The impact of food packaging on measured food intake: A systematic review of experimental, field and naturalistic studies.

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Abstract

Chronic excess energy intake contributes to the development of overweight and obesity. Solutions are needed to guide consumers towards reducing food intake, especially high energy density (HED) and highly palatable foods. Food packaging, a key element of the eating environment, offers a potential solution to assist consumers in portion control. To investigate whether packaging design influences measured food intake, a systematic search was undertaken in four electronic databases (Ovid Medline; Ovid PsycInfo; Ovid Embase and Web of Science). This process yielded 1671 discrete papers, of which 23 articles containing 40 relevant studies were retrieved. Overall, most ($n = 36$) of the manipulated packaging features influenced consumption quantity with. The largest effect sizes were observed for packaging which guided consumers either by visual or functional features. For example, packaging size, images on the front of the pack, as well as functional features such as partitioning and resealability all helped to reduce intake. However, individual differences and attentional focus mediate packaging effects. Overall, packaging features can be used to reduce the intake of HED foods and increase the intake of nutrient-dense foods (e.g., carrots). Future studies on packaging for portion control (downsizing) might benefit from long term, randomised control trials to test effects outside of the laboratory context and applied to everyday usage.

Keywords: packaging design; food intake; portion control; healthy eating; downsizing; social norms

1. Introduction

Changes in production, pricing and availability of foods and beverages have made it possible for highly palatable items to be offered in large portions at affordable prices, which in turn has contributed to the increased prevalence of overweight and obesity (Haws and Winterich, 2013, Hetherington, 2007, Ledikwe et al., 2005, Vermeer et al., 2014). At the individual level, excess body weight is the result of energy imbalance where energy intake is greater than energy expenditure over time (Obri and Claret, 2019). Overall, it appears that increased energy intake is responsible for the energy accumulation rather than a decrease in physical activity (Scarborough et al., 2011, Swinburn et al., 2011). A diet pattern that is low in fruit and vegetables and high in intake of energy-dense foods (high in salt, fat and sugar) leads both to excess energy intake relative to requirements and to poor nutrition (Vecchio and Cavallo, 2019). Overconsumption is preventable by limiting the frequency of eating or eating smaller portion sizes (House et al., 2015, Livingstone and Pourshahidi, 2014). Large portion sizes of HED foods play a significant role in overconsumption and may lead to weight gain over time (Crino et al., 2016, Ello-Martin et al., 2005), thus, solutions for controlling food intake deserve attention.

Food portion sizes can be signalled by package size and packaging is important for conveying information about the appropriate amount as well as nutritional composition (Jeffery et al., 2007, Smith and Ditschun, 2009). Here packaging includes all types of covering around and containing the food and beverage (e.g., bottles, bags, cans, boxes). In most situations, consumers purchase pre-packed food items and so they are generally exposed to packaging design and information. Consumers are accustomed to judging food by its cover (Magnier et al., 2016, Mai et al., 2016). Besides its primary functions (e.g., containment, protection), food packaging has gradually become a communication tool (Azzi et al., 2012, Young, 2004), influencing consumers' attention, perceptions, expectations, purchase decisions as well as the food and serving size choices among adults and children (Ares and Deliza, 2010, Labbe et al., 2013, Liao et al., 2015, Ng et al., 2013, Rebollar et al., 2012, Rolls et al., 2004, Tang et al., 2020). Packaging cues are influential even without consumers' awareness. Be more specific, consumers may not aware of they use packaging cues to judge the quantity of food products (Folkes and Matta, 2004), to estimate the healthiness and the taste of foods (Becker et al., 2011, Kunz et al., 2019), as well as to make some serving or consumption decisions (Antonuk and Block, 2006, Cakir et al., 2013). Given the importance of food packaging to a number of influential processes in food intake, and ultimately to achieving a healthy diet, packaging deserves further scrutiny (Hetherington et al., 2018). To date, research has focussed on the impact of various packaging features such as size (Aerts and Smits, 2017), images on the package (Neyens et al., 2015), package shape (Koo and Suk, 2016)) on food intake. There appears to be a strong link between the packaging cues and food intake, independent of the food quality and even the food taste in some occasions (Keller et al., 2012, Rolls et al., 2004, Wansink and Kim, 2005). In contrast, some studies failed to show any effect of packaging cues on amount eaten (Eykelboom et al., 2018, Versluis et al., 2015).

Within the current, competitive food market environment, alongside diverse food ranges, packaging is also varied and used as a market tool (Shekhar and Raveendran, 2016, Yonezawa and Richards, 2016). While packaging designs have changed as markets adapt and grow, and portion sizes have increased over time, it is not clear how changes to packaging might influence food intake. While the effects of on-pack label (ingredients and nutrition facts) have been considered across a number of reviews (Anastasiou et al., 2019, Cecchini and Warin, 2016, Kiszko et al., 2014), the specific impacts of packaging features on food intake has not been systematically studied. Thus, the present systematic review was initiated to consider the effectiveness of various packaging features on food intake. It is predicted that a comprehensive and systematic review of studies

manipulating packaging design could reveal the specific impact of packaging features on food intake. Furthermore, the potential benefits of packaging design as a means to limit food intake could have implications for achieving a healthy diet for consumers.

This systematic review aims to investigate the effectiveness of packaging to influence food intake. The specific objective was to assess the efficacy of specific packaging features to reduce measured food intake in a wide range of age groups. Interventions which compared packaging manipulations in field and laboratory settings in healthy adults or children were searched. Of interest was any exposure that described packaging cues as the main manipulation or cross designed with other manipulations. The primary outcome was measured actual or intended intake with access to real food. The primary question was: Does manipulation of food packaging influence actual or intended food intake? The secondary question was: Which type(s) of packaging variant had the greatest and most consistent effect on food intake?

2. Methods

2.1. Protocol and registration

This systematic review was conducted following a specific protocol containing a pre-specified search strategy with inclusion and exclusion criteria, registered in the Open Science Framework (<https://osf.io/6t2e3/>). The current review was reported according to the guidelines of PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) (Moher et al., 2009).

2.2. Eligibility criteria

Articles with any type of experimental study (e.g., experimental trial, field experiment, randomized controlled trial) and any experimental duration (e.g., from a few minutes to several weeks) were considered. All age groups were included. All food types for human were included (e.g., snacks, meals, fruits, vegetables, beverages). Any type of measurement of actual or intended food intake was included (e.g., consumption volume, consumption quantity, energy intake). Articles involving animals or animal feed were not considered. Where papers did not report a relevant outcome, or were validation studies, these were excluded. Papers involving patients (e.g., with diabetes, infectious, eating diseases) or studies involving consumers with restrictive diets such as pregnancy or vegetarian were excluded. Articles were excluded if they only measured estimated food consumption instead of actual or intended food intake. Articles which investigated the role of labels that focused on the food nutritional content rather than physical packaging variants were disregarded since they have less relevance to the packaging design and have been widely reviewed. All review articles were excluded.

2.3. Data sources and search strategy

A systematic search was conducted using four scientific research databases: Ovid Medline; Ovid PsycInfo; Ovid Embase and Web of Science. The search took place between November and December 2019. The search strategy was organised around two key variables: packaging manipulations (any comparisons carried out based on food packaging) and food intake (measured actual or intended quantity). The specific keywords used in the search were drawn from previous relevant literature including some relevant reviews. The search terms were text-words (including article title and abstract) and were adapted for use in all searched databases (see OSF link).

Limits were set to include all journal articles published in the English language in the last ten years, in healthy humans with experimental data. Some relevant articles were identified via retrieved, eligible research and some were retrieved from other sources, which were taken as supplemental to this systematic review.

2.4. Study selection

The selection phase of this review applied the PRISMA flow diagram. After checking for duplicates, articles were identified for screening, including additional relevant articles obtained from other approaches. One researcher was involved in the initial selection process, screening all titles and abstracts of remaining articles to define potentially relevant literature to this review, then, irrelevant records were excluded. Two additional senior researchers among the authors independently assessed the titles and abstracts based on the inclusion and exclusion criteria described above. Further assessment for the retained studies was performed on the basis of the full text by the main reviewers. Any disagreement over the eligibility of particular studies was discussed among all three reviewers until consensus was reached.

2.5. Data extraction and data items

Data were extracted using an adapted extraction form to include the characteristics of each included study (Reference: authors, year; study ID; packaging comparisons; efficacy; experimental food). More detailed information from each study was also extracted into an extended version of the form, including information on the study design (authors, year, study type, experimental setting), participant characteristics (sample size, sex, mean age), details of the intervention (intervention type, food type, condition format), main outcome measures and the summary of findings. Due to the heterogeneity of both the packaging manipulations and diversity of methods for assessing food intake, a qualitative synthesis was developed since a quantitative synthesis (meta-analysis) was not possible.

2.6. Synthesis of measures and results

The primary outcome of measured food intake was calculated by counting the number of food units consumed or by subtracting the leftover weight in grams from the amount served, or by converting food weight into corresponding energy content using nutritional composition tables. Intended intake was recorded by ratings in the presence of real food. The results section of each paper was synthesized and a judgment was made about efficacy by defining success as a statistically significant difference in measured food intake following the manipulation relative to a control; the magnitude of this effect was calculated as a percentage of change in intake relative to the control condition.

2.7. Risk of bias

Individual studies were assessed for possible sources of bias in relation to how the study was performed. For example, were the methods rigorous in ensuring participants were screened in advance for liking of food items, for food allergies or intolerance and for dietary restrictions. Since eating behaviour is influenced by knowledge of the experimental purpose or perceived purpose (Nix and Wengreen, 2017, Robinson et al., 2014, Robinson et al., 2015). The true purpose is generally concealed and participants' perception of the purpose of the study then assessed to reduce demand characteristics (Boutron et al., 2007, Robinson et al., 2018, Sharpe and Whelton, 2016). Good experimental practice such as whether a cover story was offered to participants, whether a distractor task was employed and whether individual characteristics of participants such as sex, body mass index (BMI) and hunger level – all known to influence food intake outcomes and therefore recorded in this review. Risk of

bias across the study was assessed using a checklist with twenty questions (full score resulting in 21), appropriate for both randomized and nonrandomized studies, allowing an overall quality assessment score for each article (Downs and Black, 1998).

3. Results

3.1. Study selection

The outcome of the search strategy and application of the eligibility criteria to yield the final, retrieved papers were illustrated in Figure 1 as recommended within the PRISMA guidelines. After duplicates were removed, 1671 papers were identified as potentially relevant, after titles were screened, 262 articles remained and after full text screening 22 papers were retained and an additional article retrieved from the references of these identified articles provided a final count of 23 papers.

Figure 1 Systematic review PRISMA flow diagram

Of the 23 papers, 13 reported more than one independent study, thus, there were 54 different experiments contained within the included articles. Of these, 14 studies measured other outcomes (e.g. perceptions of healthfulness, estimation of energy content) instead of actual or intended food intake, which were excluded from the analysis. Therefore, 40/54 studies were reviewed. Of the remaining 40 studies, 25 experiments were

laboratory-based studies, and the other 15 experiments were field-based, five of these were conducted at home and the remainder were performed in other naturalistic settings (e.g. school classroom, school dining room, office, theatre, club).

3.2. Study characteristics

In total, 14 different packaging manipulations were reported from the retrieved articles, these were then grouped into three main categories: visual characteristics (1.1, 1.2, 2.1, 2.2, 3.2, 3.3, 6.1, 6.2, 6.3, 6.4, 6.5, 7, 12.5, 13.3, 13.4, 13.5, 13.6, 14, 15, 16, 18.2, 20, 21.2, 22.3), functional features (4.3, 5.2, 5.3, 8, 9, 10, 19, 23) and cognitive processing (3.1, 3.4, 3.5, 11.1, 11.2, 11.3, 17.2, 17.3).

Visual packaging manipulations were further divided into physical attributes and on-pack visual cues. The physical attributes involved package size, bottle size or shape, and transparency of packaging. The on-pack visual cues included the food unit number shown on the package, pictorial suggested serving size, portion size illusion (looks with bigger or smaller portion) and the location of energy content. Functional packaging manipulations included package partitioning, package resealability and the presence of a toy inside the package. Cognitive processing packaging manipulations involved package status (package present or absent; original or plain packaging or “low fat” label packaging) and branding status (branded packaging, unbranded packaging, plain packaging, packaging with cartoon characters). Besides packaging manipulations, other manipulations were also involved in 17 studies. 9 out of 17 studies manipulated food feature such as food flavour, food healthfulness, food visually attractive and unit size (1.1, 1.2, 2.1, 2.2, 4.3, 6.1, 6.2, 16, 19). The impact of diet consciousness was assessed in three studies (10, 12.4, 21.2). Cognitive load was manipulated in two studies (3.5, 13.4). In other studies, TV and advertising during meals were also used as manipulations (8, 9).

The reported experiment duration ranged from a five minutes single session to multiple sessions over seven weeks. Measured food intake was calculated by subtracting the leftover weight in grams from the amount served, some of those studies also converted food weight into corresponding energy content (8, 9, 11.1, 11.2, 19, 23) or millilitres for beverages (12.4, 16). Another method used was counting the units left in the packaging (5, 13.3, 13.4, 13.5, 13.6). In five studies, measured intakes were self-reported (5.2, 13.4, 13.5, 14, 20). In particular, food diaries were used to record food intake (participants were asked to weigh and photograph their leftovers or to weigh each food bag before and after consumption). Also, in 16 studies, additional activities were involved as well as eating (e.g., watching a movie, cartoon or video, filling in the questionnaires). Some studies also measured whether the participants noticed the packaging manipulations and how much they relied on this information when making consumption choices during the experiment (3.5, 5.2, 5.3, 13.3, 18.2, 22.3).

Sample sizes varied across studies from 16 to 1680 participants. The total number of participants across all studies was 5610. Participants consisted of three age groups: children, young adults (18 years $\leq$ age $\leq$ 30 years) and adults (age $>$ 30 years). The mean age of the participants varied from 4.4 years to 70.5 years. Young adults were the main participants (24/40), most of whom were undergraduate students recruited from the authors' universities. Children were involved in 10 studies and all of them were less than 10 years old, most of whom were recruited in primary schools. Only six studies recruited adult participants from the wider community drawn from a variety of occupations (e.g. teachers, agriculturalists, university staff, general consumers). Of these studies targeted at adults, two involved older adults (age $\geq$ 50 years) (7, 19), who were contacted via local newspaper advertisements, an existing database or from social clubs.

3.3. Risk of bias

Quality assessments were made on retrieved 23 papers using the Downs and Black checklist with a score out of 21 (Downs and Black, 1998). Quality scores achieved an average of 16.5/21, and 78% were rated as high quality. These studies scored high on reporting quality (M = 9.3/10, so 93% positive scores) and internal validity-bias (M = 4.8/6, 80% positive). Whereas, relatively low scores were obtained for external validity (M = 0.6/1, 61% positive) and internal validity-confounding (selection bias) (M = 1.8/4, 45% positive). All details of scores are presented in Appendix A. According to the quality scores, the majority of articles were of high quality, and were therefore retained for further analysis in this review.

Within the included studies just over half used a cover story (e.g., informed participants the experiment was for testing the new snacks) to strengthen the results, but 10 studies did not report these details (8, 9, 11.1, 11.2, 11.3, 17.2, 17.3, 18.2, 19, 20). Also, only six studies recorded whether participants had worked out the true purpose of the study (3.1, 7, 12.5, 14, 15, 21.2). 12 studies checked the liking of target foods (1.1, 1.2, 2.1, 2.2, 3.1, 5.2, 6.1, 11.1, 15, 16, 21.2, 22.3). In some studies, it was measured after consuming the food, which was used as a covariate or to align with the cover story. Almost half of these studies measured body mass index and hunger level which might influence food intake outcomes. The tendency of consuming the entire portion (e.g. eat the whole bag once opened, plate cleaning tendency) was assessed in four studies (5.2, 15, 21.2, 22.3). Ideally, studies should balance the gender ratio with an equal number of males to females (Tannenbaum et al., 2016). In three studies gender balance was achieved (8, 9, 12.5) and broadly balanced in the remainder except in one case by Madzharov and Block, (2010), with no information on gender ratio. However, in some studies, there was an obvious imbalance, with two studies involving more than 70% males (15, 18.2) and five studies using more than 70% females (5.3, 6.4, 7, 14, 19), whereas three studies enrolled only female participants (3.1, 3.4, 3.5).

3.4. Studies Results

Overall, most studies of packaging manipulations reported significant changes in food intake, details of which are described in Table 1. More detailed information of these studies (e.g., study design, participants characteristics) are presented in Appendix B. The types of packaging manipulations that influenced intake are clustered together and summarised in Table 2. Packaging features were organised by theme – visual, functional and cognitive.

3.4.1. Effects of visual cues

The most common manipulation of packaging (24/40) was visual cues. Of the studies manipulating physical visual cues, most of these (12/14) demonstrated a significant reduction in food intake, and of these four showed conditional effects (e.g. only influenced some participants, only worked under certain conditions). All of the studies that manipulated the on-pack visual image (10/10) reported a significant effect on intended or actual food intake. A schematic representation of these on-pack packaging images are given in Figure 2. The results confirmed the power of the visual manipulation of packaging as powerful drivers for reducing food intake, especially the package size (5/7) and the food pictorial visual variables on the packaging (9/9), although for 2/16 studies the effect was significant for only some of the participants (21.2, 22.3).

3.4.1.1. Effects of physical visual characteristics

Five out of seven studies found a significant effect of packaging size on food intake. Stroebele et al. (2009) demonstrated reduced intake with smaller packages in a field study (20). In this study, participants received either 100 kcal snack packages or the standard size packages, and this was alternated for the second week. Smaller pack sizes produced reduced intake across both weeks. Similarly, a laboratory-based study (15) reported a significantly lower intake of candies when they were offered in a smaller container, even when the portion size offered was controlled. Two further studies confirmed that a small package size reduced food intake for HED foods but had no effect on carrot consumption (1.1, 1.2). Another study (21.1) showed that no overall effect of package size was found in measured intake, although the diet prime reduced intake of peanuts among restrained eaters (21.2). In one case where packaging size did not affect consumption, older adults were offered peanut butter in a large or small jar and how much they spread on one slice of bread was measured (7). Amounts were not influenced by jar size and the authors explained this as habitual intake exerting greater influence than jar size on amount spread.

Table 1 Characteristics extraction of the studies included in the systematic review (NA = not available; ↑ = increased; ↓ = decreased; → = no difference across different packaging conditions)

Reference	ID	Packaging comparisons	Did the packaging manipulation work?	Consumption change in percentage (%)	Experimental food
(Aerts and Smits, 2017)	1.1	Small package VS Large package	Yes	48% ↓	Popcom
	1.2	Small package VS Large package	Mixed	22% ↓ 15% ↓ (not significant)	Cookies Carrots
(Aerts and Smits, 2019)	2.1	Small portion on-pack sticker VS Large portion on-pack sticker	Mixed	15% ↓ →	Grapes Chocolate nuts
	2.2	Small portion on-pack sticker VS Large portion on-pack sticker	Mixed	23% ↓ (first slice)	Bread spread
(Argo and White, 2012)	3.1	No package VS Presence of package	Yes	56% ↓ (low ASEs)	Candies
	3.2	Non-partitioned packages VS Partitioned packages	Yes	NA	Candy-coated chocolates
		Opaque package VS Transparent package	Yes	45% ↓ (partitioned + low ASEs)	Candy-coated chocolates
	3.3	Back caloric information and No caloric information VS Front caloric information	Yes	40% ↓ and 43% ↓ (low ASEs)	Chocolates
	3.4	No package VS Presence of package	Yes	NA	Candy-coated chocolates
	3.5	No package VS Presence of package	Yes	NA	Candy-coated chocolates
(Bui et al., 2017)	4.3	Partitioned packages VS Non-partitioned package	Mixed	37% ↓ →	Granola Cookies
(De Bondt et al., 2017)	5.2	Resealable package VS Non-resealable package	Yes	61% ↓	Jelly beans
	5.3	Resealable package VS Non-resealable package	Yes	31% ↓ 29% ↓ 12% ↓ 27% ↓	M&M's; Gummy bears; Mini cookies; Salted peanuts
(Deng and Srinivasan, 2013)	6.1	Opaque package VS Transparent package	Mixed	41% ↓ →	Froot loops Cheerios
	6.2	Opaque package VS Transparent package	Yes	37% ↓ 40% ↑	M&M's candies M&M's cookies
	6.3	Opaque package VS Transparent package	Yes	43% ↓	M&M's candies
	6.4	Opaque package VS Transparent package	Yes	47% ↓	M&M's candies
	6.5	Opaque package VS Transparent package and partially transparent package	Yes	85% ↑ and 71% ↑	Baby carrots
(Eykelboom et al., 2018)	7	Small jar VS Large jar	No	→	Peanut butter
(Gregori, 2013)	8	Toy inside the package VS No toy	No	→	Chocolates

(Gregori et al., 2014)	9	Toy inside the package VS No toy	No	→	Chocolates
(Holden and Zlatevska, 2015)	10	Non-partitioned package VS Partitioned packages	Mixed	62% ↓ (diet-consciousness was activated)	M&M's candies
(Keller et al., 2012)	11.1	Unbranded containers VS Original branded packaging	Mixed	~41 cal less (overweight only))	Meals
	11.2	Unbranded containers VS Containers with the logo of a popular fast food	Yes	8% ↓ 14% ↓ (girls)	Meals
	11.3	Containers decorated with cartoon characters VS Plain containers	Yes	NA	Fruits and vegetables
(Koo and Suk, 2016)	12.5	Wider bottle VS Taller bottle	Mixed	16% ↓ (When primed to be mindful of calorie intake)	Mango smoothie
(Madzharov and Block, 2010)	13.3	Fewer product units on the package VS More product units on the package	Yes	73% ↓	Animal crackers
	13.4	Fewer product units on the package VS More product units on the package	Yes	40% ↓ 63% ↓ (no-load condition)	Animal crackers
	13.5	Fewer product units on the package VS More product units on the package	Yes	56% ↓ (at a high level of visual processing)	Pretzels
	13.6	Fewer product units on the package VS More product units on the package	Yes	87% ↓ (at a high level of visual processing)	Pretzels
(Mantzari et al., 2017)	14	Four different bottle sizes	No	→	Cola
(Marchiori et al., 2012)	15	Small container VS Large container	Yes	56% ↓	M&M's
(Neyens et al., 2015)	16	Smaller image-size on the front of pack VS larger image-size on the front of pack	Yes	23% ↓ (in total) 32% ↓ (sugar content was low)	Cereal
(Werle et al., 2016)	17.2	Original package VS Plain package.	Mixed	23% ↓ (Males)	M&M's peanuts
	17.3	Original package VS Plain package and "Low Fat" label packaging	Yes	25% ↓ and 25% ↓ → ,and 36% ↓ (females) 37% ↓ and → (males)	M&M's peanuts
(Petit et al., 2018)	18.2	On pack food served in a smaller bowl VS On pack food served in a larger bowl	Yes	20% ↓ 23% ↓ (medium scores of mental simulations) 36% ↓ (high scores of mental simulations)	Cereal
(Raynor et al., 2009)	19	Single serving packages VS Non-portioned packages	Yes	18% ↓ 12% ↓	Cereal and peaches Applesauce and cheese
(Stroebele et al., 2009)	20	100 kcal packages VS Standard size packages	Yes	32% ↓	Snacks
(Versluis and Papies, 2016)	21.2	Small package VS Large package	Mixed	21% ↓ (afternoon)	M&M's peanuts
(Versluis et al., 2015)	22.3	Package with the pictorial serving size recommendation sticker VS Package with no serving size recommendation sticker	Mixed	24% ↓ (Figure 3) (pictorial serving size recommendation was noticed)	M&M's peanuts
(Wansink et al., 2011)	23	Partitioned packages VS Non-partitioned package	Yes	25% ↓ 54% ↓ (overweight people)	Crackers

Table 2 Packaging manipulations of the studies (n = 40) and whether it influenced food intake.

Packaging Cluster		Specific Packaging Manipulation	Did the packaging manipulation change intake?	Reference (ID)
Visual characteristics	Physical visual variables	The package size	Yes	Aerts and Smits, 2017 (1.1)
		The package size	Mixed	Aerts and Smits, 2017 (1.2)
		The package size	Yes	Stroebele et al., 2009 (20)
		The container size	Yes	Marchiori et al., 2012 (15)
		The package size	Mixed	Versluis and Papies, 2016 (21.2)
		The package size	No	Eykelenboom et al., 2018 (7)
		The bottle size	No	Mantzari et al., 2017 (14)
		The bottle shape	Mixed	Koo and Suk, 2016 (12.5)
		The transparency of package	Yes	Argo and White., 2012 (3.2)
		The transparency of package	Mixed	Deng and Srinivasan, 2013 (6.1)
		The transparency of package	Yes	Deng and Srinivasan, 2013 (6.2)
		The transparency of package	Yes	Deng and Srinivasan, 2013 (6.3)
		The transparency of package	Yes	Deng and Srinivasan, 2013 (6.4)
		The transparency of package	Yes	Deng and Srinivasan, 2013 (6.5)
	On-pack visual variables	The number of product units displayed on package	Yes	Madzharov and Block, 2010 (13.3)
		The number of product units displayed on package	Yes	Madzharov and Block, 2010 (13.4)
		The number of product units displayed on package	Yes	Madzharov and Block, 2010 (13.5)
		The number of product units displayed on package	Yes	Madzharov and Block, 2010 (13.6)
		The image size on the front of pack	Yes	Neyens et al., 2015 (16)
		The portion size illusion	Yes	Petit et al., 2018 (18.2)
		The serving size recommendation sticker	Mixed	Aerts and Smits, 2019 (2.1)
		The serving size recommendation sticker	Mixed	Aerts and Smits, 2019 (2.2)
The serving size recommendation sticker		Mixed	Versluis et al., 2015 (22.3)	
The location of the caloric content		Yes	Argo and White., 2012 (3.3)	
Functional features	The resealability of package	Yes	De Bondt et al., 2017 (5.2)	
	The resealability of package	Yes	De Bondt et al., 2017 (5.3)	
	The presence of toy inside the package	No	Gregori, 2013 (8)	
	The presence of toy inside the package	No	Gregori et al., 2014 (9)	
	The partitioning of package	Yes	Argo and White., 2012 (3.2)	
	The partitioning of package	Mixed	Bui et al., 2017 (4.3)	
	The partitioning of package	Mixed	Holden and Zlatevska, 2015 (10)	
	The partitioning of package	Yes	Raynor et al., 2009 (19)	
	The partitioning of package	Yes	Wansink et al., 2011 (23)	
Cognitive processing	The presence of packaging	Yes	Argo and White., 2012 (3.1)	
	The presence of packaging	Yes	Argo and White., 2012 (3.4)	
	The presence of packaging	Yes	Argo and White., 2012 (3.5)	
	The packaging type	Mixed	O.C. Werle et al., 2016 (17.2)	
	The packaging type	Yes	O.C. Werle et al., 2016 (17.3)	
	The brand state of the package	Mixed	Keller et al., 2012 (11.1)	
	The brand state of the package	Yes	Keller et al., 2012 (11.2)	
	The branding cues on the package	Yes	Keller et al., 2012 (11.3)	

Two studies tested the effect of bottle size and bottle shape on drink volume, respectively (12.5, 14). Specifically, study 12.5 tested the effect of the bottle shape on actual consumption that more smoothie was consumed from the elongated bottle than from the wider bottle when the participants were presented with health messaging about fruit smoothies. This suggests that bottle shape influenced intake only when combined with a health prime. The authors also proposed that the elongated packaging gave the impression of a lower energy content than the wider bottle, which might explain the outcome. In study 14, no significant consumption difference was found in different bottle size conditions. According to the authors, the amount and the frequency of supplying sugar-sweetened beverages may override differences in package size, and they found that consumers preferred the convenience of smaller bottles, which may modify the pack size effect.

Transparency of packaging was manipulated across six laboratory-based studies (3.2, 6.1, 6.2, 6.3, 6.4, 6.5) and all found a significant impact on food intake. Studies 6.3 and 6.4 found that less intake was associated with opaque packaging compared to both fully and partially transparent packaging. Study 6.1 revealed that opaque packaging decreased the intake of visually attractive (colourful) cereal (Froot Loops TM) compared to the transparent packaging, but not for the monochrome, plain cereal (Cheerios TM). In study 6.2, participants ate less of a larger chocolate cookie and more small chocolate candies from the transparent package than from the opaque package. However, with baby carrots (6.5), participants consumed fewer carrots from the fully and partially transparent package than from the opaque package. These results suggest the effect of packaging transparency is varied by food type. Study 3.2 manipulated both transparency and package size, in which the characteristics of consumers were also taken into account. This study tested whether consumers with different levels of appearance self-esteem (ASE) responded differently to package size and transparency. Results showed that consumers with low ASE who tend to monitor intake and depend on external cues to assist with self-regulation (Scott et al., 2008) ate more when candies were made visible in small packages.

3.4.1.2. Effects of on-pack visual variables

Madzharov and Block (2010) tested the effect of the product units' number on the front of the packaging with four studies (13.3, 13.4, 13.5, 13.6). All food intake was reduced by the lower number of units displayed which means the fewer food units people saw on the front of packaging, the less they consumed. Study 13.4 also revealed a significant interaction effect between cognitive load and on-pack units' number on food intake. It suggested that people respond to on-pack product units only when cognitive resources are available to attend to this variable. In line with previous findings, study 13.5 also found the same effect of the on-pack pretzel number on actual intake, while it was also noticed that this effect was found only among participants at a high level of visual processing. Meanwhile, in this study, the serving size was also presented to the participants in the form of written information on a card. Despite viewing this information, the consumption behaviour of the participants seemed not to rely on it and the fewer on-pack units' number still significantly reduced food intake.

Three studies (2.1, 2.2, 22.3) investigated the effect of on-pack recommended serving size images on food intake. Importantly, all the pictorial serving size recommendations were shown as stickers. Two studies (2.1, 2.2) tested these effects in children. Study 2.1 revealed that the larger suggested portion sticker increased intake of grapes, however, this was not found for chocolate nuts, suggesting this effect only worked for a relatively healthy food. In study 2.2, the children were provided with bread and one of four spreads differing in type (cheese spread vs chocolate spread) and the spread amount was varied (regular-sized vs large-sized). Results showed that children used and ate less spread on the first slice when they had the jar with a smaller serving size sticker, but there was

no difference in total consumption from subsequent slices of bread. As the authors pointed out, on-pack visual cues may only influence the quantity of food selection at the beginning, while, after that, the total consumption might depend on many other factors (e.g. hunger level, food taste). Versluis et al. (2015) compared the intake from a bag of peanuts with either a serving size recommendation sticker or not (22.3). Results showed that pictorial recommended serving size decreased the amount of food poured, but it reduced the amount of food eaten only when it was noticed. This suggests that serving size manipulations affect the amount served but may not necessarily the amount eaten. However, this study provided a limited time (13 minutes) for eating and 10/89 participants ate all that had been poured into the bowl, which may have influenced the outcome.

Study ID	On-pack visual manipulations		Study ID	On-pack visual manipulations	
Aerts and Smits, 2019 (2.1)				200 grams grapes or chocolates	
Aerts and Smits, 2019 (2.2)				200 grams chocolate or cheese spread	
Versluis et al., 2015 (22.3)			Argo and White., 2012 (3.3)
Madzharov and Block, 2010 (13.3)			Madzharov and Block, 2010 (13.4)
Madzharov and Block, 2010 (13.5)			Madzharov and Block, 2010 (13.6)
Neyens et al., 2015 (16)			Petit et al., 2018 (18.2)

Figure 2 Systematic of on-pack visual manipulations used in included studies.
(images were created on the basis of the pictures or description provided by the original authors)

One study measured the intended and actual cereal intake in children who were presented with either a smaller image of cereal or a larger image of cereal on the front of packaging (16). It reported that more cereal was poured and eaten from the package with a larger on-pack image and this effect was stronger for the

cereal with lower sugar. Similarly, study 18.2 also controlled for the portion size of cereals in the same quantity shown on the front of packages but the cereals were served either in a larger or a smaller bowl in the picture, which could cause a perceptual bias known as the Delboeuf illusion (McClain et al., 2014). The smaller-rimmed bowl on the package lowered the amount of cereal poured by participants than the larger-rimmed bowl on the package. Only Argo & White (2012) assessed the effect of the energy content location on the package on food consumption (3.3). The results revealed a significant effect of the front of pack energy information where it increased chocolate intake with those scoring low on appearance self-esteem (ASE) compared to the back of pack information or no information, and compared to high ASEs who showed no difference in intake.

3.4.2. Effects of functional features

In this review, nine studies investigated the effect of functional features of packaging on food intake. Effects were mixed with 7/9 studies demonstrating a link between functional features and food intake both in the laboratory and field settings. Both partitioning (5/5) and resealability (2/2) of the packaging significantly reduced intake.

In a field-based, cross-over design (19) participants were provided with two types of breakfast foods within a weight-control program for seven weeks. Participants were offered food packaged either in single servings or non-partitioned packages. The partitioned packages resulted in significantly reduced energy intake of both types of breakfasts, suggesting that the sub-packaging promoted portion control. Also, participants consumed less granola and crackers, respectively from the partitioned than from the non-partitioned packaging (4.3, 23). This effect confirmed previous findings of Raynor and Wing, (2007) involving participants with overweight, that partitioning serves as portion size reminder. Interestingly, one study demonstrated a partitioning paradox indicating different outcomes when diet consciousness was also manipulated. Here two opposing effects were shown (10). Partitioned portions led to significantly higher consumption than non-partitioned portions when diet consciousness was activated. While, without diet activation, the partitioned portions lowered intake. In addition, Argo and White (2012) revealed an opposite effect of the partitioning on food intake that people ate many more chocolates when they were exposed to eight small packages than when they were exposed to two large packages (3.2). Under some conditions, therefore, food in unpartitioned package formats may increase the need to deliberate and plan intake more for those with self-regulatory concerns (Coelho do Vale et al., 2008).

The data from two field-based studies (5.2, 5.3) confirmed the effectiveness of resealability on controlling intake. In both environments (theatre and home), resealable packages reduced intake compared to non-resealable packages. Importantly, both studies only targeted energy-dense, small-sized and palatable snacks. Providing a toy inside the package was tested in two studies in Latin America children (8) and Indian children (9) respectively. The influence of exposure to a cartoon on TV with and without advertisements, was also tested. Contrary to the hypothesis, no differences were found on intake across conditions. These studies indicate intake of a highly liked, chocolate egg-shaped snack was not influenced by the packaging having a toy promotion, nor the presence/absence of TV. It may be that this food is so palatable and desirable to children that environmental cues including toys and adverts had no effect in intake.

3.4.3. Cognitive processing of packaging features

In eight studies, manipulations involved absence/presence of packaging, branding or logos. This cluster of

manipulations involves attention and/or emotional triggers. Most studies (6/8) found a significant effect on intake, two revealed mixed outcomes (11.1, 17.2) and individual differences interacted with packaging manipulations to influence intake (5/8).

Three studies (3.1, 3.4, 3.5) assessed effects on intake with and without packaging. All three demonstrated that intake increased when the food was packaged in multiple small packages than when presented unpackaged in a bowl, especially for participants with low ASE. Specifically, study 3.1 showed that when candies were presented in small packages, the low ASE participants ate more, while high ASE participants ate the same in both conditions. Further, study 3.4 showed under the small packaging condition, low ASEs ate more when they were informed that the energy content was low than it was high or with no such information. Study 3.5 participants with a low ASE ate more when the cognitive load (memory task) was low than when it was high. Again, participants with high ASE was similar across conditions. Interestingly, it seems that only those with a lower ASE show the paradoxical effect of eating more when the package is present than absent, which may be related to greater sensitivity to external cues (Polivy et al., 1988).

A series of studies tested the effect of the packaging type (plain or original) with or without fat content labels on intake (17.1, 17.2, 17.3). In studies 17.2 and 17.3, less was eaten with the original compared to the plain packaging, but only in males. In study 17.3, females ate more when the “Low Fat” label was added to the packaging compared to plain packaging. These studies showed specific gender effects of packaging familiarity and labelling. Mixed results with plain packaging have been found with children (11.1) where children with overweight/obesity ate less from plain than from the original packaging, in contrast, children with a healthy weight consumed more from plain compared to original packaging.

Another study (11.2) reported the effect of popular brand logos children’s intake. It showed that children responded to a recognisable brand logo by consuming more food at dinner from this packaging than from the plain packaging. But no significant differences in food consumption among children of different weight status was found. Brand logos also increased the intake of healthy food (e.g. carrots, apples) and relatively less healthy food (e.g. ham and cheese sandwich and chocolate milk). The on-pack cartoon character was an important branding cue, the presence of which increased healthy food consumption of children, which was confirmed by study 11.3. In this 7-week randomised controlled trial, the children in the intervention group received the fruit and vegetable (F&V) in containers decorated with cartoon characters during treatment weeks and the same F&V in plain containers during the other weeks. In contrast, the control group received the F&V in plain containers across all weeks. The intervention group increased their consumption to a greater extent than the control group did during the treatment period and even during the follow-up period when there were no more branding cues on the packaging. This finding suggested that once consumption habits are developed or changed by packaging stimulus, its influence could last a relatively long time.

4. Discussion

4.1. Main findings

A total of 23 identified articles (comprising 40 experimental studies) targeting the relationships between packaging cues and food intake were retrieved and assessed. Overall, most of the manipulated packaging features influenced food intake and only four studies failed to show any effect of altered packaging features on consumption. Some studies (11.3, 19, 20) even provided initial evidence that some packaging cues (e.g., brand cues, partitioning and

packaging size) may have a long-term effect on food intake. The effect of packaging cues on intake also varied by participant characteristics, food features as well as other external stimuli.

4.1.1. Effective packaging features and their effects

The on-pack pictorial visual cues consistently reduced food intake. Specifically, fewer product units displayed on the package reduced food intake significantly, especially when consumers attention was drawn to this. Also, the smaller pictorial serving size recommendation downsized intake. However, showing too small on-pack food portion might nudge consumers to overserve (Guthrie et al., 2015, Thaler and Sunstein, 2009). Neuroimaging research may explain the function of food pictures on packaging as mental simulations, activating reward, experience and food related areas of the brain (Basso et al., 2018). Thus, food representations on packaging serve to encourage intake; however, suggesting small serving sizes might prompt social norm processes. Consumption norms suggesting the “appropriate” amount to consume are powerful determinants of intake (Raynor and Wing, 2007, Sevilla, 2012). Furthermore, providing a physically small package rather than only a pictorial representation can downsize intake, compared with providing a large package. Similarly, partitioning also lowers food intake, and may do so via providing a “brake” on intake or reminder to stop eating. However, partitioning and smaller pack sizes seemed to have a paradoxical effect among diet conscious consumers.

Resealability was also an effective package function in reducing the food intake across different types of snacks; this allows. In support of the suggestion that food pictures can prompt intake, so too transparent packaging enhanced intake relative to opaque packaging. Transparency might stimulate intake via food prime cues and enhanced taste expectancy (Simmonds et al., 2018, Spence, 2016). Opaque packaging significantly reduced intake by 50%, especially for visually attractive, small, colourful and palatable foods. However, the fully transparent packaging reduced intake of relatively healthy foods and larger items (full size cookies). This is might due to when people view the product directly through a transparent window rather than a printed image on the packaging, the food would be more salient. For visually attractive food (Froot Loops™), the visual salience of food may also increase the expectation of food taste and food cravings as well as the food trust (Chandran et al., 2009), thus, the intake increased. While, for some larger products, transparent packaging may invoke greater monitoring effects more than salience. As for healthy vegetables, transparent packaging may increase salience but not liking, thus decrease the intake. These packaging features may work as different nudging (e.g., soft push; guidance) formats to achieve healthier food intake (Arno and Thomas, 2016).

4.1.2. Varying effects depending on food characteristics

Packaging manipulations were carried out on a range of food categories, including snacks, meals, fruits, vegetables and beverages. As discussed above, food visual attractiveness is a key factor for the effects of packaging cues on food consumption. The findings also suggested that some characteristics of foods such as energy density, palatability, expected taste and healthfulness determined the effect of packaging cues on intake.

Some packaging features particularly work for relatively healthier food, not the HED and palatable food. For example, large portion on-pack sticker increased the intake of grapes but had no influence on chocolate nuts consumption (2.1). Similarly, unpartitioned packaging led more granola consumption, however, it did not change the intake of cookies (4.3). On the contrary, packaging size only affects the less healthy food, such as the study 1.2, in which the smaller packaging decreased the consumption of cookies, but had no effect on carrots.

As demonstrated, both the actual and perceived healthfulness of food could influence the effect of packaging cues on food intake. Besides, it also indicated that communicating healthfulness of the food through packaging design (Carrillo et al., 2012, Mead and Richerson, 2018) may also contribute to portion control. Some packaging features have only been tested for HED food, such as the plain packaging can more than double the food intake of HED snacks compared with no packaging situations, since that further work is needed to understand its effect on healthy foods.

The taste of food also differs the consumption impact of some packaging features. To be specific, the sugar level of food significant influenced the effect of package size and on-pack image, such as in the study 1.1 and 16. For the food low in sugar, both smaller package size and smaller on-pack image decreased the food intake, while, for the food relatively high in sugar, the effect on food intake is significant and nearly not exist respectively. This may be due to the effect of some packaging features on food intake are not strong enough to moderate the palatability attractiveness of food with high level of sugar. Besides, the target population were children in both two studies, the liking of foods high in sugar during childhood (Coldwell et al., 2009, Liem and de Graaf, 2004) may explain why the sweet taste was highly connected to the consumption quantity and influenced the effect of packaging features on food intake among children. The finding also suggests a need for greater testing with other tastes and age groups. For example, whether the salty taste has a similar impact as the sweet taste has since the children are also keen on salty snacks (Matsuzuki et al., 2008, Mennella et al., 2014).

Food features need to be further examined to explore and summarize the effect of packaging features on consumption of food with particular characteristics. For example, in all studies that tested the influence of packaging size, only two studies (7, 14) reported no effect. One of the key differences between these two and other studies is the texture of tested food. That they are both non-solid food, semi-liquid food (peanut butter) and liquid food (cola) respectively, in contrast, the food used in the other studies are all solid. This means food texture should be considered as one possible explanation for the inconsistent results of the package size since several studies proved its influence on satiety and food intake (Hogenkamp et al., 2012, Tournier and Louis-Sylvestre, 1991).

4.1.3. Varying effects due to individual differences

This review assesses relevant studies with diverse people across age groups. Although there is a lack of studies targeted at teenagers, there is no evidence showing the effect of any packaging feature that varies due to the age differences. When linking these studies together, some characteristics of participants are highly connected to the effect of packaging on the food intake, including gender, weight status, visual attention and the level of ASE.

Females and males respond differently to packaged food, which are supported by three studies (11.2, 17.2, 17.3). The results indicated that males tend to eat more from the plain packaging than from the original packaging or the packaging with “low fat” label, however, females prefer eating more with the “low fat” label, (17.2, 17.3). In addition, girls ate more branded meals than unbranded meals, while, boys were not influenced by brand logo (11.2). These findings suggest the necessity to consider gender elements in the experiment design and result analysis. Individual bodyweight status also differs the packaging cues effect. Specifically, the overweight/obese (OW) people consumed more food with branded packaging (11.1) or in partitioned packaging (23). In contrast, people with healthy weight ate less from the branded packaging and did not respond to partitioning status. The lack of influence among participants with healthy weight might relate to less experience in responding to external cues to help self-regulation. These findings supported that the OW people heightened reactivity to

external food cues (Meyer et al., 2015). As for which packaging cues people are more particularly sensitive to still need more evidence.

Further, people have different visual attention to environmental cues, which has been linked to obesity (Castellanos et al., 2009, Doolan et al., 2015). It can be noticed from these studies that some on-pack visual cues only work on consumption when consumers pay visual attention to the packaging design. Three studies indicated that the number of product units and the portion recommendation stickers only influence the consumption when the participants pay attention to the packaging visual features (13.5, 13.6, 22.3). Furthermore, two studies (3.5, 13.4) supported this finding that people only responded to the packaging cues in consumption when they were not cognitively occupied, so they could devote attention to the packaging features. In addition, five studies (3.1, 3.2, 3.3, 3.4, 3.5) reported that the effect of packaging cues on food intake is modified by the ASE level of consumers. Low ASEs actively responded to the packaging features, suggesting their eating behaviours were more likely to rely on external control, similar to the obesity and restrained people (Fedoroff et al., 2003). More investigations should be conducted to identify which individual difference could differ the packaging influences on food intake.

4.1.4. Effects are moderated by other variables

Some of the studies reviewed indicated that the effects of some packaging exposures are moderated by other variations. The value of the diet-consciousness activation as part of the portion control packaging intervention was found through four studies (3.4, 10, 12.5, 21.2), which investigated the effects of the packaging manipulation on the consumption when the participants' diet-consciousness was raised via different methods (e.g. informing the calories level of the food, asking the participants to complete a body image questionnaire, instructing participants to read a newspaper article about target food, providing the diet commercials). Specifically, the packaging status, the partitioning of the package, the bottle size and the packaging size didn't work on food consumption without the diet prime stimuli. This finding echoes studies on diet reminders (Buckland et al., 2014, Papies and Veling, 2013).

In the published research, all the diet-consciousness was manipulated by additional artificial stimuli. Given the success of raising health consciousness before offering packaging manipulations for downsizing, further work can be conducted to investigate the impacts of presenting the healthy goals in packaging design (e.g. picture, text) (Buhrau and Ozturk, 2018). Interestingly, when to conduct the experiment also influence the intake outcome., such as in the study 21.2, results showed that there was no pack size effect in the morning, but the pack size significantly influence the food intake. which arouse the question that if the experiment time during a day matters to the effect of other packaging features? Also, only one study (3.2) investigated the interactions between two packaging features on food intake, the transparency of the packaging and package size. It prompted the importance of assessing the interaction between the packaging features.

4.2. Limitations and strengths

The current review is limited in several respects. First, a meta-analysis was not conducted due to the heterogeneity of packaging manipulations and the inconsistent measurement units (e.g., grams, kcal, units, pieces). Secondly, the checklist of Downs and Black (1998) is a validated instrument, but for these studies, some questions were not relevant, thus the appropriateness of the quality assessment of these experimental articles may be influenced. Thirdly, although multiple age groups were included in these studies, undergraduate students

were in the majority, and the adolescent age group was largely neglected in published research, suggesting this age group deserves greater attention. Some key information (e.g., gender, mean age) of participants was not available in some studies. Of those who reported gender ratios, one quarter of studies recruited much more males or females and three of these studies included only females, which suggests a need for a balanced participants gender rate. Finally, some studies did not report if the real aim of the experiment was disclosed, thus, it is unclear whether the participants were aware of the true purpose of the study and whether this may influence intake outcomes.

To our knowledge, this is the first review that systematically investigated the impact of packaging features on the food intake. Unlike other related reviews, most of which only targeted at one type of manipulations, this review provides an overview of the relationships between different packaging features and food intake. These packaging manipulations were orderly displayed through grouping them into clusters based on their characteristics, although other researchers may have different opinions on the packaging categorisations because of the overlap between the packaging features. The effect and effective conditions of various packaging cues were comprehensively discussed, providing insights for further research.

5. Conclusion

Overall, this systematic review synthesised evidence from different studies with different packaging exposures. Over 90% of the studies reviewed have reported positive results and revealed that most types of packaging cues are effective in changing (decreasing or increasing) food intake. The packaging cues which produced downsizing included: the package size, on-pack visual cues and functional features of packaging. Furthermore, the individual differences (e.g., gender, weight status, visual attention and the level of ASE), experimental food features (e.g., food healthfulness and taste) and experiment setting (e.g., diet-consciousness activation and experiment time) have shown great influence on the intake outcomes. Overall, packaging can be a valuable tool to provide healthy consumption norms for foods and beverages. However, as a developing area, many packaging cues like packaging colour, packaging textures and materials remain unexplored. Also, current experimental studies showed mixed and inconsistent results about some packaging cues (e.g., packaging size and partitioning) on measured intake, thus, it is premature to draw firm conclusions on the inconsistent and sustained effects of packaging features on food intake. Much more work is needed to examine the association between the packaging design features and food intake to promote healthier consumption in consumers.

Conflicts of interest statement

No conflict of interest is declared.

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