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A healthy breakfast each and every day is important for students' motivation and achievement

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ABSTRACT

Breakfast is often cited as the most important meal of the day and vital for students' academic functioning at school. Although much research has linked students' breakfast consumption to better achievement, there has been debate about why and how breakfast has academic benefits. The present study of 648 Australian high school students investigated (a) the role of breakfast consumption and breakfast quality in students' self-reported motivation and their achievement in a science test, (b) the role of motivation in mediating the link between breakfast consumption and quality and students' achievement, and (c) the extent to which breakfast consumption effects are moderated by the quality of breakfast (e.g., more vegetables, fruit, dairy/protein, wholegrains, cereals, water; less sugary drinks, processed meat, fast take-away, unhealthy snack foods). Findings indicated that beyond the effects of personal, home, and classroom factors, breakfast consumption predicted higher adaptive motivation ($p < .05$), breakfast quality predicted lower maladaptive motivation ($p < .05$), and in turn, students' adaptive (positively, $p < .01$) and maladaptive (negatively, $p < .01$) motivation predicted their achievement. Moreover, adaptive motivation significantly mediated the relationship between breakfast consumption and achievement ($p < .05$). The effect of breakfast consumption was moderated by the quality of breakfast such that consuming a high-quality breakfast in the morning was associated with the highest levels of adaptive motivation ($p < .01$) and achievement ($p < .05$) later in the day. Findings have implications for educational practice and policy seeking to promote a healthy start to the school day to optimize students' motivation and achievement.

1. Introduction

In 1954, Davis (1954) recommended "Eat breakfast like a king, lunch like a prince, and dinner like a pauper" (p. 19), and since then, the view that breakfast is the most important meal of the day has attained the status of a near universal truth. Consumption of a healthy breakfast has frequently been linked to physical, cognitive, and social-emotional health and well-being in many facets of life (Reeves et al., 2013). The academic domain is no exception, with healthy breakfast consumption associated with increased learning and achievement (Jackson & Vaughn, 2019). In contrast to many factors that are predominantly beyond a student's control (e.g.,

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instruction, home background) or factors that can take time to improve (e.g., study skills), eating breakfast is something that students may have some immediate control over or that can be readily addressed at school (e.g., through curriculum-based health education, communication to the home, meals/snacks provided by the school). To the extent that breakfast is linked to students' motivation and achievement, this small and relatively achievable presence in a student's life has the potential to have a significant positive impact on their academic development (Hau, 2016). Thus, school psychologists and other educators could view the encouragement of students to have a healthy breakfast each day as a type of universal intervention.

1.1. Research purpose and foreseen yields

Research into breakfast patterns and links to academic outcomes is important because there are substantial numbers of adolescents making poor food choices at the start of the day or skipping breakfast altogether (Adolphus et al., 2013; Benton & Jarvis, 2007; Mhurchu et al., 2010; Rani et al., 2021; Van Horn et al., 2012; Yao et al., 2019). Additionally, relatively few studies have examined the breakfast habits of adolescents (see Hoyland et al., 2009, for a review). This developmental period is important to study because adolescents' rapid growth and changes in metabolism may lead to quite distinct breakfast effects (Cooper et al., 2012). Adolescents' schoolwork also tends to be more complex and more demanding than what they were responsible for as children, and this additional academic stress could alter nutritional effects on cognitive functioning (Cooper et al., 2012). There also is a lack of research on breakfast effects among adolescents in ecologically valid contexts, such as in-class tests (Adolphus et al., 2013). In these respects, adolescence is an important period in which to examine breakfast effects. In the present study, we considered breakfast in relation to students' motivation and achievement in science. Many students see science as a difficult and stressful school subject (Coe et al., 2008); furthermore, there have been declines in high school students' participation in science subjects in Australia, which is the context for the present study (Office of the Chief Scientist, 2014). It is also the case that in early to middle high school (Years 7–10), the development of behaviors, attitudes, and emotions in Science, Technology, Engineering, and Mathematics (STEM) coursework can shape STEM subject choices in senior high school (Martin et al., 2015). Thus, science represents an important domain in which to explore breakfast effects.

Our investigation addresses numerous research gaps that pose a barrier to fully understanding the role of breakfast patterns in adolescents' educational outcomes. First, research typically looks at the association between breakfast consumption and academic achievement, but overlooks potentially influential mediators, such as motivation, that may play a role in this link (Corcoran et al., 2016; Jackson & Vaughn, 2019). To the extent motivation is implicated, educational interventions that do not accommodate motivation will not be sufficiently effective or comprehensive. Second, research typically assesses breakfast consumption (i.e., whether a student eats breakfast) but not the impact of the nutritional quality of that breakfast on academic outcomes (Burrows et al., 2017; Ptomey et al., 2016). Third, there is limited research on breakfast effects among adolescents and in ecologically valid assessment contexts such as in-class tests (Adolphus et al., 2013). Fourth, relatively few studies have accounted for a comprehensive range of personal, home, and classroom factors that must be included in research designs to ascertain the unique effects of breakfast on motivation and achievement (Adolphus et al., 2013; Whatnall et al., 2019).

With a focus on adolescents in science classrooms, we attended to all four research gaps by investigating (a) the extent to which breakfast consumption and breakfast quality was associated with motivation and achievement, (b) the role of motivation in mediating the relationship between breakfast (consumption and quality) and achievement, (c) the extent to which breakfast consumption effects were moderated by the quality of breakfast, and (d) mediation and moderation effects after accounting for the influence of a comprehensive range of personal, home, and classroom attributes (i.e., covariates).

1.2. Key constructs in the present investigation

We draw diverse literatures together to investigate the role of breakfast consumption in students' motivation and achievement. To appropriately foreground the concepts and research to be reviewed, we first briefly explain key terms as relevant to this investigation.

1.2.1. Breakfast consumption and breakfast quality

Two key dimensions of breakfast that are the focus of most research include breakfast consumption and breakfast quality. *Breakfast consumption* refers to whether and/or how regularly breakfast is eaten. Relative to breakfast quality, defining and assessing breakfast consumption is not overly contentious. In the vast body of research and across multiple research domains (e.g., education, health), breakfast consumption refers to the consumption of the day's first meal after waking from a night's sleep (e.g., Yao et al., 2019). In most studies, breakfast consumption is operationalized in terms of whether breakfast was consumed that morning (i.e., a dichotomous No/Yes), but it can also be operationalized in terms of how many times in each period breakfast was consumed (i.e., an ordinal or continuous scale).

Breakfast quality typically refers to how healthy it is, and the definition of "healthy" can be a source of debate as scientific understanding of diet evolves (Cena & Calder, 2020). The purpose of the present study was not to engage with this debate per se, but instead posit that the quality of students' breakfast is best assessed in terms of the guidelines set in their national and public health contexts, and thus may most closely align with the messages (both implicit and explicit) that they receive about "healthy" breakfast. Our study is set in Australia, so we assess breakfast quality using the Australian Dietary Guidelines published by the National Health and Medical Research Council (NHMRC, 2013). This frames a healthy diet as comprising a sufficient daily quantity (see the NHMRC Guidelines for specified amounts) of vegetables, fruit, reduced-fat dairy, wholegrain cereals, small servings of lean meat or fish or eggs, and water, as well as low intake of take-away and snack foods high in saturated fats (e.g., pizza, deep fried food, burgers, pies), foods

and drinks high in sugar content (e.g., sweet bakery goods and energy and soft drinks) or salt content (e.g., highly processed foods). Thus, a breakfast comprising ingredients such as wholegrain toast with egg or lean meat, or reduced fat low-sugar yogurt, or natural oats muesli with reduced fat milk, or fruit would provide examples of a healthy breakfast in the Australian context.

1.2.2. Motivation

Motivation refers to the energy, drive, and inclination to learn (Martin, Ginns, Anderson, Gibson, & Bishop, 2021). Researchers have identified the yields of studying motivation from a multidimensional perspective—including positive and negative dimensions of motivation (Martin, 2023; Wigfield & Koenka, 2020). Researchers have consistently identified that positive and negative dimensions of motivation are not simply opposite ends of the same motivational spectrum (Martin, 2009); rather, positive and negative dimensions can occur, leading to differential outcomes for students (e.g., engagement, achievement). Said another way, optimizing students' motivation is not only about promoting adaptive dimensions (akin to the idea of "switching on" in academic engagement literature; Collie et al., 2019), but also about redressing any maladaptive motivation ("switching off"). Following prior motivation research in school science (Martin, Ginns, Burns, Kennett, Munro-Smith, et al., 2021; Martin, Ginns, Burns, Kennett, & Pearson, 2021; Martin, Kennett, et al., 2021), which is also the context for the present study, we adopted the multi-dimensional Motivation and Engagement Wheel (Martin, 2007, 2009) as the operational framework for the present research. The Wheel comprises six first-order factors subsumed under positive motivation (i.e., self-efficacy, valuing school, and mastery orientation) and negative motivation (i.e., anxiety, failure avoidance, and uncertain control). The Wheel is aligned with other conceptualizations from Pintrich (2003), who outlined major areas for an integrative motivational science that drew on theories of self-efficacy, attributions, valuing, control, self-determination, goal orientation, need achievement, and self-worth. Therefore (and as fully detailed elsewhere; e.g., Liem & Martin, 2012; Martin, 2009, 2013), (a) social-cognitive (self-efficacy) theory (Bandura, 2001) is reflected in the self-efficacy dimension of the Wheel, (b) attribution and control theories are reflected in the uncertain control dimension (Weiner, 2010), (c) situated expectancy value theory (Eccles & Wigfield, 2020) is seen in a valuing dimension, (d) self-determination theory (especially by way of intrinsic motivation; Ryan & Deci, 2000) and goal theory (Elliot, 2005) are reflected in a mastery orientation dimension, and (e) need achievement and self-worth theories (Covington, 2000) are reflected in failure avoidance and anxiety.

1.3. Theories and mechanisms: the how and why of breakfast effects

Theories and mechanisms explaining how and why breakfast (or diet more generally) impacts physical, cognitive, and social-emotional functioning traverse physiological and psychological domains (Bellisle, 2004). Indeed, the integration of these domains in understanding human behavior is not new, with major theories emphasizing the close links between "body and mind" (Blascovich, 2008; Martin, Kennett, et al., 2021; Schultheiss & Wirth, 2018). For example, biopsychological perspectives emphasize the importance of understanding the joint operation of physiological and psycho-social processes involved in how individuals navigate their world (e.g., Blascovich, 2008), including their academic life (Martin et al., 2023; Martin & Burns, 2023; Martin, Kennett, et al., 2021). Adopting an integrative approach that takes these processes into account augments practitioners' understanding of the most salient factors implicated in students' academic outcomes.

1.3.1. Physiological processes

The relationship between food intake and energy expense is an important one. When food is metabolized, the body produces glucose, a primary energy source relied on throughout the day. Therefore, eating breakfast is critical for the sustained release of glucose into the blood stream and to the brain through the morning (Mahoney et al., 2005; see Adolphus et al., 2013, Hasz & Lamport, 2012, and Rani et al., 2021, for reviews). Thus, for example, Murphy (2007; see also Adolphus et al., 2013) theorized that breakfast consumption provides the energy available for the cognitive processes involved in navigating the academic demands of a school day. A good quality diet can also correct nutritional deficiencies, such as iron and iodine deficiencies, that are involved in cognitive functioning that in turn impact academic performance (Adolphus et al., 2013). Whatnall et al. (2019) indicated that there are many nutrients known to have vital roles in brain function and development (e.g., folate, iron, omega 3) and the link between achievement and diet quality may be explained by better nutrient intakes (see also Hasz & Lamport, 2012; Hoyland et al., 2009; Masoomi et al., 2020; Peña-Jorquera et al., 2021).

Particularly relevant to the present study is the role of physiological aspects of diet in students' motivation. There is not a lot of research into this, but we infer from related constructs to draw relevant connections. For example, Mahoney et al. (2005) found that breakfast containing more fiber and protein was associated with differences in reported motivation. According to Widenhorn-Müller et al. (2008), breakfast impacts performance via the energy (that may be construed as motivation from a drive perspective) caused by the macronutrient composition of a meal. The concept of homeostatic energy regulation (to maintain energy levels) has been cited in relation to goal pursuit with, for example, Jackson and Vaughn (2019) finding that many people are driven to eat to acquire the necessary energy to achieve goals. Indeed, Jackson and Vaughn (2019) found that diet was associated with goals, with increased consumption of high-caloric foods being associated with aspects of motivation such as performance goals. Some foods that can be part of a good quality breakfast are also rich in elements that target serotonin receptors (Mahoney et al., 2005) that play a role in regulation of mood (Bamalan et al., 2022; Berger et al., 2009), thereby providing a potential explanation for how a quality breakfast (one part of a quality diet) may impact aspects of students' motivation such as their academic anxiety (Stuntz et al., 2017). Indeed, this latter point is part of our rationale for adopting a multidimensional motivation framework where maladaptive dimensions of motivation (such as anxiety) are included. Investigating the association between breakfast consumption/quality and both adaptive and maladaptive dimensions of motivation afforded a more comprehensive insight into breakfast effects and guarded against the risk of neglecting

important motivational constructs (e.g., academic anxiety) that play a notable role in students' academic experience.

1.3.2. Psychological processes

Many psychological theories, including psycho-educational theories, cite diet and/or food as influencers of motivational states and behavior. In early work, theorists and researchers identified satisfying physiological needs as the primary driver or goal of motivated behavior (e.g., Freud, 1933/1965; Hull, 1952; Maslow, 1943). For example, under drive theory, individuals are motivated to satisfy fundamental drives such as hunger and thirst (Hull, 1952). However, this and subsequent adaptations (e.g., Berlyne, 1950; Harlow, 1950) did not adequately explain the relationship between drives and intrinsic motivation. Consequently, a cognitively oriented shift in the field was suggested that unified the satisfaction of physiological needs with psychological needs. This substantially influenced theory and research in education and psychology. As a case in point, under self-determination theory, Deci and Ryan (1985) identified the importance of satisfying "primary tissue needs" (p. 21; also see Ryan & Deci, 2020) for intrinsic motivation and highlighted the need to eat for the regulation of energy expenditure as a "homeostatic urgency" (p. 234) that can disrupt intrinsic motivation if not met. Stuntz et al. (2017) accordingly found that healthier lifestyle patterns (including a healthy breakfast) impacted satisfaction of psychological needs and self-determined motivation that in turn led to enhanced behavior (that in our study is posited in terms of academic achievement).

1.4. Breakfast and academic achievement

Much of the school-based breakfast research investigates effects of breakfast consumption and quality on academic achievement and cognitive functioning. Breakfast consumption is positively associated with higher academic achievement and cognitive functioning among children and adolescents (see Adolphus et al., 2013, Hasz & Lamport, 2012, Illøkken et al., 2022, Liu et al., 2021, Mahoney et al., 2005, Murphy, 2007, Ptomey et al., 2016, and Yao et al., 2019, for research and reviews). Conversely, skipping breakfast has been associated with poorer memory and recall and interferes with adolescents' learning (Basch, 2011).

The quality of breakfast (as separate from its consumption) also impacts children's and adolescents' achievement and cognitive performance. Ptomey et al. (2016; see also Adolphus et al., 2013; Hasz & Lamport, 2012; Peña-Jorquera et al., 2021) found a positive link between the nutritional quality of food consumed (especially whole-grains) at breakfast and achievement, but their study was of young children; they recommended similar research be conducted among adolescents. Whatnall et al. (2019) found that a diet better aligned with nutritional guidelines (e.g., higher diet quality, such as those that include more vegetables and fruit) was associated with higher grade point averages (GPA) among university students, as did O'Dea and Mugridge (2012) with regards to literacy achievement among a sample of children in Grades 3–7. In contrast, high-calorie, nutrient-poor foods can impede performance (Cornil et al., 2020) and consumption of snack food and low nutrient-dense food (or a diet low in dairy content) was associated with poor school performance among adolescents (Faught et al., 2017).

The weight of evidence thus suggests a positive association between breakfast consumption and quality and academic achievement. Where breakfast is skipped or where the quality is questionable, there appears to be adverse implications for students' academic performance. We therefore hypothesized that breakfast consumption and quality would be positively associated with academic achievement in the present study.

1.5. Breakfast and academic motivation

We also posit that breakfast has implications for students' academic motivation. In most breakfast research, motivation is typically assessed by way of an inferred or implied motivation construct (e.g., school happiness, connectedness, mood at school) or in classic "drive" and physiological terms (e.g., energy, alertness). Using these inferred indicators of motivation, breakfast consumption has been associated with better psychosocial functioning among children at school (Mhurchu et al., 2010). Adolescent students have also reported more positive feelings, alertness, and interest in their schoolwork following breakfast consumption (Widenhorn-Müller et al., 2008), whereas regular breakfast intake has been associated with greater connectedness among adolescents at school (Sampasa-Kanyinga & Hamilton, 2017). However, it should be noted that there is less research examining "classic" motivational constructs, such as self-efficacy, that reside under educational and school psychology theories (see Pintrich, 2003, for review) and thus there is a need to further explore these associations.

Relatively less research has investigated the role of breakfast quality in students' motivation. Stuntz et al. (2017) indicated that eating fruit and vegetables was associated with psychological need satisfaction and intrinsic motivation among university students. Similarly, among adolescents, improving nutrition has been linked to motivation to learn (Basch, 2011), whereas a high-fiber breakfast has been associated with improved psychosocial functioning at high school (Godin et al., 2018). Mahoney et al. (2005) found that breakfast containing more fiber and protein led to greater alertness and motivation among elementary students. In contrast, a poor-quality breakfast has been associated with problematic motivation. For example, malnourished elementary students were more likely to be anxious (Murphy et al., 1998). Additionally, a poor nutrition breakfast has been associated with school disengagement and low academic expectations in childhood and adolescence (Jackson & Vaughn, 2019; Michael et al., 2015).

We expand on this research base by investigating breakfast and motivation in more well-established psycho-educational terms via adaptive motivation (comprising self-efficacy, valuing, and mastery orientation) and maladaptive motivation (comprising anxiety, failure avoidance, and uncertain control) consistent with psycho-educational research over the past 2 decades (e.g., Elphinstone & Tinker, 2017; Martin, 2009; Martin, Ginns, Anderson, Gibson, & Bishop, 2021; Plenty & Heubeck, 2013). Because there has been no breakfast research investigating these psycho-educational motivation constructs, we infer from the cognate research summarized

above to hypothesize a positive association between breakfast consumption and quality and students' adaptive motivation and an inverse association between breakfast consumption and quality and students' maladaptive motivation.

1.6. Does motivation mediate the link between breakfast and achievement?

Researchers have also suggested it is important to examine the extent to which breakfast may be linked to school students' achievement via key mediating factors (Corcoran et al., 2016). Motivation has been theorized as one mediator, often in terms of the improved energy and alertness afforded by the consumption of breakfast by children and adolescents (e.g., Adolphus et al., 2013; Murphy, 2007; Widenhorn-Müller et al., 2008). Prior research has also demonstrated that motivation is a key mediator between other personal (e.g., home life) and contextual factors (e.g., teacher-student relationships) and students' academic performance. It may be that motivation plays a similar mediating role for the effects of breakfast consumption and quality. The present study sought to expand on this by investigating the mediating role of motivation factors typically assessed under psycho-educational paradigms, including (a) adaptive motivation (e.g., self-efficacy, valuing, mastery orientation) and (b) maladaptive motivation (e.g., anxiety, failure avoidance, uncertain control; Martin, Ginns, Anderson, Gibson, & Bishop, 2021). Considering the research summarized above suggesting that breakfast is associated with motivation and prior research demonstrating that the adaptive and maladaptive motivation factors are positively and negatively (respectively) associated with academic achievement (see Liem & Martin, 2012, for a review), we hypothesized a significant indirect effect between breakfast and achievement via motivation in addition to the bivariate path between breakfast and achievement.

Diverse research has identified motivation as an important precursor to academic outcomes (e.g., engagement, achievement). For example, Reeve (2012) described how students' inner motivational resources allowed them to engage and perform in the classroom. Cleary and Zimmerman (2012) distinguished between 'will' and 'skill', with the former indicating motivation and the latter indicating performance-related dimensions. Schunk and Mullen (2012) detailed the energizing role of motivation and the impact of this on achievement. This motivation to achievement link may provide some insight into better explaining and understanding how breakfast is associated with achievement. Thus, in addition to the well-established physiological mediators involved in the link between breakfast and achievement (e.g., via cognitive functioning, mood), our study explored the potential role of motivational mediators to gain a more complete picture of how breakfast might influence achievement. The extent to which breakfast consumption and quality are associated with motivation and, in turn, achievement, provides information for educators on what factors may also be addressed to augment motivation interventions. Given that breakfast is amenable to effective educational policy and school practice (Hau, 2016), it constitutes a sustainable and scalable means to advance educators' motivation efforts.

1.7. Do the effects of breakfast consumption vary as a function of breakfast quality?

It is also possible that the effects of breakfast consumption for school students may vary as a function of its quality (Anzman-Frasca et al., 2015), suggesting the need to test for interactions between breakfast consumption and breakfast quality. For example, regular consumption of a high quality (vs. irregular consumption or a low quality) breakfast may have benefits for both motivation and achievement. A review of school performance by Taras (2005) found that a regular and high-quality breakfast enhanced cognitive functioning. Similarly, Adolphus et al. (2013) reported that frequency and quality of diet was positively linked to academic performance, particularly for undernourished children and adolescents (see also Antonopoulou et al., 2020, in relation to university students; Hoyland et al., 2009, in relation to elementary and high school students). We therefore tested the interaction between breakfast consumption that morning (No/Yes) and the quality of breakfast typically consumed (a continuous diet quality score). We hypothesized that consumption of a high-quality breakfast that morning (relative to a low-quality breakfast that morning or skipping breakfast) would be associated with more adaptive motivation and achievement.

1.8. Personal, home, and classroom factors important to accommodate

The links between breakfast and motivation, breakfast and achievement, and motivation and achievement (i.e., the key relationships in this study, see Fig. 1 and Fig. 2) must be disentangled from personal, home, and classroom factors that are known to be significantly implicated in students' academic development. Many studies of breakfast do not adequately account for enough covariates and confounds, which is a limitation that needs to be addressed to ascertain the unique effects of breakfast on students' academic outcomes (Adolphus et al., 2013; Whatnall et al., 2019). These variables may precede or co-occur with the consumption of breakfast and thus may explain variation in student motivation and achievement that must be accounted for when seeking to determine the unique effects of breakfast.

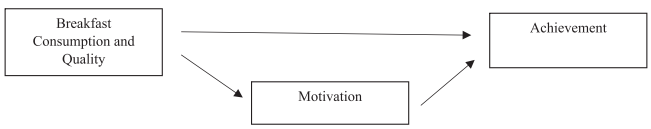

Fig. 1. The study's conceptual model.

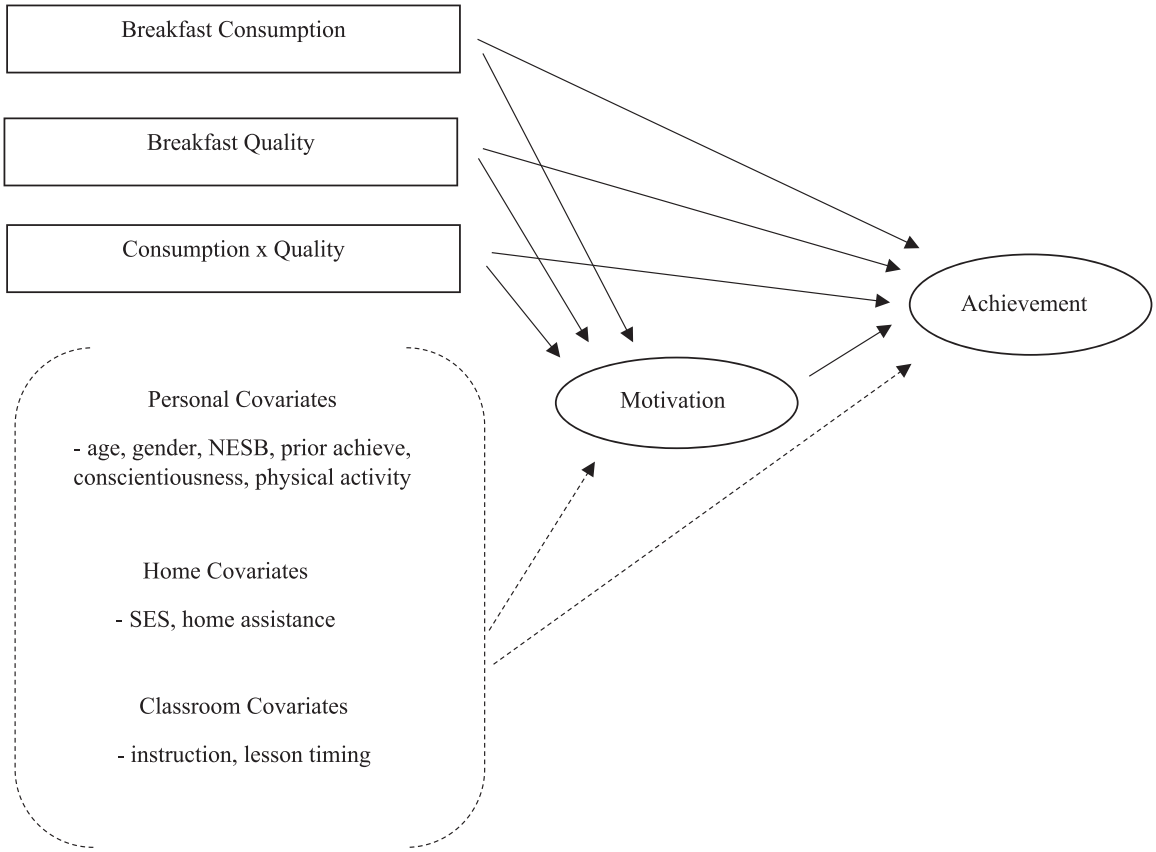

Fig. 2. The study's hypothesized model.
Note. Observed/single-item breakfast variables are represented in bolded rectangles. Latent motivation and achievement variables are represented in ellipses (as described in Materials, achievement was an error-adjusted score and thus depicted here in an ellipse). Covariates are represented in dashed parentheses (all were observed/single-item indicators except instruction, which was estimated as a 5-item latent factor). The breakfast variables were correlated and each predicted motivation and achievement. The covariates were correlated with each other and with breakfast consumption, breakfast quality, and the interaction to control for shared variance among them. Each covariate predicted motivation and achievement.

1.8.1. Personal factors

There are several background socio-demographic (e.g., age, gender, language background) and personal attribute (e.g., conscientiousness, prior achievement, physical activity) factors that are relevant to these processes that ought to be accounted for in modeling. Including age as a factor in our study is important because research reveals age-related declines in motivation (e.g., Burns et al., 2019; Fredricks & Eccles, 2002). There are also gender differences to recognize, with females in high school generally more motivated than males (Martin, 2009) and more likely to skip breakfast (Cohen et al., 2003). Given the Australian context for this research, non-English-speaking background (NESB) was also included as research has revealed mixed motivation (Martin et al., 2011) and achievement (Glick & Hohmann-Marriott, 2007) findings relating to language background. Students' psychological attributes also seem relevant. For example, it is unclear if breakfast is uniquely linked to motivation and achievement and/or whether students with conscientious and hardworking traits (who are also likely motivated and achieving; Ginns et al., 2014) tend to have more regular and healthier breakfast patterns (Hau, 2016); thus, conscientiousness was included in the present study to separate this personal trait from more situation-specific motivation and achievement. Additionally, prior achievement is identified as being related to subsequent motivation and achievement (Hattie, 2009), suggesting the need to account for students' prior academic performance when examining breakfast effects. Finally, given that metabolism and energy are implicated in breakfast effects, students' level of physical activity, which has metabolic consequences, is important to control for, especially given the positive links between students' physical activity and academic outcomes (Donnelly & Lambourne, 2011).

1.8.2. Home factors

Various home factors are also relevant to our focal variables. Researchers have identified socio-economic status (SES) as a factor positively associated with students' motivation (Martin, Ginns, Anderson, Gibson, & Bishop, 2021), achievement (Sirin, 2005), and food insecurity and students' access to quality breakfast (Dykstra et al., 2016). It has also been suggested that intrinsic motivation may be predicted more by time spent with and support from family than by breakfast intake (Tanaka & Watanabea, 2012), pointing to the

salient role of home assistance. In any case, home/parental support may also be correlated with provision and consumption of children's regular and healthy eating habits (Faber et al., 2018) and with motivation (George et al., 2012).

1.8.3. Classroom factors

Classroom factors are relevant to students' motivation and achievement and thus important to control for when seeking to ascertain the unique effects of breakfast on motivation and achievement. For example, improvements in motivation and achievement are known to be associated with instruction (Hattie, 2009). Interestingly, the nature of instruction may also be implicated in metabolic processes. More cognitively demanding tasks require an increase in metabolic resources to successfully perform them (Defeyter & Russo, 2013; Spence, 2017). Thus, teachers who do not adequately adjust instruction to the cognitive demands of academic tasks may yield differences in students' achievement that are in part a function of differences in their metabolic processes. This being the case, instructional practices that help students manage cognitive burden are relevant (Sweller, 2012). Load reduction instruction is one such pedagogical practice (Martin & Evans, 2018, 2021; Martin, Ginns, Burns, Kennett, Munro-Smith, et al., 2021; Martin, Ginns, Burns, Kennett, & Pearson, 2021) and was included in the present study as a covariate. In addition, because the metabolic effects of breakfast consumption vary throughout the course of the day, it is important to account for the timing of the lesson in which students' motivation and achievement are assessed (Stuntz et al., 2017). The present study did so by including lesson timing as a covariate as both a linear effect and a non-linear (quadratic) effect to account for a possible rise and fall (or fall and rise) through the school day.

1.9. Aims of the present study

Our aims for this study were to identify (a) the role of breakfast consumption and breakfast quality in high school students' motivation and achievement, (b) the role of motivation in mediating the link between breakfast and achievement, (c) the extent to which breakfast consumption effects are moderated by the quality of breakfast, and (d) these mediation and moderation effects after accounting for the influence of a comprehensive suite of personal, home, and classroom attributes (covariates). Fig. 1 shows the basic conceptual model guiding the study and Fig. 2 shows the detailed hypothesized model. We hypothesized that breakfast consumption and breakfast quality would positively predict adaptive motivation and inversely predict maladaptive motivation. We hypothesized that breakfast consumption and breakfast quality would positively predict achievement. We hypothesized a significant indirect relationship between breakfast (i.e., consumption and quality) and achievement via motivation. Finally, we hypothesized that consumption of a high-quality breakfast that morning (relative to a low-quality breakfast that morning or skipping breakfast) would be associated with more positive patterns of motivation and achievement.

2. Method

2.1. Participants and procedure

The lead researcher's university provided human ethics approval. Approval was then provided by school principals. Parents/caregivers and participating students then provided their consent. Participants in this study were 648 Australian high school students from five schools. The schools were in a major city in New South Wales (NSW) and from the independent (non-government) school sector. Two of these schools were single-sex boys' schools, two were single-sex girls' schools, and one school was co-educational. Sixty-one percent of students were boys. Students were in Year 7 (32%), Year 8 (35%), and Year 9 (33%), which are the first 3 years of high school in Australia. The mean age of students was 13.52 years (SD = 0.98). Eight percent of students spoke a language other than English at home (the largest group was Mandarin/Cantonese at 2.8%, followed by Spanish, German, Arabic, and Filipino/Tagalog each

Table 1
Correlations with substantive factors (from CFA).

	Breakfast Consumption	Breakfast Quality	Adaptive Motivation	Maladaptive Motivation	Achievement
Age	0.015	0.068	-0.092	0.108	0.031
Gender (Male/Female)	-0.159***	0.051	-0.071	0.261***	-0.048
NESB (No/Yes)	0.061*	-0.063	0.141***	-0.117*	0.132***
Prior achievement	0.114**	0.088	0.390***	-0.377***	0.374***
Conscientiousness	0.059	0.171***	0.353***	-0.231***	0.150***
Physical activity	0.093**	0.059	0.056	-0.078	0.039
SES	-0.048	0.113*	0.050	-0.017	0.044
Home assistance	0.056	-0.061	0.257***	-0.075	0.031
Instruction (LRI)	0.104**	-0.020	0.617***	-0.332***	0.147**
Lesson timing	0.005	0.074	0.088	-0.017	0.032
Breakfast consumption	–	0.111**	0.205***	-0.203***	0.084*
Breakfast quality		–	0.093*	-0.114**	0.096*
Adaptive motivation			–	-0.449***	0.329***
Maladaptive motivation				–	-0.288***
Achievement					–

Note. NESB = non-English speaking background; SES = socio-economic status; LRI = load reduction instruction.
*$p < .05$. **$p < .01$. ***$p < .001$.

with <1%, and 'Other non-specified' at 3.7%; however, we did not explicitly ask students about their ethnic/cultural background in the survey). Students varied in SES (range = 866–1181, *M* = 1121, *SD* = 46) based on the Australian Bureau of Statistics Index of Relative Socio-Economic Advantage and Disadvantage classification with higher scores indicating higher SES; in aggregate, students were higher than the Australian average of 1000 (*SD* = 100). Sixteen percent reported they had not eaten breakfast the morning of data collection (Table 1 provides data on what student characteristics were associated with breakfast consumption).

The survey (including items about breakfast quality and consumption) and science test were all conducted via an online survey in a single sitting of a normally scheduled science class in Term 2 (of four school terms) of the school year. The study was part of a larger research program exploring psychological and physiological responses in students' motivation and learning in STEM courses. Several datasets were collected through this research program, including the present dataset relevant to students' dietary habits and potential impacts in each classroom lesson at school (in this case, a science lesson). Participating schools were those opting in from a Heads of Science schools network invited to be part of the larger research program. For students from these schools to be eligible to participate, they needed to be in the early to middle years of high school (comparable to Grades 7–9 in the US) and have parent/guardian consent; no other inclusion or exclusion criteria were applied.

Although the study was conducted in Australia, we believe it has generalizability to diverse national contexts. For example, the measures we used for motivation have been validated in other countries (e.g., in the UK, US, Canada, and China; Martin et al., 2016, 2017) and thus our motivation findings may have broader applicability. The science achievement test we administered comprises items that are common across other national science syllabi (e.g., UK, US; Mullis et al., 2016) and thus may have broad applicability. Our breakfast quality assessment was based on a healthy eating diet quiz that was developed in consultation with international health guidelines and literatures (NHMRC, 2013). Finally, our hypotheses were based on the international literature reviewed in the Introduction; the extent to which these hypotheses are supported by the results of this study will further underscore the generalizability of our research.

2.2. Materials

Materials were comprised of items asking students about breakfast consumption, breakfast contents (to indicate quality), motivation, and achievement, as well as various personal, home, and lesson attributes that were modeled as covariates. Descriptive statistics and reliability are shown in Table 2.

2.2.1. Breakfast consumption and breakfast quality

Following prior recommendations (i.e., Burrows et al., 2017; Ptomey et al., 2016), students reported on their breakfast on the same day as they completed the achievement test and completed the motivation measures. Self-reports of breakfast have been shown to be valid for children over ages 8 years (Burrows et al., 2013). For breakfast consumption, participants were asked "Did you eat breakfast this morning?", to which they responded either No (scored 0) or Yes (scored 1). Breakfast quality was a summed index based on eight survey indicators that were scored to align with the Australian Dietary Guidelines Quiz (NHMRC, 2013, p. 6). Using a question stem ("Each week, how often do you usually eat the following for breakfast before school?"), participants were asked to rate on a 4-point scale (1 = *Never* to 4 = *Five days*) how often they ate/drank (a) vegetables and fruit, (b) dairy and protein, (c) wholegrains and cereals, (d) water, (e) sugary soft drink (reverse scored), (f) processed meat (reverse scored), (g) fast take-away food (reverse scored), (h) unhealthy bakery goods (reverse scored), and (i) unhealthy snack foods (reverse scored). Thus, following Whatnall et al.'s (2019) recommendations, a quality indicator of breakfast quality comprised both healthy and unhealthy food. Indeed, the range of breakfast quality indicators was part of our rationale for asking about breakfast quality across the course of a school week (rather than just that morning) to capture a valid measure of breakfast quality as best we could. Also, if we restricted our breakfast quality measure to just

Table 2
Descriptive and reliability statistics.

	Range	*M*	*SD*	Skew	Kurtosis	Reliability
Age (years)	12–16	13.52	0.98	0.00	−0.96	–
Gender (Male/Female)	0–1	0.61	0.49	−0.45	−1.81	
NESB (No/Yes)	0–1	0.08	0.27	3.22	8.38	
Prior achievement	1–3	2.34	0.65	−0.49	−0.71	–
Conscientiousness	1–7	5.46	1.24	−0.93	1.05	–
Physical activity	1–4	3.40	0.72	−1.14	1.22	–
SES	866–1181	1121.26	45.95	−1.85	5.19	–
Home assistance	1–5	1.89	1.13	1.10	0.19	–
Instruction (LRI)	1–7	5.26	1.18	−0.73	0.03	0.872
Lesson timing	1–7	3.16	1.70	0.39	−0.65	–
Breakfast consumption	1–2	1.84	0.37	−1.84	1.39	–
Breakfast quality	0–8	4.55	1.39	−0.78	1.20	–
Adaptive motivation	1–7	5.68	0.89	−0.79	0.19	0.831
Maladaptive motivation	1–7	3.81	1.13	0.00	−0.44	0.700
Achievement	0–12	6.41	2.38	−0. 05	−0.32	0.600

Note. NESB = non-English speaking background; SES = socio-economic status; LRI = load reduction instruction. Reliability (coefficient omega) is not available for single-item factors, as indicated by a dash.

the morning of the survey, we would not know the effects of skipping breakfast for students who otherwise typically have (un)healthy breakfast habits; hence, our decision to ask about breakfast quality across the week and consumption that morning. Consistent with the Australian Dietary Guidelines Quiz, participants answering a 4 (i.e., 5 days a week for each school day) received one point and all other responses received zero points. Based on the relevant survey items, participants could receive a maximum score of 8, indicating regular high-quality breakfast (as shown in Table 2; $M = 4.55$, $SD = 1.39$, approximately normally distributed). Thus, this measure is a formative sum (not a latent factor; Diamantopoulos & Winklhofer, 2001) consistent with the NHMRC (2013) and validity data by Marshall et al. (2012). Diet scores that are the sum of healthy/unhealthy foods eaten have been used in prior research linking diet to achievement (Gibney et al., 2018; Whatnall et al., 2019); Florence et al. (2008) suggested a diet score is preferable over modeling of individual nutrients because individuals do not consume single nutrients, but rather consume combinations of foods that are reflected in diet scores. Taken together, breakfast consumption indicated whether participants had eaten breakfast that morning and breakfast quality was an index of the typical quality of breakfast eaten.

2.2.2. Motivation

Motivation was assessed using the domain-specific (science) form of the Motivation and Engagement Scale–High School (MES-HS; Martin, 1999–2021), validated by Green et al. (2007). Following Martin et al. (2013), an adaptive motivation latent factor and a maladaptive motivation latent factor were modeled. Adaptive motivation comprised items (a) asking about self-efficacy which refers to students' belief in their ability to understand or to do well in their schoolwork (four items; e.g., "If I try hard, I believe I can do well in this science class"); (b) valuing that connotes students' beliefs that what they learn is useful, important, and relevant (four items; "Learning in this science class is important"); and (c) asking about mastery orientation, which is being focused on learning, effort-oriented mastery, and developing skills (four items; e.g., "I feel very pleased with myself when I do well in this science class by working hard"). Maladaptive motivation comprised items asking students about their anxiety (i.e., feeling nervous and worrying about schoolwork and assessment; four items; e.g., "When exams and assignments are coming up for this science class, I worry a lot"), failure avoidance (i.e., students' motivation to do their schoolwork to avoid doing poorly or being seen to do poorly; four items; e.g., "Often the main reason I work in this science class is because I don't want people to think that I'm dumb"), and uncertain control (students' uncertainty about how to attain success or avoid poor performance; four items; e.g., "I'm often unsure how I can avoid doing poorly in this science class"). Each item was rated on a scale of 1 (*strongly disagree*) to 7 (*strongly agree*). Each factor was approximately normally distributed and had adequate reliability (see Table 2).

2.2.3. Achievement

Achievement was assessed via 12 questions in an online science test that was part of the online survey. Martin, Ginns, Burns, Kennett, and Pearson (2021) described instrument piloting, development, and validation (see also Burns et al., 2023, for further validation evidence). Test items were aligned with the participants' state science syllabus; thus, two parallel forms were devised, with one form to match the Stage 4 (Years 7 and 8) state science syllabus and the other form to match the Stage 5 (Years 9 and 10) state science syllabus. This also ensured the tests were appropriately challenging for a given stage, which is important given that breakfast may benefit emotional responses when performing demanding tasks (Benton et al., 2001). Test items were based on syllabus units relevant to Physical World, Earth and Space, Living World, and Chemical World and tapped into the following skills: questioning and predicting, planning and conducting investigations, processing and analyzing data, and problem solving. The test was aimed to have an approximately 30/70 ratio of content-focused to skill-focused questions. The relatively easier questions focused on content and the more difficult questions focused on skill application. All answers were in multiple-choice format and recoded as dichotomous (0 = incorrect; 1 = correct). Correct answers were summed to generate a total score. We then standardized these total scores by year level ($M = 0$; $SD = 1$ for each year level); consistent with prior research using this achievement measure (Martin, Ginns, Burns, Kennett, & Pearson, 2021), error-adjusted scoring was used to avoid inflated or unreliable standard errors (Kline, 2016). We did so by using the following equation: $\sigma^2_h * (1 - \omega_h)$, where σ^2_h was the estimated variance of achievement and ω_h was the reliability estimate of achievement (h). The intraclass correlation for achievement was 0.07 (see Data Analysis for our approach to adjusting for clustering of students within classrooms). The test had adequate reliability and scores were approximately normally distributed (see Table 2).

2.2.4. Background attributes

As described in the Introduction, to establish the unique effects of breakfast consumption, including a comprehensive range of covariates was important in this study. Three groups of student-reported covariates were thus included: (a) personal (i.e., age, gender, language background, prior science achievement, physical activity, and conscientiousness from Gosling et al., 2003), (b) home (i.e., socio-economic status and home/parent assistance via provision of science learning resources), and (c) classroom (i.e., timing of science lesson in the day, including linear and quadratic effects, as well as load reduction instruction from Martin & Evans, 2018). The scoring and range of these variables are shown in Table 2.

2.3. Data analysis

Confirmatory factor analysis (CFA) was used to first ascertain the factor structure and latent correlations for the full set of measures. Following this, structural equation modeling (SEM) was used to test the hypothesized model. Both were conducted with M*plus* version 8.70 (Muthén & Muthén, 1998–2021). We used the MLR (maximum likelihood robust to non-normality) estimator that provides parameter estimates with standard errors and a chi-square test statistic that are robust to non-normality (Muthén & Muthén, 1998–2021). Adequate model fit was indicated where the Comparative Fit Index (CFI) is >0.90 and Root Mean Square Error of

Approximation (RMSEA) and Standardized Root Mean Square Residual (SRMR) are <0.08 (Kline, 2016). Missing data (0.21% total missingness, with most missing on SES [1.5%, $n = 9$] and conscientiousness [2.5%, $n = 16$]) were handled via the M*plus* default, Full Information Maximum Likelihood (FIML; Arbuckle, 1996). We implemented the "cluster" and "type = complex" commands in M*plus* to adjust standard errors for students nested within the 88 classrooms (with an average class size of approximately 11 students, which is not unduly disproportionate to the staff-to-student ratio for high schools in the independent school sector, taking into account non-teaching staff numbers, non-participation, and student absences; Australian Bureau of Statistics, 2019).

For the CFA, the following factors were included: breakfast consumption (single-item indicator, binary), breakfast quality (single-item indicator, summed index), adaptive motivation (latent factor), maladaptive motivation (latent factor), achievement (single-item indicator, summed error-adjusted index), and personal, home, and lesson covariates (each single-item indicators, with the exception of instruction which was estimated as a latent factor), thus, this was a 15-factor CFA. All single-item indicators had their loading set at 1.00 and residual at 0.

In the SEM, (a) breakfast consumption, breakfast quality, their interaction, and all personal, home, and lesson covariates predicted adaptive and maladaptive motivation and in turn, (b) these factors, including adaptive and maladaptive motivation, predicted achievement (thus, a "fully-forward" model). The covariates were correlated with breakfast consumption, breakfast quality, and their interaction to control for shared variance among them. The interaction term (breakfast consumption x breakfast quality) was created by finding the product of zero-centered breakfast consumption and breakfast quality (Aiken et al., 1991) and then included as a correlated predictor of motivation and achievement alongside its lower-order terms (as per Hayes, 2022; moderated mediation with a moderated direct effect). When modeled as such, the lower-order effects of breakfast consumption, for example, can be interpreted as the difference in motivation scores between participants who did and did not consume breakfast on data collection day when breakfast quality for the past week was average. In the event of any significant interaction effects (i.e., breakfast consumption x breakfast quality effects), follow-up simple slope effects were graphed to understand the nature of this interaction (with low/high groups determined as 1 *SD* below or above the mean, as per Dawson & Richter, 2006). Our data also enabled tests of indirect (mediation) effects which were conducted in subsidiary analyses. This involved parametric bootstrapping and explored the extent to which motivation mediated the relationship between breakfast factors (i.e., consumption, quality, and consumption x quality; Hayes, 2022) and students' achievement. These analyses were based on bootstrapped standard errors of 1000 draws (MacKinnon et al., 2002; Shrout & Bolger, 2002).

3. Results

3.1. Correlations among key factors

A CFA was conducted in which all covariates and substantive factors were included. This yielded an acceptable fit to the data, $\chi^2 = 415.152$, $df = 137$, $p < .001$, CFI = 0.912, RMSEA = 0.057, SRMR = 0.040. This CFA also generated a correlation matrix for all factors. Table 1 shows bivariate correlations with the substantive factors. Breakfast consumption was associated with higher adaptive motivation ($r = 0.21$, $p < .001$) and achievement ($r = 0.08$, $p < .05$) and associated with lower maladaptive motivation ($r = -0.20$, $p < .001$). Thus, having breakfast in the morning was linked with more adaptive motivation and achievement later that school day. Breakfast quality was associated with higher adaptive motivation ($r = 0.09$, $p < .05$) and achievement ($r = 0.10$, $p < .05$) and associated with lower maladaptive motivation ($r = -0.11$, $p < .01$). Thus, a better-quality breakfast was associated with more positive motivation and achievement. Breakfast consumption was also associated with higher breakfast quality ($r = 0.11$, $p < .01$), adaptive

Table 3
Standardized beta coefficients from hypothesized model.

	Adaptive Motivation	Maladaptive Motivation	Achievement
Covariates			
- Age	0.000	0.109*	0.044
- Gender (Male/Female)	-0.030	0.247***	0.033
- NESB (No/Yes)	0.031	−0.005	0.083*
- Prior achievement	0.255***	−0.307***	0.227***
- Conscientiousness	0.190***	−0.131**	0.018
- Physical activity	-0.060	0.027	0.007
- SES	0.032	−0.037	0.020
- Home assistance	0.167***	−0.005	−0.051
- Instruction (LRI)	0.526***	−0.236***	−0.076
- Lesson timing (linear)	0.009	0.089	−0.018
- Lesson timing (quadratic)	-0.079	0.003	0.111*
Breakfast			
- Breakfast consumption	0.109**	−0.080	0.017
- Breakfast quality	0.047	−0.089*	0.021
- Consumption x Quality	0.069**	0.054	0.089*
Mediators			
- Adaptive motivation	–	–	0.219**
- Maladaptive motivation	–	–	−0.123**

Note. NESB = non-English speaking background; SES = socio-economic status; LRI = load reduction instruction.
*$p < .05$. **$p < .01$. ***$p < .001$.

motivation was associated with higher achievement ($r = 0.33$, $p < .001$), and maladaptive motivation was associated with lower achievement ($r = -0.29$, $p < .001$). Taken together, these bivariate associations provide preliminary support for the hypothesized connections between breakfast, motivation, and achievement. Analyses thus proceeded to test the hypothesized model in Fig. 2.

3.2. Effects in the hypothesized model

Structural equation modeling yielded an acceptable fit to the data, $\chi^2 = 433.417$, $df = 153$, $p < .001$, CFI = 0.912, RMSEA = 0.054, SRMR = 0.038. Table 3 reports paths in the final model; Fig. 3 shows only the substantive paths that were significant in this final model. All significant and non-significant paths (including effects of covariates) are presented in Table 3. Breakfast consumption predicted higher adaptive motivation ($\beta = 0.11$, $p < .01$) and this effect was accompanied by a significant interaction with breakfast quality (described below). Breakfast quality predicted lower maladaptive motivation ($\beta = -0.09$, $p < .05$). In turn, adaptive motivation predicted higher achievement ($\beta = 0.22$, $p < .01$) and maladaptive motivation predicted lower achievement ($\beta = -0.12$, $p < .01$). Although breakfast consumption and quality were both associated with academic achievement in the bivariate correlations in the CFA, they demonstrated no predictive association with achievement in the SEM after accounting for all other paths.

3.3. Interaction effects in the hypothesized model

There were two significant interaction effects such that breakfast quality moderated the effect of breakfast consumption on adaptive motivation ($\beta = 0.07$, $p < .01$) and achievement ($\beta = 0.09$, $p < .05$). Results of follow-up tests of the interactions are shown in Fig. 4 and Fig. 5 (which present effects adjusted for all other predictors in the model). In Fig. 4, students who typically eat high quality breakfast and ate breakfast that morning showed the highest levels of adaptive motivation. In contrast, relatively lower levels of adaptive motivation were observed for students who ate that morning but typically ate a poor-quality breakfast or consumed no breakfast that morning (regardless of whether they typically eat a poor- or high-quality breakfast). In Fig. 5, consuming a high-quality breakfast that morning was associated with the highest levels of test achievement later that day. Students scoring lowest on the achievement test were those who consumed a poor-quality breakfast that morning or consumed no breakfast that morning when they would typically eat a high-quality breakfast.

3.4. Indirect effects in the hypothesized model

Indirect effects were examined to determine the extent to which motivation may have mediated the association between students' breakfast consumption and breakfast quality and students' achievement. Of the six possible indirect effects, three were tested because they represented significant predictive paths between the predictor → mediator and between the mediator → outcome (i.e., in cases where both components of an indirect effect were significant): breakfast consumption → adaptive motivation → achievement; breakfast quality → maladaptive motivation → achievement; breakfast consumption x quality → adaptive motivation → achievement. Of the three indirect effects tested, one was statistically significant at $p < .05$, as follows: breakfast consumption → adaptive motivation → achievement ($\beta = 0.024$, $p < .05$). This result suggests that students' adaptive motivation mediated the connections between breakfast consumption and students' achievement. Indeed, combined with the lack of bivariate paths between breakfast consumption and students' achievement, motivation emerged as a noteworthy factor in explaining how breakfast may play a role in students' academic performance.

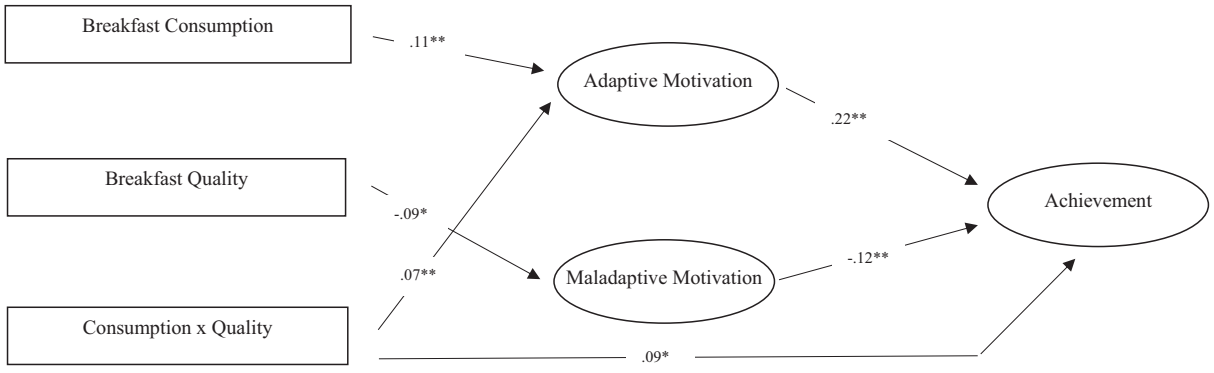

Fig. 3. Significant predictive (standardized beta) paths.
Note. The figure displays only the substantive paths that were significant in the final model. Table 3 reports on all paths (significant and non-significant) in the final model.
*$p < .05$. **$p < .01$.

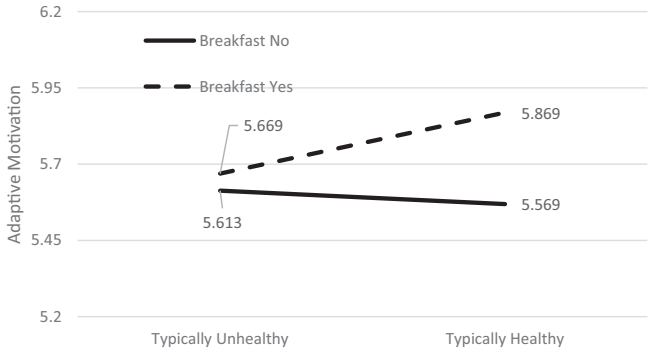

Fig. 4. Plot for effects of breakfast interaction (breakfast consumption x breakfast quality) on adaptive motivation.
Note. Adaptive motivation is on original scale of 7-point rating.

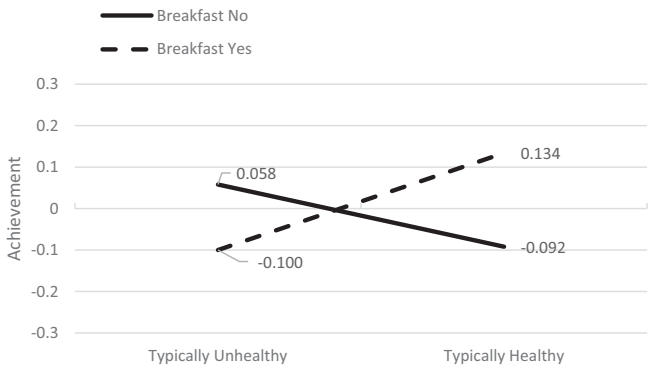

Fig. 5. Plot for effects of breakfast interaction (breakfast consumption x breakfast quality) on achievement.
Note. Achievement is on standardized scale where $M = 0$.

4. Discussion

Although a good deal of research has linked students' breakfast consumption to better achievement at school, there has been debate about why and how breakfast has its academic benefits. It is also unclear whether breakfast consumption has positive effects for academic outcomes after controlling for a range of previously unexamined and potentially confounding background factors. The present study addressed these concerns. Results demonstrated significant associations between students' breakfast habits and their motivation and achievement, beyond the effects of numerous background factors. Moreover, because preliminary bivariate correlations revealed that some of these previously unexamined background factors were significantly associated with the central substantive factors, the multivariate analyses meaningfully add to current understanding of the unique effects of breakfast and students' motivation and achievement.

4.1. Findings of note

The findings revealed that different aspects of breakfast were associated with different dimensions of motivation: breakfast consumption was positively associated with adaptive motivation (and we also note the effect of breakfast consumption here was accompanied by an interaction with breakfast quality), whereas breakfast quality was negatively associated with maladaptive motivation. Breakfast consumption may be considered an energizing factor that was positively implicated in students' adaptive motivation. This is consistent with the literature suggesting that breakfast consumption fuels the individual (Jackson & Vaughn, 2019) and provides energy and drive (Murphy, 2007; Widenhorn-Müller et al., 2008) that connotes positive motivation. Conversely, the benefit from better breakfast quality seemed to be a protective factor in that it was associated with lower levels of maladaptive motivation. Why this is the case requires further investigation, but it appears that a healthy breakfast may be helpful for students seeking to reduce academic anxiety, fear, and other variables in line with other accounts suggesting the benefits of a healthy breakfast and diet for reducing ill health (Jackson & Vaughn, 2019; Michael et al., 2015; NHMRC, 2013). Taken together, both the consumption of breakfast and the quality of what is consumed were associated with students' academic motivation. To the extent this is the case, it appears that simply having breakfast is not sufficient; to gain the full benefits of eating breakfast, its quality is also important for optimal motivation. Interestingly, neither consumption nor quality had effects on achievement, but they did have moderated and mediated roles.

Findings supported the well-established connection between motivation and achievement (Liem & Martin, 2012). In educational research, this is not headline news. But in health research, it is noteworthy. Specifically, although there is a good deal of health research demonstrating a direct link between breakfast and achievement (see Adolphus et al., 2013, Burrows et al., 2017, Faught et al., 2017, Hasz & Lamport, 2012, Mahoney et al., 2005, Murphy, 2007, Ptomey et al., 2016, and Yao et al., 2019, for research and reviews), there remain unanswered questions about how exactly breakfast translates into better achievement. There has been speculation about possible mediating factors that explain the link (Corcoran et al., 2016). One thesis is that breakfast fuels and energizes the individual, which provides the impetus for enhanced performance (Murphy, 2007; Widenhorn-Müller et al., 2008). This brings into focus the role of motivation (e.g., Murphy, 2007) and our study indicated that (a) breakfast predicted motivation, (b) motivation predicted achievement, and (c) breakfast did not predict achievement (although it did as an interaction effect). Moreover, adaptive motivation significantly mediated the relationship between breakfast consumption and achievement. This indirect effect suggests that a comprehensive response to enhancing students' achievement must not only address their adaptive motivation, but also attend to other antecedents in their lives, such as their breakfast consumption.

Notably, breakfast consumption and breakfast quality did not just operate as independent effects as they also interacted such that some effects of breakfast consumption were moderated by its quality. Specifically, the findings demonstrated that for adaptive motivation, it was not only important to have breakfast on a given morning, but to also ensure it was of high quality (see also Adolphus et al., 2013; Taras, 2005). Interestingly, the tests for moderation also revealed that students low in adaptive motivation and achievement were those who typically ate a healthy breakfast, but who had skipped breakfast that morning. The precise reason for this requires further research; for example, is it a result of nutritional disruption or because a breakfast routine in the home was disrupted by an event such as an argument with parents that led to reduced motivation and achievement later that day (e.g., George et al., 2012)? Alternatively, it may reflect a broader trend of inconsistent consumption of breakfast. In any case, it is a novel contribution because the effect of a disrupted breakfast routine on academic motivation (for example) has not received research attention, although Mahoney et al. (2005) and Benton et al. (2001) suggested that this disruption could adversely affect children's cognition, mood, and behavior. This finding reinforces the importance of maintaining a healthy breakfast each morning.

A strength of the study was the inclusion of multiple covariates and potential confounds that the literature has identified as critical to account for when seeking to ascertain the unique effects of breakfast. The findings demonstrated that beyond salient personal, home, and classroom factors, breakfast consumption and breakfast quality were uniquely associated with motivation and achievement. Researchers have emphasized some key factors to disentangle from breakfast effects; for example, research has suggested that older school students, girls, and students from low SES backgrounds are more likely to skip breakfast (Mhurchu et al., 2010; Widenhorn-Müller et al., 2008; Yao et al., 2019), whereas higher achieving students may make more informed choices about breakfast (Whatnall et al., 2019). By including these background factors as predictors (covariates), we could ascertain breakfast effects controlling for variance attributable to these factors. Indeed, these background attributes are also implicated in students' motivation and achievement and so their presence in the model held even greater significance for interpreting breakfast effects.

4.2. *Implications for theory*

The findings are a further contribution to theories that emphasize the critical nexus between “body and mind” in human functioning (e.g., Blascovich, 2008; Martin, Kennett, et al., 2021; Schultheiss & Wirth, 2018), including young people's academic functioning (Bellisle, 2004; Martin et al., 2023; Martin & Burns, 2023; Martin, Kennett, et al., 2021). For psycho-educational theorizing, the study reinforces the importance of holistic perspectives that account for the health and physiological factors involved in students' motivation. Of course, seminal psycho-educational theories often do recognize these factors (e.g., self-determination theory; Deci & Ryan, 1985), but we posit that the present study adds more concretely to these theories in that it explicitly positions breakfast consumption and quality in this educational space. Thus, for example, theories around learning might not only attend to the relevant instructional inputs, but also to how well the students started the day by way of adequate nutritional input via breakfast consumption and breakfast quality.

The findings also suggest the importance of incorporating psycho-educational perspectives in models and processes that are central to health-related disciplines. In the present study, academic motivation appeared to be a potentially energizing mechanism mediating the link between breakfast and achievement. Whereas educational and school psychology have long promoted motivation as a key factor in learning and achievement, the present study formally links this psycho-educational concept to health and lifestyle antecedents. This has implications for health and related literatures seeking to conduct more encompassing and integrative research to better understand young people's development.

Our study also reinforces the importance of integrative multi-dimensional perspectives on student motivation in this space. Motivation research is populated by diverse theories and multitudes of constructs that can present problems for researchers and practitioners whose objective is to implement parsimonious and cohesive motivational approaches to support students' educational development (see Hattie et al., 2020, Martin, 2023, Wigfield & Koenka, 2020, and Wong & Liem, 2021, for reviews). To respond, researchers have recommended studying motivation from multidimensional perspectives, including in terms of its positive and negative dimensions (Martin, 2023). In our Introduction, we identified the rationale for adopting a motivation framework where maladaptive dimensions of motivation (such as anxiety) were included. We argued it was important to understand the association between breakfast and both adaptive and maladaptive dimensions of motivation as this would enable a more comprehensive insight into breakfast effects and reduce the risk of missing important motivational constructs (such as maladaptive dimensions) that play a notable role in students' academic experience. Our findings quite clearly indicate that this cohesive approach representing both adaptive and maladaptive dimensions was warranted as not only was breakfast associated with these two motivation dimensions in

distinct ways, but the two dimensions were each uniquely associated with achievement.

4.3. Implications for practice

The results reveal three main points for educational intervention: (a) incorporating a healthy breakfast or morning snack into the school day, (b) ensuring information about breakfast is included in school curricular/syllabus units (and communicated to home), and (c) addressing aspects of motivation that mediate the link between breakfast and achievement. These are discussed more below.

First, regarding the provision of a healthy breakfast or morning snack at school, Faught et al. (2017; see also Oostindjer et al., 2017) suggested that schools are a critical site where students' breakfast habits are addressed with a view to optimizing their academic development. Free school-based breakfast programs are one avenue for this (O'Dea & Mugridge, 2012). Alternatively, schools might consider providing students with a snack later in the morning (Benton et al., 2001). Because breakfast (or snack) intervention is logistically straightforward (Hasz & Lamport, 2012; Hau, 2016) and cost-effective (e.g., a piece of fruit and a glass of milk are cost effective relative to tutoring intervention conducted at scale), this has been recommended as a front line for intervention (Yao et al., 2019), especially for students from disadvantaged homes, food-insecure homes, or food-scarce neighborhoods (Jackson & Vaughn, 2019). Indeed, the bivariate correlations in the present investigation suggested that socio-economic status was significantly associated with breakfast quality. This relationship reinforces the need to consider such interventions at a policy level rather than by individual school. More specifically, this finding suggests the importance of considering funding for such programs across schools to ensure the schools that cater to students who have least access to (quality) breakfast can access it. In addition, if a school breakfast (or snack) program is implemented, there is also a need to ensure that barriers to participation are addressed (Dykstra et al., 2016), potentially via encompassing health educational programs. For example, a desire to lose weight and body image concerns (Godin et al., 2018; O'Neil et al., 2014) may impede students' adoption of breakfast programs if not effectively countered through other educational and health avenues.

Second, Jackson and Vaughn (2019) emphasized the importance of educating students about the inter-connectedness of breakfast consumption and academic well-being. This can be via curricular/syllabus units at school (e.g., health and physical activity subjects). O'Neil et al. (2014) recommended that achieving the goals of a quality breakfast is best done when it is seen as a partnership between school, home, and student. Thus, O'Neil et al. (2014) advised communication to the home and via in-school parent information sessions aimed at empowering and building confidence, such as strategies for preparing food, getting portable and non-perishable items ready for the school week, and buying in bulk so there is enough food for the week.

Finally, motivation was a significant mediator in the study and so interventions that promote motivation are also relevant. Consistent with Martin, Ginns, Anderson, Gibson, and Bishop (2021), the adaptive motivation construct comprised self-efficacy, valuing, and mastery orientation, and each of these has well-established practice guidelines. For example, boosting self-efficacy entails individualizing tasks so students have opportunity to succeed as a basis for confidence (McInerney, 2000); it also entails encouraging students to develop more positive beliefs about themselves and their capacities (Wigfield & Tonks, 2002). To enhance valuing, educators can encourage students to see the relevance and importance of school subjects or topics (Eccles & Wigfield, 2020) and model their own valuing of these subjects/topics to students (Bandura, 2017). For mastery orientation, it can be helpful to direct students' focus on effort, skill development, and mastery, with less focus on comparisons and competition (Elliot, 2005). Maladaptive motivation in this study comprised anxiety, failure avoidance, and uncertain control (following Martin, Ginns, Anderson, Gibson, & Bishop, 2021). For anxiety and failure avoidance, fear of failure is a contributing factor (Covington, 2000) and can be addressed by encouraging students to see that mistakes provide diagnostic information about how to improve and do not imply that the student is lacking in worth (Covington, 2000). For uncertain control, educators might like to direct students' attention to aspects of schoolwork they do control, such as their effort, strategy, and attitude (Martin, 2010).

4.4. Limitations and future directions

There are several study limitations to note when interpreting findings and that also provide direction for future research. First, the diet score was based on students' self-reports and there are limitations with these types of data, such as retrospective bias and inaccurate recall, although we note that self-report dietary intake has been found to be valid (Burrows et al., 2013). Future research might look at contemporaneous food diaries or parent reports of breakfast habits. The central motivation measures were also self-reported, but as these are intra-psychic constructs, the use of self-report is deemed feasible. Nonetheless, future research might look to also garner teacher reports of students' motivation. Regarding achievement, however, we point out that this was an actual test and so was free of the potential biases implicated in self-report. It is also the case that diet surveys vary (Gibney et al., 2018; O'Neil et al., 2014). The present findings must be interpreted in the context of a survey developed around national guidelines relevant to our Australian sample (viz. NHMRC, 2013). We also point out that our measure of breakfast quality reflected students' typical diet (across the course of the week) and not just for the morning of the survey. In the Method section, we explained that this was to ensure valid (and avoid narrow) measurement of breakfast quality and to capture typical breakfast quality for students who do eat breakfast but did not do so that morning. Indeed, this approach revealed findings suggesting the importance of maintaining a quality breakfast each day. That said, we urge some caution when interpreting findings because we do not know if students ate a quality breakfast on the morning of the survey (we only know the typical quality across the course of the week) or the role of that morning's breakfast quality in students' motivation and achievement in science later that day. We also do not know the students who never eat breakfast (we only know if they did not eat breakfast that morning). Our breakfast quality measure was 1 = *Never* to 4 = *Five days*, but a rating of *Never* here signals the frequency of consumption of particular food types; it does not mean they never eat breakfast. In addition, regardless of whether a

student ate breakfast that morning, we do not know if they were feeling hungry in the science lesson, which is important as feeling hungry has been negatively associated with students' learning (International Association for the Evaluation of Educational Achievement, 2020). Future research is needed to disentangle these issues, with a particular focus on including a measure of that morning's breakfast quality, an item that asks students how often they eat breakfast (regardless of its quality), and how hungry they are feeling at the time of the survey.

Second, our data were collected in a single online survey sitting and in this sense were cross-sectional. That said, students were reporting on food eaten that morning (which necessarily preceded the science lesson). In addition, the role of motivation in leading to achievement is a well-established one, both theoretically and empirically (e.g., Lazowski & Hulleman, 2016; Marsh & Martin, 2011). Thus, although our data were collected at the one time, there was a logic to modeling in the way we did (breakfast → motivation → achievement). Nonetheless, future research design needs to be implemented over the medium to longer term to verify the ordering of factors we hypothesized. Third, although we included many covariates, there is a need to investigate other factors. For example, Benton et al. (2001) observed that poor glucose tolerance was associated with poor cognitive performance and thus more detailed information on glucose intake and tolerance would be helpful. Similar information on vitamin and mineral intake would be informative as well. Another factor is students' knowledge of nutrition as it is possible that students are not making unhealthy choices, but rather they simply do not know what a healthy diet is (Cornil et al., 2020). Knowing the size of the student's breakfast may also be important (Nyaradi et al., 2016). There are also cultural factors we could not account for, such as Ramadan which fell in part of the term two data collection period. Although we do not have data on which students were observing Ramadan, we do not anticipate it unduly affected results (e.g., < 1% of students reported Arabic as their home language, and we included non-English speaking background as a covariate). In addition, although we included an indicator of home assistance, we did not have more detailed information about students' attachments to parents which is a factor associated with their eating habits (e.g., Faber et al., 2018).

Fourth, we only assessed one aspect of students' diet: breakfast. It is important to ascertain breakfast effects in the context of students' broader dietary intake to better understand the unique effects of breakfast (Burrows et al., 2017). Related to this was the fact we did not have information about whether students had eaten sometime between breakfast and the science lesson. In part we dealt with this using lesson timing (time in the day of the science lesson) as a covariate and something of a proxy control for aspects of the daily routine (including snacking) that are important to disentangle from breakfast consumption. But including lesson timing does not directly or sufficiently deal with this potential confound and so future research should also include post-breakfast food intake measures. Finally, our schools were higher in SES than the national average. This being the case, our students may be considered relatively well-nourished or have greater access to nutritious foods. It is unclear how our findings generalize to students who are lower in SES. In a follow-up analysis, we tested the extent to which SES moderated the association between breakfast consumption (via a consumption * SES interaction term), breakfast quality (quality * SES), and consumption by quality (consumption * quality * SES), and students' motivation and achievement. No interaction terms attained statistical significance at $p < .05$; nevertheless, we recommend further research among schools serving lower SES communities.

5. Conclusions

A healthy breakfast has traditionally been associated with improved cognitive and academic performance, but research has been piecemeal and the motivational factors that are implicated in the process have not been well understood. The present study brought together a wide variety of dietary, academic, personal, home, and classroom factors and demonstrated a positive role for a regular healthy breakfast for students' academic motivation and achievement. We conclude that this small and relatively achievable change in a student's life has the potential to have positive implications for their academic outcomes.

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