\chi 2 = 5.781$, df (diff.) = 1, p = .016; Emotional overeating: $\Delta\chi 2 = 7.150$, df (diff.) = 1, p = .007). The association between food responsiveness and surgency also increased with age ($\Delta\chi 2 = 7.007$, df (diff.) = 1, p = .008), whereas slowness in eating was less strongly associated with surgency by increasing age ($\Delta\chi 2 = 4.822$, df (diff.) = 1, p = .028). The positive association between effortful control and slowness in eating, on the other hand, increased with age ($\Delta\chi 2 = 3.878$, df (diff.) = 1, p = .049). No further age-differences were found.

4. Discussion

This study aimed to establish whether temperament is involved in the etiology of eating behavior in middle childhood, by studying a sample of Norwegian 4-year olds followed up at ages 6, 8 and 10, and applying a statistical approach that accounts for all unmeasured time-invariant confounders (e.g., genetics). We found that higher negative affectivity predicted higher levels of food responsiveness, emotional overeating, emotional undereating, satiety responsiveness, food fussiness, slowness in eating and desire to drink. Lower effortful control predicted more food fussiness, food responsiveness, emotional overeating and desire to drink, whereas higher effortful control predicted more enjoyment of food and slowness in eating, although not consistently through all time-points. Higher levels of surgency was prospectively associated with more enjoyment of food and food responsiveness, as well as lower satiety responsiveness, food fussiness and slowness in eating, but again, not consistently through all time-points.

4.1. Negative affectivity

The results indicated that among the three temperamental dimensions examined, negative affectivity was the one most consistently related to eating behavior, which accords with a previous cross-sectional study of pre-schoolers capturing several temperamental dimensions (Haycraft et al., 2011). As hypothesized, over time, negative affectivity predicted more emotional over- and undereating, food fussiness, slowness of eating and desire to drink. Although emotional distress may trigger eating (e.g., for those who have learned that eating soothes negative emotions (Kaplan & Kaplan, 1957)), the most natural response to distress is to eat less because gut activity decreases in the presence of emotional arousal, normally suppressing hunger and eating (Heatherton et al., 1991; Van Strien & Ouwens, 2007), possibly explaining why negative affectivity forecast both emotional over,- and undereating. Research does show that emotions can both increase and decrease food intake, but less is known about which emotional or individual characteristics predict more or less eating (Macht, 2008). It might be, for example, that highly negative reactive children eat more under positive circumstances and less during negative ones, being especially malleable to environmental influences, for better or worse, as suggested by the differential susceptibility hypothesis (Belsky & Pluess, 2009).

The fact that fear makes humans more reluctant to try new foods (Pliner et al., 1993) and that negative affectivity is characterized by fear and related constructs such as shyness and discomfort may explain why highly negative affective children become more food fussy over time. Interestingly, negative affectivity also predicted more food responsiveness and higher satiety responsiveness, the latter association possibly being due to high satiety sensitivity indicating a poorer or smaller overall appetite. This also fits with the finding that negative affectivity predicted more slowness in eating (i.e., eating slower if reduced appetite), which has also been found in a former study of young children (Haycraft et al., 2011). Although further studies are needed before conclusions can be drawn, the same physiological mechanism as described above might therefore explain the relationship between negative affectivity and satiety responsiveness and slowness in eating finding (i.e., emotional arousal – decreased gut activity – reduced appetite).

4.2. Effortful control

Children with lower levels of effortful control were more food responsive (from ages 4 to 6), displayed more emotional overeating (from ages 6 to 8) and were less fussy (through all time spans) about food two years later. Higher levels of effortful control, on the other hand, predicted more enjoyment of food and a slower eating pace (from ages 6 to 8 and 8 to 10); in line with this finding, a link has previously been reported between behavioural inhibition (i.e., the ability to inhibit behavior) and slowness in eating (Vandeweghe, Vervoort, Verbeken, Moens, & Braet, 2016). The relationship between effortful control and enjoyment of food might seem surprising though, given that enjoyment of food is also considered to be a food-approach behavior. Although they are positively associated, greater 'food responsiveness', in contrast to 'enjoyment of food', is indicative of less self-regulated eating. Children high on temperamental effortful control may indeed enjoy food, but still be better at self-regulating their food intake because they have the ability to withhold impulses (i.e., inhibition) and re-direct behavior (Rothbart & Bates, 2006), and thus display lower food responsiveness.

In contrast to what we expected, satiety responsiveness was unaffected by children's effortful control. Satiety responsiveness, or 'fullness' sensitivity (Carnell & Wardle, 2008) has a strong genetic basis (Carnell, Haworth, Plomin, & Wardle, 2008; Llewellyn, Trzaskowski, van Jaarsveld, Plomin, & Wardle, 2014; Llewellyn, van Jaarsveld, Johnson, Carnell, & Wardle, 2010) and reflects the homeostatic appetite system; this controls hunger and satiety according to energy needs, primarily via the melanocortin pathway, which is regulated by hormones that signal shorter- and longer-term energy balance (e.g., gut hormones released periodically in response to energy intake, and adiponectins produced by adipose tissue) (Anderson et al., 2016). The biological basis of satiety sensitivity may make it less amenable to modification by psychological processes such as effortful control. Food approach behaviors such as food responsiveness, on the other hand, are regulated by the hedonic appetite system (i.e., 'eating for pleasure'), which involve the neuropsychological processes of wanting and liking, regulated by the dopamine pathways, and the opioid and endocannabinoid systems (Zheng & Berthoud, 2008). Food responsiveness may thus be more likely to be affected by psychological factors such as effortful control. In summary, our study extends the existing cross-sectional research that has shown effortful control (or corresponding concepts/phenomenon such as executive function and self-regulation) to correlate with 'food approach' behavior (Godefroy et al., 2016; Leung et al., 2014). One may argue that common underlying neurobiological functions (i.e., the genetic basis of executive functions) might influence both, but our findings indicate that effortful control also predicts 'food approach' behaviours independently of such time invariant factors.

4.3. Surgency

Our results further revealed that higher surgency may promote more 'food approach' ('Food responsiveness', 'Enjoyment of food'; from age 6–8 years; 'Desire to drink'; from age 6–10 years) and less 'food avoidant' behavior ('Food fussiness', 'Satiety responsiveness'; from ages 6 to 8 and 6–10 years; 'Slowness in eating': from ages 4 to 6 ang 8–10 years), as we hypothesized. No former longitudinal studies of surgency and 'food approach' behavior exist, but our finding corresponds to earlier research reporting cross-sectional associations between surgency and 'food approach' behaviors (e.g., food responsiveness) (Leung et al., 2016). Even though replications are needed, it might be that the outgoing, explorative style of surgent children, akin to 'openness to experience' in adult personality, do cause them to be more open towards novel food experiences as well (i.e., less food fussiness) and to enjoy food more, which might also cause them to be more prone to eat in response to external food cues, and eat at a faster pace. Highly surgent children whose focus is on the outside world might also be less sensitive to inner signals, such as those of fullness, and therefore display lower levels of satiety responsiveness, compared to less surgent children.

We hypothesized that the prospective relationships between temperament and eating behaviors would strengthen with age, which was confirmed with regards to the association between negative affectivity and food responsiveness and emotional overeating, respectively. Other age-related increases in associations were also observed; surgency was a stronger predictor of food responsiveness from age 6–8 years as compared to the years from age 4 to 6, and the magnitude of the association between effortful control and slowness in eating also increased with age. However, one exception was revealed - the associated between surgency and slowness in eating weakened by age. Our findings may indicate that as children take more responsibility for their own eating as they mature (i.e., less parental control), their inner dispositions such as temperament are able to play a greater role in shaping their own eating behavior.

Unmeasured time-invariant factors, such as changes in parenting over time may also affect both temperament and eating behavior, and thus produce spurious associations between them. For example, parental sensitivity is associated with fussiness in children (Steinsbekk, Bonneville-Roussy, et al., 2017), a parent characteristic that may vary over time (Dallaire & Weinraub, 2005) and which is also linked to the development of temperament (Parade, Armstrong, Dickstein, & Seifer, 2018). Furthermore, parental stress can vary over time and may undermine the development of effortful control (Gartstein, Bridgett, Young, Panksepp, & Power, 2013), and stress is also associated with higher levels of food responsiveness in children (Boswell, Byrne, & Davies, 2018) and might thus have contributed to the associations between temperament and eating behavior found here. We have previously shown that negative affectivity predicts emotional feeding and emotional eating in children, the latter two being reciprocally related (Steinsbekk, Barker, et al., 2017). In sum, a range of factors may interact and change over time, to influence eating behavior.

4.4. Limitations

The present study has many strengths; a large community sample, longitudinal data, and the use of an analytical technique that allowed us to discount the influence of all unmeasured time-invariant confounders. Nevertheless, there were some limitations. Parents reported on both their child's temperament and eating behavior, which could have inflated associations between temperament and eating behavior due to common rater bias. Notably though, rater bias contains both transient/time-varying (e.g., mood-of-the-day effects) and more stable aspects (e.g., social desirability or acquiescence) (Moum, 1988) and because the latter part is partly time-invariant, this time-invariant aspect was accounted for in our hybrid fixed-effects approach. Furthermore, temperament was measured at ages 4 and 6, whereas eating behavior was measured at ages 6, 8, and 10. We could not therefore account for baseline levels of eating behavior when examining the associations between temperament and eating from age 4 to 6 and eating behavior at age 10 was predicted by temperament at age 6. However, both temperament and eating behavior are considered biologically based/dispositional characteristics displaying modest to moderate stability (Ashcroft, Semmler, Carnell, van Jaarsveld, & Wardle, 2008; Roberts & DelVecchio, 2000). Even so, prospective associations tend to decrease with increasing time span between predictor and outcome. Thus, the age 6 temperament to age 10 eating behavior paths may have been attenuated compared to the association obtained if we measured temperament at age 8. Furthermore, child temperament has its own origins, and merits separate studies that could complement the present one to provide a fuller picture of the temperament-eating association. Finally, although the influence of time-invariant factors (e.g., genetics) was ruled out, uncontrolled time-varying factors such as unstable aspects of parenting (e.g., changes due to the child's development, family situation) or negative life-events may affect both temperament and eating, and thus influence the results.

5. Conclusions

Following a community sample of 4-year-olds with biennial assessments until age 10, we found that negative affectivity was prospectively associated with a range of eating behaviors, whereas low effortful control may be involved in the development of 'food approach' behavior specifically. Surgency negatively predicted 'food avoidant' behavior and was inconsistently related to 'food approach' behavior. We add to existing research by using a longitudinal design, examining several different temperamental dimensions and eating behaviors in multivariate models and, perhaps most importantly, by using an approach that accounts for time-invariant factors such as genetics and common-methods effects. Our findings therefore indicate that temperament is involved in the etiology of eating behavior, and specific temperamental dimensions likely influence specific eating behaviors. Although temperament can be difficult to modify in order to promote healthy eating behavior in children, a recent obesity prevention study did show responsive parenting to reduce reported infant negativity and increase regulation (Anzman-Frasca et al., 2018). Raising awareness among caregivers that some eating behaviors are associated with higher risk for overweight and eating problems may help caregivers of highly negative affective children to be mindful of how feeding practices affect the development children's eating behavior and use such knowledge to promote healthy eating for their children.

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Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.appet.2020.104640.

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