COLOUR AS A CUE TO EAT: EFFECTS OF PLATE COLOUR ON SNACK INTAKE IN PRE-SCHOOL CHILDREN

Sharon A. Carstairs[1], Samantha J. Caton[2], Marion M. Hetherington[3], Barbara J. Rolls[4], Joanne E. Cecil[1]

[1] Population and Behavioural Sciences, School of Medicine, University of St Andrews, St Andrews KY16 9TF, UK; sc295@st-andrews.ac.uk (SAC); jc100@st-andrews.ac.uk (JEC)

[2] School of Health and Related Research (ScHARR), University of Sheffield, S1 4DA, UK; s.caton@sheffield.ac.uk (SJC)

[3] School of Psychology, University of Leeds, LS2 9JT, UK; m.hetherington@leeds.ac.uk (MMH)

[4] Department of Nutritional Sciences, The Pennsylvania State University, University Park, PA 16802, USA; bjr4@psu.edu (BJR)

*****Correspondence: sc295@st-andrews.ac.uk; Tel.: +44-1334461895

ABSTRACT

Environmental cues, such as the colour of food and dishware, have been shown to influence food and drink consumption in adult populations. This proof of concept study investigated whether plate colour could be utilised as a strategy to reduce intake of high energy density (HED) snacks and increase intake of low energy density (LED) snacks in pre-school children. In a between and within-subjects design, children were randomly assigned to either a control group (no colour message) or intervention group (received a colour message: red = stop, green = go) and were provided a snack at nursery on three occasions on differently coloured plates (red, green, white), for each snack type (HED, LED). Snack intake, colour preference, colour association, and anthropometrics were recorded for each child. The results showed that there was no effect of group (control vs intervention) on HED (p=0.540) and LED intake (p=0.575). No effect of plate colour on HED (p=0.147) or LED snack intake (p=0.505) was evident. Combining red and green plates for a chromatic versus achromatic comparison showed that there was no significant effect of chromatic plate on HED (p=0.0503) and LED (p=0.347) intakes. Despite receiving a brief learning intervention, the use of plate colour was found in the present study to be an ineffective strategy to control snack food intake in pre-school aged children. Rather, we suggest that food intake in young children may best be predicted by portion size, energy density and eating behaviour traits.

Keywords: Colour; Food Intake; Children; Visual Cue; Dishware

Highlights

- Plate colour did not influence snack intake in this group of pre-school children
- No significant effect of chromatic vs white plate colour on snack intake was found
- Colour association or preferences did not impact intake from different coloured plates
- Pre-schoolers may be too young, or require repeated exposure, for colour associated learning in the context of food consumption
- Portion size and eating traits are predictors of snack intake in 3-5yr olds

1. INTRODUCTION

The sensory experiences of sight, smell, texture and taste each play an important role in eating and drinking behaviour (Delwiche, 2004). In particular, the modifying role of visual cues on food and drink appeal, preference and taste perception has been an area of interest over the past four decades (Donadini, Fumi, & Faveri, 2011; Spence, Levitan, Shankar, & Zampini, 2010; Stillman, 1993; Tuorila-Ollikainen, 1982; Zampini, Sanabria, Phillips, & Spence, 2007). In their review, Wadhera *et al* (2014) concluded that visual cues associated with food itself, such as the proximity of food items on the plate, surface area, variety, colour, size, shape and number of food items, can influence consumption and the eating experience. External visual cues directly associated with food (e.g. altered dishware and utensils) have been manipulated in recent investigations of portion control (Benton, 2015; DiSantis et al., 2013; English, Lasschuijt, & Keller, 2015; Rolls, 2014) and have the potential to change consumption. In the present study, we investigated the effect of plate colour on food intake in pre-school children.

Previous research has examined the effect of dishware colour on an individual's perception of the sensory attributes of food (Harrar, Piqueras-Fiszman, & Spence, 2011; Piqueras-Fiszman & Spence, 2012; Spence, Harrar, & Piqueras-Fiszman, 2012) and on food and drink consumption in adults within laboratory or opportunistic settings (Bruno, Martani, Corsini, & Oleari, 2013; Geier, Wansink, & Rozin, 2012; Genschow, Reutner, & Wanke, 2012; Reutner, Genschow, & Wänke, 2015). The colour red is associated with signals for warning and danger (e.g. its use in traffic lights and road signs) due to its high contrast to natural colours in the environment, and has been shown to elicit avoidance behaviour (Mehta & Zhu, 2009). In an opportunistic experiment conducted with university students, Genschow *et al* (2012) showed that consumption of food and drink was reduced when offered on red compared with blue or white dishware. The authors surmised that the colour red functioned as a subtle avoidance signal motivated through learned and embedded cultural associations with danger and stop. Based on these findings, Reutner *et al* (2015) expanded on this experiment by investigating the effect of a red plate on both 'healthy' and 'unhealthy' snack intakes in adults and found that when presented on a red plate, lower amounts of 'unhealthy' snacks were consumed compared with the 'healthy' snacks, a finding not evident when presented on white plates. The authors suggested that red dishware could be used to limit intakes of high-energy dense (HED), nutrient poor foods without affecting intakes of low-energy, nutrient dense (LED) foods, such as fruits and vegetables. However, contrary to these and previous colour manipulation studies (Bruno et al., 2013; Genschow, Reutner, & Wanke, 2012), a recent cross-over study (Akyol, Ayaz, Inan-Eroglu, Cetin, & Samur, 2018) failed to find an inhibitory effect of red dishware on food consumption, and found no difference between chromatic colours in an adult population, raising some uncertainty about the effect of plate colour on food consumption. What is also unclear is whether colour, and particularly the colour red with its ‘avoidance’ association, can influence consumption in pre-school aged children.

Nutrition labels using traffic lights to categorise foods have been developed and used in school-aged children to help promote understanding of the frequency of consumption recommended for different food and drinks (Ellis & Ellis, 2007; Stamos, Lange, & Dewitte, 2019). However, whether the colour concept ‘red = stop and green = go’ is understood or evaluated in children is uncertain. The aim of this study was to investigate whether the visual cue of colour could be used to influence intake of HED and LED snack foods in pre-school aged children as a method of portion control. We hypothesised that children would consume less HED snack foods when presented on a red coloured plate in comparison to when presented on white or green plates following a message on traffic light colour meanings (red = stop, green = go). In addition, we hypothesised that children would consume more LED snack foods when presented on a green plate in comparison to when presented on a white or red plate, following the same message on traffic light colour meanings. Children’s food consumption can also be influenced by behavioural factors, such as individual differences in eating traits (e.g. satiety responsiveness) (Kral & Hetherington, 2015) and parental feeding practices (e.g. pressure to eat) (Yee, Lwin, & Ho, 2017). Thus, we explored the potential influence of child eating traits on HED and LED snack intake.

2. MATERIALS AND METHODS

2.1 Experimental Design

In a between and within-subjects (2x3) design with six weekly conditions (Table 1), children were offered a snack at nursery during a normal snack-time setting. The research was conducted in four nurseries. Child participants were grouped in nurseries according to cognate attendance days. Each group of children within nurseries was randomly assigned to either the control (no message) or the learning intervention (a colour message: red = stop, green = go). Children were provided a HED snack (defined as >2.5 kcal/g as per Albar *et al* (2014)) and a LED snack on two separate days across the week. Each snack was presented to the children on a different coloured plate: white, red, green. White plate was included as a standard comparator. The plate colour order of the experimental conditions across the 3-week experimental period was counterbalanced using Latin squares assigned for each nursery group and by alternating the starting snack type. The plate colour was consistent per week. Testing was conducted by the same researchers across nurseries.

During the pre-test and familiarisation session, children's favourite colour was recorded. Pre- and post-test, children's association with the colours red and green, and whether they showed an indication for colour confusion were recorded. Children in the learning intervention group were additionally presented once to a colour message during the pre-test session, this included a song with an accompanying image of a traffic light which indicated that 'red means stop' and 'green means go' (see Supplementary Material).

Table 1: Experimental design

Group	Week 1	Week 2		Week 3		Week 4	
	Experimental Condition						
	1	**2**	**3**	**4**	**5**	**6**	**7***
Control	Pre-test & familiarisation without message	Plate Colour 1		Plate Colour 2		Plate Colour 3	
		HED[#] snack	LED snack	HED snack	LED snack	HED snack	LED snack
Intervention	Pre-test & familiarisation with colour message	Plate Colour 1		Plate Colour 2		Plate Colour 3	
		HED snack	LED snack	HED snack	LED snack	HED snack	LED snack

Snack order was counterbalanced between nursery groups and plate colour weekly order was randomised for each nursery group using Latin squares. * Post-test colour association was conducted on the last of the 6 conditions following snack provision. [#] HED defined as >2.5 kcal/g as per Albar et al (2014).

2.2 Participants

Pre-school aged children (3-5 years) were recruited by distributing letters to parents of children in hosting nurseries located within Fife and Tayside (Northeast Scotland). Power calculations with 80% power to detect a moderate difference in means (effect size f=0.2) at a critical alpha (0.05), assuming a correlation of 0.5 between repeated measures, identified that approximately 42 children should be recruited. Parents provided written, informed consent for their own and their child participation into the study. Children with allergies to any of the foods used in the study (following identification from screening questionnaire) were excluded from participation. The study was reviewed and approved by the University of St Andrews School of Medicine Ethics Committee (MD13093).

2.3 Test foods and procedures

The test foods served to the children during the studies were HED snacks (cheese cubes and mini breadsticks) and LED snacks (peaches and pears). The snacks presented to children were selected on the basis that they met guidelines for a balanced snack provision for early years childcare providers in

Scotland (NHS Health Scotland, 2015). These snacks are commonly consumed (Public Health England and Food Standards Agency 2014) and adhere to recommended snacks offered together for children in nursery and educational institutions (NHS Health Scotland, 2015) (nutritional information shown in Table 2). Within the HED and LED snack types, foods were matched for energy density. Children were provided 150% of the recommended portion (NHS Health Scotland, 2015) of each of the two foods within the HED and LED snacks.

Children were asked to rate their liking of each of the foods provided in the test meal during a single familiarization session (Table 1). Liking was assessed using cartoon images of faces, a method previously used with children of this age-group (Birch, 1979). Children were asked whether they thought each food was "yummy", "just okay" or "yucky". Liking data were utilised to confirm acceptance of the test foods used in this study by the participating children (Table 3).

The colour of the foods selected for this experiment was chosen to avoid the use of red and green coloured foods and control colour across HED and LED snacks. The plates used in this study were purchased with no available detail of colour parameters; colour hue, saturation and lightness (HSL). Utilising an online tool hslpicker.com (Mathis, 2012), the HSL colour models for the red and green plates were identified (red - 345:95:40; green - 95:90:60). To control for contrast of the plate against the nursery tables, a white tablecloth was placed on the table prior to serving the snacks to the children.

Table 2: Characteristics of the test meal provided at snack time

Snack Type	Food Item*	Energy Density (kcal/g)	Weight of Food Offered (g)	Total Snack Energy (kcal)
HED	Cheese (medium cheddar)	4.2	60.0	252.0
	Mini Breadsticks	4.1	11.0[#]	45.1
	Combined Snack Offered	4.2	71.0	297.1
LED	Peaches (canned in natural juice[†])	0.4	60.0	24.0
	Pears (canned in natural juice[†])	0.3	60.0	18.0
	Combined Snack Offered	0.4	120.0	42.0

All food items were Morrisons© own brand
[#] portion for mini-breadsticks is provided as a number of units and not weight-based, as per recommendations (NHS Health Scotland, 2015) (i.e. 150% portion = 6 mini breadsticks, weight 11.0g)
[†] peaches and pears were drained of the natural juice when presented on plate

Snacks were presented at a table where children sat in groups of 2-6 and were advised by the researchers that “they could eat as much or as little as they liked”. During the snack, children were observed by the researchers to ensure that they did not share foods and to ensure any dropped foods were recovered.

Table 3: Ratings for liking of snack foods served to children

	Food	Liking Rating															
		Yummy				Just Okay				Yucky				Undecided			
		Control		Intervention		Control		Intervention		Control		Intervention		Control		Intervention	
		n	*%*	n	%	n	%	n	%	n	%	n	%	n	%	n	%
HED	Cheese	11	68.8	15	75.0	1	6.3	1	5.0	1	6.3	2	10.0	3	18.8	2	10.0
	Breadsticks	9	56.3	15	75.0	2	12.5	3	15.0	2	12.5	1	5.0	3	18.8	1	5.0
LED	Peaches	9	56.3	12	60.0	0	0.0	1	5.0	3	18.8	6	30.0	4	25.0	1	5.0
	Pears	8	50.0	10	50.0	0	0.0	3	15.0	4	25.0	6	30.0	4	25.0	1	5.0

2.3 Assessment/Measures

2.3.1 Colour confusion (colour vision deficiency) and colour association

Pre-test colour related measures were conducted with children on an individual basis at a separate area to the rest of the children and the snacking table. Children were provided 10 different coloured pencils (red, orange, yellow, blue, green, purple, pink, brown, black and white). Using a second set of identical 10 pencils, researchers asked children 'to pick the colour of pencil that matches' the pencil selected by the researcher to test for colour confusion (note this method is used in place of Ishihara plates (Ishihara, 1972) which require children to be able to articulate numbers or images). The children were also asked to select the coloured pencil 'they like best', a method previously used for children of this development stage (Zentner, 2001) to establish colour preference. All children were individually asked the question '*what does the colour red/green mean?*' to provide a pre- and post-test colour association. Children in nurseries assigned to the intervention group were provided a short message in the form of a song about traffic light colour meanings (red = stop, green = go) and shown an image of a traffic light (Supplementary Material).

2.3.2 Child height and weight

During the familiarisation session, child height (cm) was measured to the nearest cm using a portable stadiometer (Seca: Hamburg, Germany) and body weight (kg) was measured to the nearest 0.1 kg using a portable digital scale (Leicester SMSSE-0260: Leicester, UK; Seca: Hamburg, Germany). Child height and weight data were used to derive BMI (wt kg/ht m^2).

2.3.3 Snack intake

The amount of HED and LED snack food consumed was calculated as the difference between pre- and post-snack weights and recorded using digital scales (Ohaus-NV511: Parsippany, NJ, USA).

2.3.4 Feeding practices and eating traits

Parents were asked to complete questionnaires on general demographic information, eating traits, parental feeding practices and frequency of eating particular foods. Four validated child eating trait and parental feeding practice questionnaires were included: Food Neophobia Scale (Pliner & Hobden, 1992); Child Food Neophobia Scale (Pliner, 1994); Child Eating Behaviour Questionnaire (CEBQ) (Carnell & Wardle, 2007; Wardle, Guthrie, Sanderson, & Rapoport, 2001); Comprehensive Feeding Practices Questionnaire (CFPQ). Parents were additionally asked to rank the frequency their child self-served themselves food on a 5-point scale (1= never, 2 = rarely, 3 = sometimes, 4 = often, 5 = always) and complete a food frequency questionnaire (FFQ) (Hammond, Nelson, Chinn, & Rona, 1993).

2.5 Data analysis

Analyses were carried out using SPSS (IBM SPSS Statistics v22, Armonk, NY, USA). Mixed design repeated measures analysis of covariance (ANCOVA) models (2(group) x 3(colour)) were conducted to investigate a between-subjects comparison of group (control vs intervention) and a within-subjects comparison of snack intake across plate colours (red, green, white) for each snack type (HED (g) and LED (g)). Plate colour was included as a fixed factor in the model, and group was included as a between-subjects factor. Child's age and BMI were added as covariates and the child's favourite colour was also added as covariate, as previous research has indicated children's selection of food and drink product packaging is associated with their colour preferences (Marshall, Stuart, & Bell, 2006). Planned contrasts were conducted to compare snack intakes across plate colours driven by our study hypotheses. Thus, consumption from red plate was compared with consumption from white and also from green for the HED snack intake model and consumption from green plate was compared with consumption from white and also from red for the LED intake model.

Pearson's correlation for linear bivariate relationships was used to explore associations between mean HED and mean LED snack intakes, child BMI, eating traits and parental feeding practices. From these analyses, linear regression analysis (stepwise method) was conducted to determine which variables predicted HED and LED snack intakes. Data are presented as means ± standard error of the mean. Results were considered statistically significant at $p < 0.05$.

3. RESULTS

3.1 Participant characteristics

Thirty-eight responses from parents for their child to participate were received. Two children were excluded based on eligibility (non-attendance at the nursery on agreed days of testing). A final total of 36 children aged 3-5 years were enrolled in the study from September 2017 to May 2018. Due to absences, one child did not complete all HED conditions and 3 children did not complete all LED conditions, thus analyses were based on a sample of n=35 for HED and n=33 for LED. Mean child age was 46.4 months; mean child BMI was 16.6 kg/m^2 (Table 4). In this sample, 27.8% (n=10) of children were categorised as overweight or obese (sex-specific BMI-for-age).

Table 4: Characteristics of children participating in the study

	All				Group			
	Girls (n=19)		**Boys (n=17)**		**Control (n=16)**		**Intervention (n=20)**	
	Mean ± SEM	**Range**	**Mean ± SEM**	**Range**	**Mean ± SEM**	**Range**	**Mean ± SEM**	**Range**
Age (months)	48.1 ± 1.7	35.0 – 60.0	44.5 ± 1.8	35.0 – 57.0	42.4 ± 6.4	35.0 -57.0	49.6 ± 7.0	37.0-60.0
BMI (kg/m^2)	16.4 ± 0.3	14.7 – 19.4	16.9 ± 0.3	15.1 – 18.8	17.3 ± 1.1	15.6 – 18.8	16.1 ± 1.2	14.7 – 19.4
% with overweight*	26.4		29.4		50		10	

*Age and sex specific classification according to Cole et al (2012; 2000)

3.2 Effects of individual plate colour and group on HED snack intake

Analyses conducted combining the two snack items within each snack type (HED, LED) representing the recommended provision of the snacks i.e. cheese with breadsticks, and peaches with pears, are presented.

Repeated measure ANCOVA revealed no significant between-subjects effect for group (control vs intervention) (F(1,30) = 0.39, p=0.540). There was no main effect of plate colour on HED intake (F(2,60) = 1.98, p=0.147) (Figure 1). Mean HED intake on the red plate was 43.1g (± 3.8), on white plate was 35.0g (± 4.3) and 39.4g (± 4.1) on green.

Despite finding no main effect of plate colour on HED intake, an interaction effect of plate colour and group (control vs intervention) (F(2,60) = 3.61, r = 0.06, p=0.033) was evident. HED intake on a red plate was higher in the intervention group than control but on green plates intake was higher in the control group than in intervention (F(1,30) = 5.37, r =0.15, p=0.027). An interaction effect of plate colour and child's BMI was also evident (F(2,60) = 3.25, r =0.05, p=0.046). HED snack intake on a white plate was reduced as BMI increased, whilst HED intake on a red plate increased with an increase in BMI (F(1,30) = 5.12, r =0.15, p=0.031). No interaction effect of plate colour and child's favourite colour (F(2,60) = 0.40, p=0.671) or with child's age (F(2,60) = 0.61, p=0.547) was found.

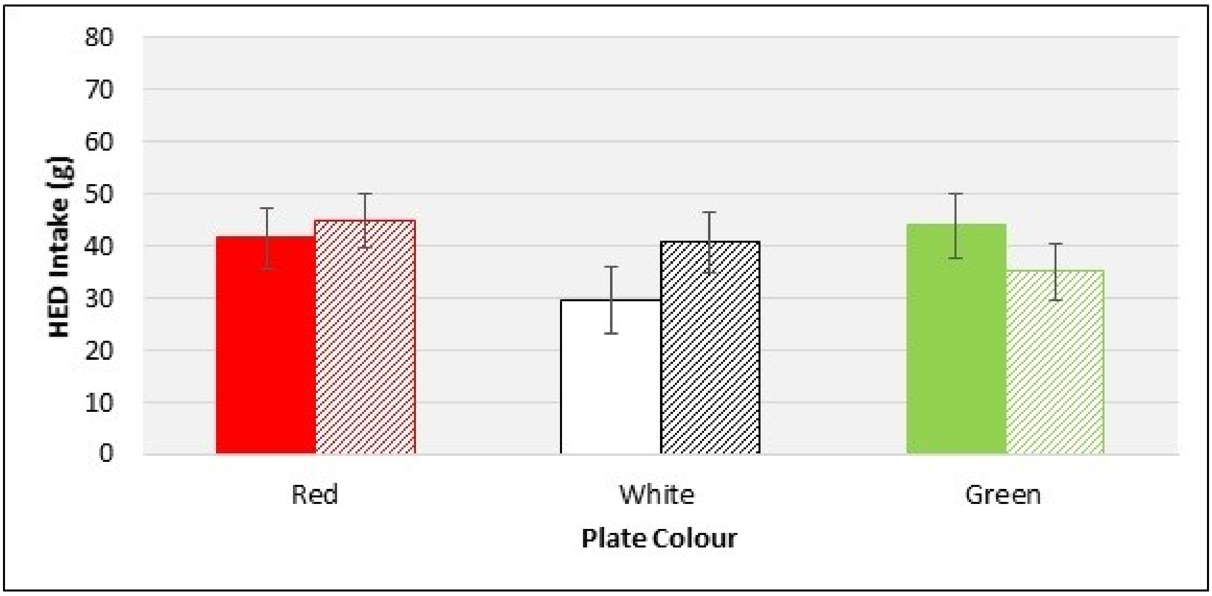

Figure 1: HED (± SEM) intake across colour plate conditions for control (n=16) and intervention groups (n=19). Solid colour represents control group, patterned colour represents intervention group.

3.3 Effects of individual plate colour and group on LED snack intake

No between-subject effect on LED intake was evident for group (F(1,28) = 0.32, p=0.575). Mauchly's test of sphericity was violated (p=0.020) thus, the Greenhouse-Geisser correction was utilised in this model. No significant main effect of plate colour was found on LED intake (F(1.6,44.8) = 0.63, p=0.505) (Figure 2) and no interaction effects were evident (p≥0.214). Mean LED intake on the green plate was 55.4 ± 9.0g, on the white plate was 55.8 ± 9.1g, and on the red plate intake was 54.5 ± 9.2g.

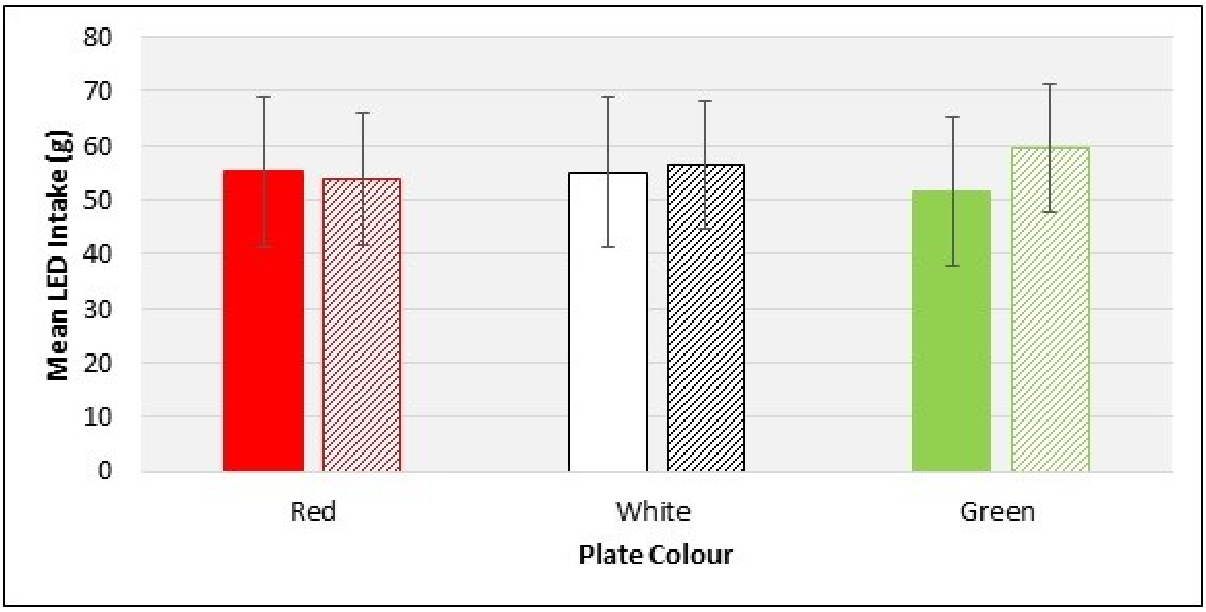

Figure 2: Mean (± SEM) LED intake across colour plate conditions for control (n=14) and intervention (n=19) groups. Solid colour represents control group, patterned colour represents intervention group

Individual analyses for each food item within the HED and LED snacks were conducted and no changes to the outcomes were found. Furthermore, removal of non-eaters of each individual food item i.e. consumed <10% of food provided across all 3 plate conditions, from the analyses resulted in no changes to the outcome.

3.4 Comparing combined chromatic plate versus white plate

The findings above indicate that our hypotheses (less HED food would be consumed on a red plate compared each with white and green plates; more LED food would be consumed on a green plate compared each with white and red plates) were not supported. Akyol *et al* (2018) also revealed no significant differences in intake presented on two coloured plates (red and black plates), thus we explored whether there was any effect of colour in general (chromatic) versus white plate on snack intake in these children. Mean intake from green and red plate conditions for both HED and LED snacks were calculated and compared with intake from white plates to investigate any chromatic vs white (achromatic) effect on intake.

No between-subjects effect was evident for group (control vs intervention) on HED intake (F(1,30) = 0.54, p=0.468). No significant main effect of plate (chromatic vs white) was found on HED intake (F(1,30) = 4.16, p=0.0503) (Figure 3). Mean HED snack intake was 41.2 ± 3.7g on a chromatic plate compared with 35.0 ± 4.3g on a white (achromatic) plate. An interaction effect of plate colour and child BMI (F(1,30) = 6.82, p=0.014) was found, indicating that the HED intake increased as BMI increased on the chromatic plate but HED decreased as BMI increased on white plate (F(1,30) = 6.82, p=0.014). No interaction effects between plate colour and group (F(1,30) = 1.63, p=0.212), plate colour and child's favourite colour (F(1,30) = 0.69, p=0.411) and plate colour and child age (F(1,30) = 0.03, p=0.873) were found for HED intake.

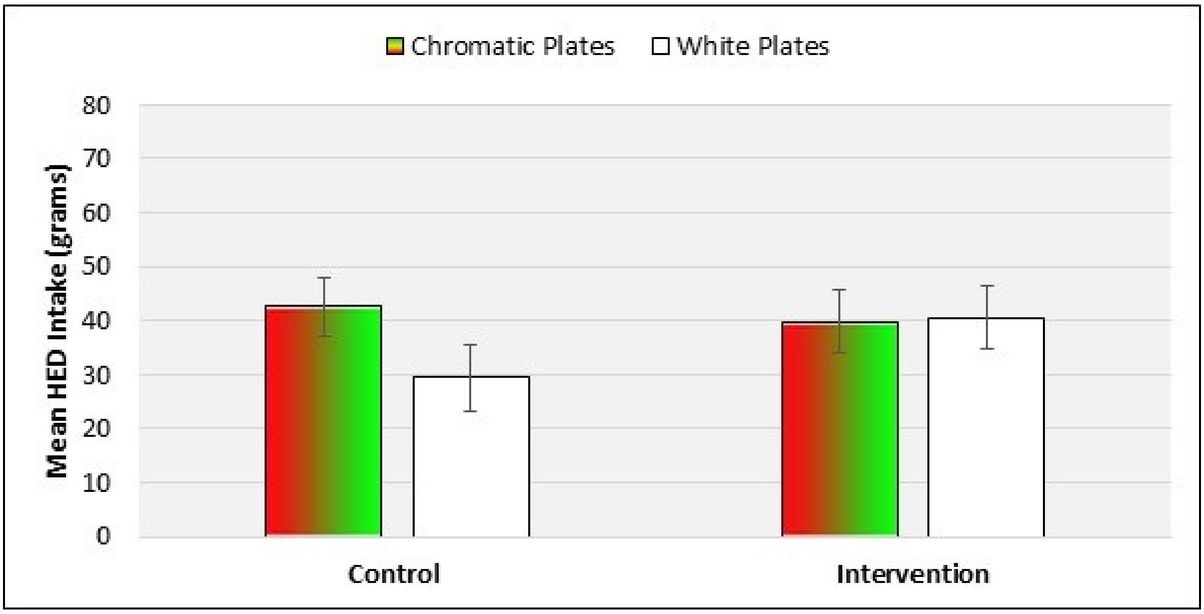

Figure 3: Mean (± SEM) HED intake between chromatic and white plate conditions for control (n=16) and intervention (n=19) groups.

No between-subjects effect was evident for group (control vs intervention) on LED intake (F(1,28) = 0.32, p=0.578). No main effect of plate colour was found on LED intake (F(1,28) = 0.92, p=0.347) and no interaction effects were evident (p≥0.373) (Figure 4). Mean LED snack intake was 56.5 ± 8.8g on a chromatic plate and 57.3 ± 9.1g on a white plate.

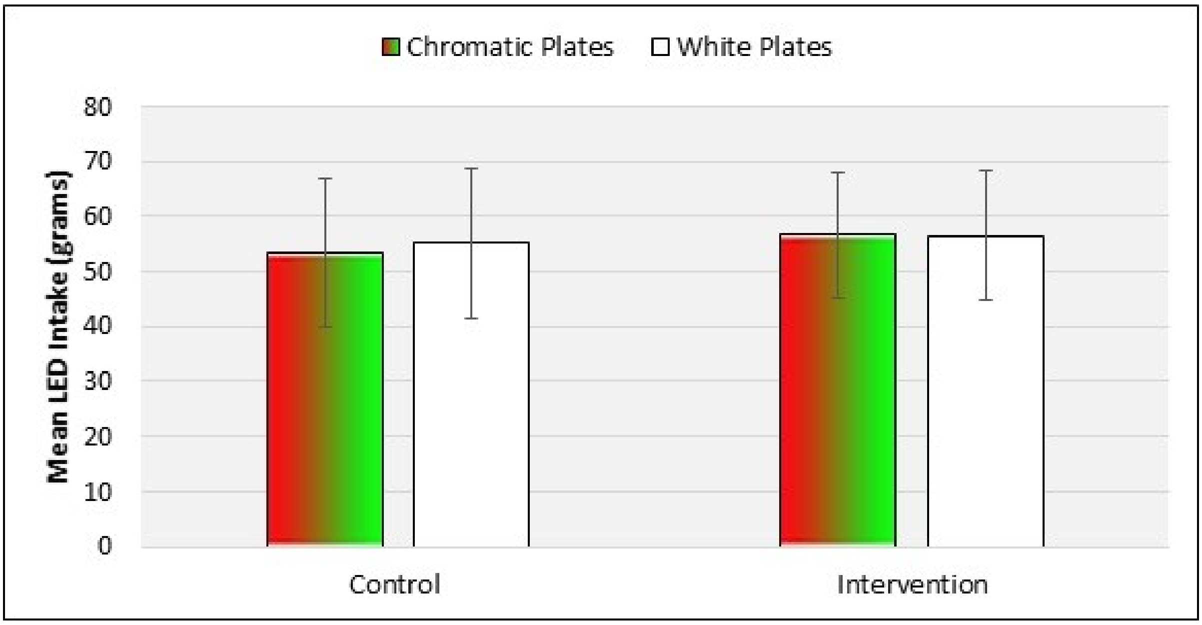

Figure 4: Mean (± SEM) LED intake between chromatic and white plate conditions for control (n=14) and intervention (n=19) groups.

3.5 Child BMI, trait eating behaviour factors and HED and LED snack intake

No significant correlations were found for mean HED or mean LED snack intake and child BMI ($p \geq 0.554$) and child age ($p \geq 0.223$). No association between child's satiety responsiveness and snack intakes ($p \geq 0.356$) were found in the present study. Mean HED snack intake was negatively correlated to CEBQ food fussiness score ($r = -0.400$, $p=0.023$). Regression analyses showed that CEBQ food fussiness scores predicted HED snack intake. Food fussiness significantly contributed to the model accounting for 40% of the variance in HED intake ($R^2=0.160$, $F(1,31) = 5.71$, $p= 0.023$). An increase in CEBQ food fussiness score by 1 unit (i.e. child is more food fussy) decreased HED intake by 8.7 ± 3.7g ($p=0.023$).

Positive correlations were found between child mean LED snack intake and CEBQ enjoyment of food ($r = 0.402$, $p= 0.025$), food responsiveness ($r = 0.566$, $p=0.001$) and CFPQ environment ($r = 0.365$, $p=0.047$). A negative correlation was found between LED intake and child food neophobia ($r = -0.493$, $p=0.010$), CEBQ slowness of eating ($r = -0.454$, $p = 0.010$) and food fussiness ($r = -0.475$, $p= 0.007$). Regression analysis showed that child food fussiness significantly contributed to the model ($R^2=0.335$, $F(1,24) = 11.59$, $p=0.002$) accounting for 58% of the variance in LED intake. An increase in child's food fussiness score by 1 unit (i.e. child is more food fussy) decreased LED intake by 29.9 ± 8.8g ($p=0.002$).

4. DISCUSSION

The current study investigated the effect of plate colour on pre-school children's snack food intake at a nursery snack-time setting. The results of this novel proof of concept study suggest that overall, plate colour did not significantly influence HED or LED snack intake in 3-5-year old children. Our data show some evidence to suggest that children with an increased BMI consume more HED snack from chromatic versus achromatic plates. Furthermore, the results show no significant difference in snack intakes between those children assigned to a learning intervention (traffic light colour message: red = stop, green = go) and those in the control group. In the present study, and under these circumstances, children's HED snack intake was not reduced (via red stop cue) when presented on a red plate compared with both the white and green plates, and LED snack intake was not increased (via green go cue) when presented on a green plate compared with both the red and white plates, independently of receiving the colour message (red stop/ green go).

The results from our preliminary study are in contrast to between-subject plate colour manipulation studies conducted in adults where the colour red is reflective of an avoidance cue and led to reduced intakes of food and drink (Bruno et al., 2013; Genschow, Reutner, & Wanke, 2012; Reutner et al., 2015). This discrepancy in findings could be due to differences in study design. For example, previous colour manipulation studies (Bruno et al., 2013; Genschow, Reutner, & Wänke, 2012; Reutner et al., 2015) provided individual participants with only one plate colour (between-subject manipulation), and included a distractor type task, where participants' attention was focussed on an unrelated (non-food consumption) activity. Thus, the design of these prior studies provided an opportunity to explore plate colour as a subtle cue, one that functions outside of conscious awareness. In our study, each child experienced eating the snack from 3 differently coloured plates without working on any other task. Instead, their focus was on the snack consumption task, representing how snacks are consumed within the nursery setting. Interestingly a recent cross-over study (Akyol et al., 2018) which blinded the adult participants to the aim of the study, also failed to support the findings of these laboratory and opportunistic between-subject studies (Bruno, Martani, Corsini, & Oleari, 2013; Genschow, Reutner, & Wänke, 2012; Reutner, Genschow, & Wänke, 2015) and showed that meal intake was increased when consumed from a red plate compared with a white plate. Akyol *et al's* (2018) findings and the lack of plate colour effect found in the present study highlight that evidence for utilising an environmental cue such as plate colour to influence food and drink consumption across population ages is inconclusive.

It is possible that young children may not yet have made associations between the colour red and ‘avoidance’ or ‘threat’, as evidenced in adult populations (Mehta & Zhu, 2009; Reutner et al., 2015), who will have established such associations through multiple repetitions throughout their lives. We included a learning intervention into the study design to introduce and emphasise this association, where children were randomly assigned to a control group or exposed to a one-off colour message which communicated the concept of ‘red = stop, green = go’. However, this one-off exposure to the colour association message may not have been sufficient for development of the children’s learned association, and repeated exposure to the colour association prior to the study may have been required. During our pre-test measures, we observed that the children sometimes found answering our pre- and post-test measure of colour association challenging (often repeating the colour name). Thus, it is possible that these young children may be aware of an association between the colour red with ‘stop’ and the colour green with ‘go’, as learned for traffic light signals, but were unable to clearly verbalise this knowledge. Any learned associations, and the ability to articulate such knowledge, may also differ across developmental stage. Alternatively, the children in our study may not have internalised the colour associations with the concept of eating per se. Furthermore, recent findings suggest that there may be heterogeneity to colour effects and their associations with behaviour in the wider field of colour psychology (Lehmann & Calin-Jageman, 2017). For example, the effect of the colour pink on reducing prisoners aggression (Schauss, 1979) was not replicated in a more recent study (Genschow, Noll, Wänke, & Gersbach, 2015). Thus, colour associations may not be as strong and generalizable as previously assumed.

Young children may be exposed to coloured plates, both in the home and in childcare settings, and thus it is possible any subtle cue of the plate colour may be attenuated though exposure. In a recent study investigating plate colour preference, children below the age of 10 years showed first choice preferences for food images on chromatic plates compared with achromatic plates (Brunk & Møller, 2019). It is possible that adults may be more familiar with standard white plates than chromatic plates and that any effects of colour on reduced food intake (Bruno et al., 2013; Genschow, Reutner, & Wanke, 2012; Reutner et al., 2015) may be a consequence of novelty in this population rather than colour association acting as a cue per se. In support of this notion, Brunk and Moller (2019) showed that adults perceived coloured plates as novel compared with achromatic plates and that their first choice preference was for food on achromatic compared with chromatic plates. Notably in our study, we adjusted our analyses for child’s colour preference, and we did not see any effects on snack food intake, so despite having preferences for bright colours (Walsh, Toma, Tuveson, & Sondhi, 1990) and previous research indicating children’s selection of food and drink product packaging is associated with their colour preferences (Marshall et al., 2006), differences between colours did not impact on child's food intake. Moreover, our findings revealed that there was no difference in snack intake when children were presented snacks on chromatic plates (combined colour conditions) compared with an achromatic plate suggesting that young children may be less susceptible to subtle colour cue manipulations than their adult counterparts.

The findings of the current study suggest that individual characteristics and traits play a role in snack consumption in young children. Children with a higher BMI had a tendency to consume more HED snack when eaten from a chromatic plate compared with achromatic plates. It is possible that these children may have experienced heightened stimulation when food was presented on coloured plates. Presenting HED, nutrient poor foods on an achromatic white plate could therefore facilitate controlled intake in these children. Irrespective of plate colour, eating behaviour traits were found to predict both mean HED and LED snack food intake. Children identified as 'fussy' consumed lower amounts of both types of snack foods. These findings support work by Gibson and Cooke (2017) who found associations between children's fruit and vegetable intake and food fussiness and neophobia. We have also shown that young children can be influenced by other environmental/visual cues, such as food portion size. When children were presented snack portions greater (150%) than recommended for their age requirements, they consumed a quantity greater than the recommended portion of LED snack (40g), supporting previous portion size studies conducted in young children (Carstairs et al., 2018; Fisher, Liu, Birch, & Rolls, 2007; Kling, Roe, Keller, & Rolls, 2016; Rolls, Engell, & Birch, 2000; Savage, Fisher, Marini, & Birch, 2012; Smethers et al., 2019). These findings, together with the lack of effect of plate colour on intake found in the present study, highlight that portion size, energy density and individual eating behaviour traits may be stronger predictors of consumption behaviour, and thus should be included in control strategies for young children's food intake.

This was a small proof of concept study, conducted with children of a young cognitive and developmental age, recruited from nurseries. The small sample size, which fell below the sample target, and homogeneity of participants in this preliminary study are acknowledged as limitations. Thus, future studies would require a larger sample size and more participant diversity. Nonetheless, this is the first study to investigate effects of colour as a visual cue on snack intake in pre-school aged children whilst mirroring recommended snack provision in a nursery/childcare setting. The study tested a limited selection of foods, despite including HED and LED snack types commonly presented to children as a snack in an ecological childcare setting and thus the findings may not be generalizable to other snack foods. Additionally, whereas the snack foods were liked by the majority of children in our study (and therefore included as test foods), some children described the LED foods as 'yucky', and we acknowledge this might be a limitation. Furthermore, our study design did not test child perception of the snack foods according to differences in energy density or according to differences in perceived healthfulness. It is possible that colour effects may be more likely in experimental studies where the perceived healthfulness of the food has been established and or within populations who have an increased cognitive awareness and understanding of the 'healthfulness' of differing food types (Reutner et al., 2015). Furthermore, the effect of colour may be heterogeneous in that perceptions of 'healthfulness' may differ across the developmental ages and between individuals. The within-subjects repeated measures design and the natural snack setting are strengths that extend the laboratory-based plate colour manipulation studies conducted to date (Bruno et al., 2013; Genschow, Reutner, & Wanke, 2012; Reutner et al., 2015). We assigned children to either a control or intervention group to explore the impact of learning the association of red to 'stop' and green to 'go'; however, it is possible that the exposure to the colour association message, and the measure to assess this colour association, were insufficient. Increased exposure to the intervention colour message might result in a stronger learned colour association in these young children. How best to assess children's associations of colour at a young age and understand if and when strong associations are developed however, requires further consideration. Future studies should investigate effects of dishware colour on food intake in a broader developmental age group, including school-aged children and young adults (5-18 years), and should test a wider range of foods.

CONCLUSION

The findings of this preliminary study showed that despite receiving a brief learning intervention (colour message), plate colour did not influence children's HED or LED snack food intake during a natural childcare snack setting. Thus, in the present study, using the visual cue of plate colour was not an effective strategy to control snack food intake in pre-school children. Rather we suggest that food intake in young children may be best predicted by portion size, energy density and eating behaviour traits.

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AUTHOR CONTRIBUTIONS

Conceptualization, JEC, SAC; Data curation, SAC, JEC; Formal analysis, SAC, JEC; Funding acquisition, MMH, SJC. JEC; Investigation, SAC, JEC; Methodology, SAC, SJC, BJR, MMH, JEC; Project administration, SAC, MMH, JEC; Validation, SAC, JEC; Visualization, SAC, JEC; Writing–original draft, SAC, JEC; Writing–review & editing, SAC, SJC, BJR, MMH, JEC.

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CONFLICTS OF INTEREST

The authors declare no conflict of interest.

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Supplementary Material

SONG: To Twinkle Twinkle Little Star

Twinkle, twinkle traffic light
On the corner shining bright
Red means stop
Green means go
Amber means go very slow
Twinkle, twinkle traffic light
On the corner shining bright

Note: point to colours on the laminated traffic light picture below