Multi-component food-items and eating behaviour: what do we know and what do we need to know?

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Abstract:

Multi-component food-items are single food products that comprise more than one food class, brought together usually via some form of processing. Importantly, individual components of the food-item remain discernible and sensorially distinguishable from each other (e.g., chocolate chip cookies or 'choc ice'). Despite a sizable research literature on the formulation of such products, there lacks a concomitant research literature on the effect(s) of multi-component food-items (compared to single component food-items) on eating behaviour. Considerable previous research has investigated the effect of *multiple separate food items* on food intake, portion size selection and palatability. However, studies rarely use test foods that capture the physical or chemical interactions between components that are characteristic of multi-component foods. Nevertheless, previous research and relevant theory allow us to generate hypotheses about how multi-component foods may affect eating behaviour; consideration of food variety and perceived sensory complexity suggest that consumption of multi-component foods are likely to increase perceived palatability of such foods, self-selected portion size and food intake. Moreover, many (but not all) multi-component foods would be considered ultra-processed, which is a driver of food intake in and of itself. One possibility is that food components brought together as part of a multi-component food-item interact to strongly drive eating behaviour. To explore this idea, researchers will need to work across disciplines to address various practical and methodological barriers including the technical preparation of test foods.

Keywords: Multi-component food-items; food variety; sensory complexity; ultra-processed foods; portion size; food intake

1. Background

Multi-component food-items are those that involve more than one food class being brought together, usually via processing of some kind, in order to make a single food product (Street, 1995). Examples offered by Street (1995) include (1) lemon meringue pie, whereby components include pastry, fruit/custard and meringue, and (2) chocolate-chip cookies, whereby the components include pieces of chocolate mixed into a biscuit batter before baking. From a food-science perspective, Street (1995) notes that the compositions of the components within a multi-component food are different, so there is scope for chemical reactions and physical changes that cannot occur if the components are considered alone, and one component can 'shelter' another component from the external environment (e.g., ice cream enrobed in chocolate).

From a consumer experience perspective, we note that a key feature of these foods is that components remain discernible and sensorially distinguishable from each other within the single food product. Such foods are also likely to be categorised/perceived as a single, usually processed, food -item (e.g., a chocolate chip cookie) rather than a meal comprising separate food items (i.e., a multi-component meal such as 'fish and chips'). Though we acknowledge that some ambiguities/overlaps between these definitions may exist, especially in cases where a multi-component food-item may be consumed as a whole meal (for example, a cheeseburger or a 'ready-meal' lasagne).

We also note the overlap between foods that would be considered 'multi-component' according to the definition above and 'ultra-processed' foods. Food processing refers to any change that is made to a food prior to consumption, including basic cooking, smoking and drying for preservation and fermentation (Monteiro, Moubarac, Cannon, Ng, & Popkin, 2013). By contrast, ultra-processing refers to the production of foods via the assembly of ingredients that have been industrially processed, they may have been extracted or refined from whole foods (Moodie et al., 2013). Examples presented by Moodie et al. (2013) include burgers, pizza, cereal bars, nuggets, confectionary and others. We note that many examples of ultra-processed foods are also examples of multi-component foods and represent an overlap between these categories (e.g., cereal bars).

Indeed, Street's (1995) definition of multi-component foods refers to the processing that is required to bring components together to create a single food and for some foods this may constitute 'ultra-processing' if components are themselves industrially processed. However, it is important to acknowledge that these terms are not mutually exclusive, and components could be assembled via basic processing of whole foods (e.g., via homecooking). Notably, Meiselman (2017) examined dishes from 19th century menus and examples of multi-component foods can be found (e.g., apple fritters) which would have been created via cooking as a form of processing (with processed flour) but unlikely to meet the definition of ultra-processing. Nevertheless, considering the overlap in foods that could be categorised as both multi-component and ultra-processed, it may be important to consider the place of multi-component foods in the context of ultra-processing of foods and eating behaviour.

Despite a considerable scientific literature on the production of multi-component food-items (e.g., Hao, Lu, & Wang, 2017; O'Connor, Favreau-Farhadi, & Barrett, 2018) and the apparent ubiquity of such products within food systems, relatively little is known about how eating behaviour is influenced by the consumption of foods that are 'multi-component' (as opposed to single component). The aim of the current article is to firstly consider multi-component foods in terms of relevant theoretical frameworks of eating behaviour (food variety, sensory complexity and ultra-processed foods). Secondly, we will draw on related research that may offer some insight into the potential effects of multi-component foods on eating behaviour. Drawing on insights from previous research and relevant theoretical frameworks, we will then consider the proposition that multi-component food-items are theoretically interesting because they may uniquely bring together food components that together strongly drive eating behaviour (see Figure 1 for a proposed model). Finally, barriers and opportunities for research on this topic are discussed.

2. Relevant theoretical frameworks:

We can consider multi-component foods in the context of eating behaviour in terms of relevant theoretical frameworks. These can be used to generate hypotheses about how multi-component food-items might affect eating behaviour. Here we focus on two frameworks which concern the incorporation of multiple food components into an eating episode (food variety and the 'variety effect', and sensory complexity). We also consider multi-component foods in the context of ultra-processed foods, because bringing multiple food classes together will often (but not always) necessitate some sort of processing including ultra-processing.

2.1 Food variety and the 'variety effect':

The 'variety effect' (for review see Raynor & Epstein, 2001; Raynor & Vadiveloo, 2018; Embling et al. 2021) was first demonstrated by Rolls and colleagues (Rolls, Rowe, et al., 1981) who showed that across successive courses of a meal, participants consume more when the foods in each course vary in taste, texture, and colour (e.g., sandwiches filled with egg salad, tomato and pepper, cheese, or ham) compared to when the same food is presented repeatedly (even if it was a favourite food). This effect has also been demonstrated in the context of a meal comprising sandwiches – relative to a single-flavour condition, participants consume a larger meal when a variety of sandwich flavours (e,g, tuna, turkey, roast beef, egg, cheese or ham) is offered. (Spiegel & Stellar, 1990).

It is likely that food variety stimulates intake because each time a food with different sensory characteristics is tasted it seems to delay satiation, and when satiation is delayed repeatedly over the course of an eating occasion, more food is eaten overall (Hetherington, Foster, Newman, Anderson, & Norton, 2006). This variety effect is thought to be underpinned by sensory specific satiety (SSS) (Brondel et al., 2009). SSS is the decline in rated pleasantness associated with a food as it is eaten relative to a food that has not been eaten (Rolls, Rolls, Rowe, & Sweeney, 1981). This effect seems to be fundamental to the human eating experience and is likely driven by habituation – a simple and universal form of non-associative learning (Epstein, Temple, Roemmich, & Bouton, 2009); there are demonstrations of SSS being preserved in amnesic patients (Higgs, Williamson, Rotshtein, & Humphreys, 2008) and being resistant to a range of cognitive manipulations (Havermans & Brondel, 2013; Wilkinson & Brunstrom, 2016).

One possibility is that multi-component foods represent a form of food variety whereby each sensorially distinct component contributes to the 'variety' experienced. Indeed, Raynor and Vadiveloo (2018) outline a form of food variety that could occur "within a food item" and also outline an 'ingredient-based approach' to considering food variety whereby each ingredient of a mixed dish contributes to variety (e.g., considering the vegetables contained within chicken soup as single units of variety). However, little research exists using this definition. Considering multi-component foods in terms of the variety effect, one might expect multi-component foods to be associated with greater food intake than a comparator single-component food.

2.2 Perceived sensory complexity:

'Perceived sensory complexity' in the context of food and drink, is a concept that refers to the perception of multiple sensations within a single mouthful of a food/ drink as well as across an eating and drinking experience as a whole (Palczak, Blumenthal, & Delarue, 2019; Palczak, Blumenthal, Rogeaux, & Delarue, 2019). The concept of sensory complexity and the accompanying 'optimal arousal theory' were first discussed by Dember and Earl (1957) and Berlyne (1967); Optimal arousal theory suggests that hedonic response to a stimulus increases with complexity (e.g., liking for particular patterns that either had few elements constituting low complexity or many elements constituting high complexity) (Berlyne, Borsa, Craw, Gelman, & Mandell, 1965), but that an optimum is reached based on previous experience. After reaching this optimum, hedonic responding declines as complexity increases (an inverted U function). In the context of fragrance/ odour, Jellinek & Koster (1983) developed the related term 'perceived or psychological complexity' which emphasises the perception of components (as opposed to components that are present but may not be perceived).

In a seminal study, Lévy, MacRae and Koster (2006) tested hypotheses based on 'optimal arousal theory' with beverages (an orange soft drink that was manipulated using flavoured oils to create seven drinks with different levels of perceived complexity). They showed that repeated exposure to a drink that had a perceived complexity level that was above an individual's initial optimum (their most liked drink) shifted their optimum (most liked) upwards (i.e., towards more complex beverages), and less complex products became less liked. By contrast, repeated exposure to a drink that had a perceived complexity level that was below an individual's initial optimum did not shift that individual's optimum.

From a theoretical perspective, this is explained in terms of a 'pacer effect' (Dember & Earl, 1957), where exposure to a stimulus with high perceived complexity shifts an individual's optimum upwards but exposure to a stimulus with low perceived complexity does not shift an individual's optimum downwards. Indeed, arousal theory predicts the experience of boredom with stimuli upon repeated exposure but only for stimuli that are below the optimum arousal level. Moreover, one possibility is that these findings are related to the experience of SSS; Lévy and colleagues reported failing to observe SSS for stimuli that had a higher perceived complexity but successfully observed it for stimuli that had a lower perceived complexity.

One possibility is that multi-component foods represent a relatively complex category of foods (due to their multiple discernible components providing multiple sensations) and that their repeated consumption shifts individuals' optimum (most liked) upwards, such that multi-component products become preferred over time compared to products that do not contain multiple components. Notably, Koster and Mojet (2016) make a similar suggestion, albeit applied to new food products more generally (rather than to multi-component foods specifically), and suggest that new products that are more complex may enjoy longer term market success compared to less complex products.

This proposition remains to be confirmed, with many existing studies focusing on complexity within food and drinks in terms of subtle 'multiple sensations.' For example, wine with a flavour profile including many different 'notes' (Spence & Wang, 2018), or dark solid chocolate bars altered with different flavourings including beet, cinnamon, cardamon and liquorice (Soerensen et al., 2015), may be described as having high perceived flavour complexity but do not constitute a multi-component food when considering a definition that prescribes a need to have discernible components that differ in composition.

2.3 Ultra-processed foods:

As mentioned above, ultra-processed foods are those that are produced via industrial processing of ingredients that have been extracted or refined from whole foods (Moodie et al., 2013). Research has shown that an inverse relationship exists between the energy-contribution of ultra-processed foods to the diet and the nutritional quality of that diet (Steele, Popkin, Swinburn, & Monteiro, 2017). Moreover, sales/capita of ultra-processed foods and drinks are positively associated with population-level body mass index trajectories (Vandevijvere et al., 2019) and an influential randomised controlled trial by Hall et al. (2019) showed that inpatients ate significantly more calories on an ultra-processed diet compared to a matched unprocessed diet.

A recent paper proposed a model that specifies the properties of ultra-processed foods that are most likely to drive excess intake and in turn weight gain (Rolls, Cunningham, & Diktas, 2020). The model contextualises ultra-processed foods as widely available, often low cost and highly convenient, suggests that ultra-processed foods engender an elevated eating rate, energy density and palatability compared to unprocessed foods and proposes that these factors contribute to the promotion of intake and weight gain. Rolls and colleagues also infer a potential mediating role for satiety with the discussion of studies that have manipulated eating rate and energy density and observed effects on satiety.

As previously discussed, there is likely to be some foods that could be considered both ultra-processed and multi-component. Considering evidence that (1) ultra-processing of food is a driver of intake, (2) that multi-component foods may constitute a form of food variety that can also in and of itself increase food intake, and (3) sensory complexity increases liking following repeated consumption; one possibility is that if a food is ultra-processed *and* multi-component, there may be a cooperative effect[1] that leads to greater intake than when a food is either ultra-processed or multi-component alone (see Figure 1).

3. Existing research

Whilst there is a paucity of studies considering multi-component food-items and eating behaviour, many studies have tested the effect of a food property (on eating behaviour) that speak in one way or another to our definition of multi-component foods.

Such findings generate plausible hypotheses focussed on multi-component food-items and eating behaviour. Studies are organised by the facet of eating behaviour explored; food intake, portion-size selection and liking or enjoyment of food.

3.1 Food intake

A number of studies have investigated the effect on food intake of consuming food ‘assortments’ (i.e., food items that are served together but have not been processed to make a single food-item). Hale and Varakin (2016) showed that participants consumed more multi-coloured chocolate candies (Mean candies = 12.5, SD = 17) compared to single-colour chocolate candies (Mean candies = 8.5, SD = 12). Guerrieri et al. (2008) found a similar result between monotonous and varied marshmallows (colour, form, taste and texture), but only in children who were higher in reward-sensitivity. Though, in an earlier study, Rolls et al. (1982) investigated whether increasing colour-only variety would increase intake in a single course compared to a single-colour condition (stimuli were selected to minimise differences in content, taste and smell), and they found no difference in intake of chocolate candies across these conditions. More recently, Vadiveloo et al. (2019) only found an effect of colour or shape variety on intake of fruits and vegetables in specific sub-groups; for example, adults over the age of 36 years old ate more peppers when colour variety was present compared to shape variety, colour and shape variety, and no variety. It should be noted that the studies that described their stimuli in terms of variety in colour, tended not to conduct sensory triangle testing or the updated tetrad testing (likely blindfolded) in order to ensure differences in colour variety were not accompanied by small or minimal differences in taste or other sensory characteristics (for a review of these protocols see (Ishii et al., 2014)).

In addition to studies concerning assortments, studies have also investigated the effect on intake of adding spices and condiments to foods (e.g., vegetable intake in children; (Savage, Peterson, Marini, Bordi Jr, & Birch, 2013). In an example in adults, an observational study has investigated food intake and the relationship between the variety of seasonings used when preparing beans and white rice (Vadiveloo, Campos, & Mattei, 2016). Using a population-based case-control approach with 1025 Costa Rican adults, higher seasoning variety (scored from a list of 8 commonly used ingredients) was associated with greater intake of beans and white rice. The addition of seasonings as a way to introduce flavour components is likely to be more subtle than the components that make up a multi-component food and a future study might consider the use of more substantial components (i.e., components that remain discernible and sensorially distinguishable from each other within the single food product).

Finally, and by contrast, Levitsky, Iyer and Pacanowski (2012) served participants either a composite meal (stir-fry containing onion, corn, carrots etc…) or a deconstructed version of this meal (e.g., onion, corn, carrots, peas and broccoli served as multiple dishes). They found that participants consumed more (grams) when foods were presented separately rather than as a composite. However, it is perhaps somewhat ambiguous whether the composite meal used in this study constitutes a multi-component food or not and a future study might consider the use of a test food that conforms more closely to the definition of a multi-component food (i.e., a single food comprising discernible components that are physically or chemically interacting with each other).

Taken together, whilst results are somewhat mixed, they suggest that when multiple components are presented they are associated with greater intake when compared with a single component. A single study has suggested that when those components are presented 'together' as a composite meal, less is consumed compared to when those components are presented as separate dishes, though future research should seek to replicate this finding.

3.2. Portion size selection

Two studies have used food photography with test foods that could be considered as multi-component foods (Wilkinson, 2013; Bulsing, Gutjar, Zijlstra and Zandstra 2015). Firstly, pilot work (N = 30) assessed the portion-size selection of cakes that differed in terms of number of components (low and high) and taste intensity (low and high), but were matched for energy density and pleasantness (Wilkinson, 2013). In this case, cakes with a high number of components were packaged 'fruit cakes' which included pieces of fruit within the cake itself and for one of the cakes, topped with a layer of marzipan and icing. For cakes with a low number of components, there were no additional components within the cakes (madeira and golden syrup cakes) and no toppings. As hypothesised, a significantly larger portion size was selected for the cakes with more components (d = .9). For now, no attempt has been made to replicate this finding and we note discussion around the risk of pilot studies yielding inflated effect sizes (Kraemer et al., 2006). It is also unclear whether this effect generalises to other foods.

In another study, Bulsing, Gutjar, Zijlstra and Zandstra (2015) produced two food photographs of a 'starter' course with a low and high number of components in single portion sizes. Participants were asked to estimate their ideal portion sizes of a main course that they would consume after each starter. A significantly smaller portion was chosen in the multi-component condition, though it should be noted that other factors were also manipulated alongside number of components, and so effects cannot be solely attributed to this factor.

Another group of studies have explored the effects of assortments on portion size selection (but without a subsequent opportunity to consume the food following selection) (Haws & Redden, 2013; Kinard & Kinard, 2016; Redden & Hoch, 2009). Whilst these findings take different approaches to each other in terms of assessing portion size decisions, they generally converge on the idea that increasing the number of components presented is associated with decisions that would result in a larger portion size being selected. In the most straight-forward demonstration of this, Haws and Redden (2013) found that compared to participants who scored higher in self-control, those who scored lower in self-control chose to consume a greater number of crisps when presented with three types of crisp rather than one type of crisp in a hypothetical task. This result was replicated even when a favourite snack was provided in the ‘one type’ condition. The authors suggested that this effect was likely driven by a greater appreciation for the increased satiety resulting from an increased amount of food (even when varied) that was demonstrated by participants with high self-control compared to low self-control.

Taken together, consistent with studies concerned with food intake, the inclusion of multiple components in a food or assortment was generally associated with the selection of larger portions to hypothetically consume, or the evaluation of that food in such a way that would suggest more would be consumed compared to a single food component.

3.3 Liking and enjoyment

Several studies have explored the effect of sensory complexity on hedonic responses to foods. Whilst some have shown no effect of complexity on hedonic response with only a subtle manipulation of flavour (e.g., salty crackers with different added flavourings) (Porcherot & Issanchou, 1998; Soerensen, Waehrens, & Byrne, 2015), others have found a limited effect on liking with a more extreme manipulation (e.g., mashed potatoes with pieces of celery and nutmeg added) (Reverdy, Schlich, Köster, Ginon, & Lange, 2010; Weijzen, Zandstra, Alfieri, & de Graaf, 2008). Notably, Weijzen et al. (2008) included test foods that would be considered ‘multi-component’ (e.g., candy bar with chocolate and nuts). Over repeated exposure, test foods that were rated as more complex (candy bar with chocolate and nuts, and wholemeal biscuit with chocolate) were more resistant to a decline in liking compared to plain chocolate and a tea biscuit.

Another approach that has been taken is to keep test foods identical across conditions (thereby controlling for liking, energy density and other potential confounding variables) and manipulate participants’ perception of the number of components (rather than the number of components themselves) (Redden, 2008; Galak, Redden, & Kruger, 2009; Embling et al. 2019).

For example, Redden (2008) asked participants to consume an assortment of multicoloured candies that were presented with either flavour specific labels (e.g. 'cherry', 'orange') or a single general label that minimised perception of differences (e.g. 'jellybean'). Redden found that participants enjoyed the candies significantly more, and a had a greater desire to continue eating, when the candies were presented with flavour-specific labels.

4.0 Future directions for research

An important question, therefore, is why research is scant in the area of multi-component foods and eating behaviour? Despite the apparent ubiquity of multi-component food items, there lacks a formal quantification or scoping of their presence across different diets. An indication of widespread access to such products might motivate further research. Future studies might consider an approach similar to studies which have aimed to quantify the availability of ultra-processed foods (e.g., Luiten et al., 2016).

Of course, one must always consider the possibility that an absence of research might be explained by the file drawer problem (failure to publish null results) (Rosenthal, 1979). Following some growth of this literature, a future systematic review and meta-analysis might consider this possibility. An alternative explanation is that studies investigating hypotheses relating to multi-component foods (from an eating behaviour perspective) are simply not being conducted; here we discuss potential directions for future research in this area.

Methodological considerations are likely to be a key barrier to research in this context and a crucial area for research development. Within the context of multi-component food-items it is likely to be more challenging to identify test foods (compared to producing an assortment of food-items for example) that facilitate hypothesis-testing in this area (i.e., a food that is available as a multi-component or non-multi-component version). It may be relevant that in studies concerned with other effects on food intake, researchers often design a bespoke test food that is manipulated in terms of a key element and matched in terms of extraneous variables. Examples include matched foods that vary only in terms of energy density (e.g., Wilkinson & Brunstrom, 2009), flavour and texture (e.g., McCrickerd, Chambers, Brunstrom, & Yeomans, 2012) and palatability (e.g., Yeomans, Lee, Gray, & French, 2001).

However, manipulation of multi-component food is likely to present more of a challenge in this regard and it may be particularly challenging to match a multi-component food condition against a 'no multi-component food' condition because the addition of sensorially-different components to a test food will often affect the energy density, palatability, and so on. Inter-disciplinary collaboration with food technologists, industry and other professionals involved in food product development is likely to be essential to facilitate the use of test foods that reflect the multi-component food experienced by consumers but also meet the needs of a rigorous experimental protocol.

Indeed, a group of studies that have probably come the closest to achieving a valid comparison between test foods that are single component and multi-component, was conducted by a multi-disciplinary team generally including authors from a laboratory of Physics and Physical Chemistry of Foods, a Division of Human Nutrition and Health, a Marketing and Consumer Behavior Group, and a public-private partnership that aims to bring together enterprise, industry and research institutes (Aguayo-Mendoza et al., 2020; Aguayo-Mendoza et al., 2021; Santagiuliana et al., 2018).

For example, a recent study involved the addition of bell pepper gel pieces to processed cheese and followed a similar study which added peach gel particles to peach yogurt (Aguayo-Mendoza et al., 2020). The aim of this approach was to create 'heterogenous' model foods by using a matrix to which components may be added to or not and to assess effects on oral processing behaviour. In both example studies (Aguayo-Mendoza et al., 2020; Aguayo-Mendoza et al., 2021), the addition of particles increased the number of chews and consumption time, which reduced eating rate. Though the magnitude of effect was dependent on the overall texture of the matrix, with larger effects associated with a softer matrix compared to a harder matrix. While another study has shown that the addition of particles to model soups and gels led to a decrease in liking (Santagiuliana et al., 2018).

The heterogenous model foods created by Aguayo-Mendoza and colleagues likely fulfil the definitions of ultra-processed foods and multi-component food-items discussed here. Though future research might consider extending such approaches to achieve greater ecological validity, for example, the inclusion of different flavours of components, indulgent category components/ matrix foods and variations in energy density (carefully matched across single component and multi-component test foods). In addition, the outcomes investigated by these studies did not include intake and portion size selection. More generally, the results of this line of research highlight the nuance required when considering ultra-processed and multi-component foods from a health perspective; here results suggest that the addition of fruit/vegetable-based components to model foods may engender beneficial oral processing behaviours such as slowing eating rate. It may also be that these approaches could be capitalised on to aid rather than undermine consumer health, whether that involves increasing intake of low energy density, nutrient-dense, foods or decreasing intake of high energy density, nutrient-poor foods.

Another approach, and distinct question, is to consider a potential ‘dose response’ effect whereby the relationship between eating behaviours and number of components within a multi-component food is explored. From a test-food production perspective, this might be relatively easy, because the inclusion of components in a ‘control’ test food allows for further variation of those components for comparison with a greater number of sensorially distinct components. This approach could be implemented via the incorporation of pre-existing products with ‘built in’ sensory variety (like different coloured and flavoured candies that already tend to be calorie-matched) into a base food, for example, a chocolate brownie with all of one colour/ flavour candy compared to a chocolate brownie with multi-coloured/ flavoured candies.

However, the inclusion of bespoke test foods in research may be a barrier to study execution because of costs associated with food production and other practical ramifications. One approach that might allow for such research to be conducted without prohibitive costs is to make use of photograph-based methodologies. The use of photographs of foods to assess portion size selection has previously been used and validated against food intake more generally (Wilkinson et al., 2012) but has also been used to demonstrate the classic variety effect (Wilkinson, Hinton, Fay, Rogers, & Brunstrom, 2013). This involves taking photos of a particular test food in different portion sizes (incrementally increasing from a very small portion size to a very large portion size). By taking this approach test foods only need to be produced for the purpose of creating the set of portion size photographs. The photographs can then be presented to participants in a portion size selection task rather than as a test food. Of course, this approach might not be appropriate if the sensory manipulation of a test food is not visually obvious, although creative solutions might mitigate this problem, for example, cross-sections of foods might allow for 'hidden' components to be viewed or the accompaniment of a small taste test portion might allow for subtle taste manipulations to be appreciated without the cost of producing larger portions. Ideally, both portion size selection and actual intake would be assessed, but this approach may allow for preliminary work to be conducted to inform more expensive subsequent research.

Finally, in a related highly innovative approach, the effect of within-meal vegetable variety on portion size selection (from vegetables) has been investigated using a buffet of replica foods (Fake Food Buffet) (Bucher, van der Horst, & Siegrist, 2011). This meant that fresh foods were not required for each testing session, removing significant costs and preparation requirements from the study. They found that, compared to presenting participants with the choice of a single vegetable side dish, participants would select larger portions when they could choose from two vegetable side dishes as part of a meal.

Alongside foundational work which aims to quantify the basic effect of multi-component foods on outcomes such as intake, researchers might also consider potential moderators of such effects, including the assessment of individual differences. For example, because previous research (reviewed above) has shown that children with high reward sensitivity are especially sensitive to the effects of exposure to monotonous and varied foods (Guerrieri et al., 2008), this trait merits further investigation. Researchers might also consider the effect of perceived healthiness of particular components on overall intake of a multi-component food. For example, the inclusion of a component that is likely perceived as healthy in a multi-component food that might otherwise be considered unhealthy (e.g., carrot pieces included in carrot cake). Previous research has suggested that perceived healthiness can be a driver of food intake (Provencher et al., 2009) but such effects remain unexplored in the context of multi-component foods.

5.0 Conclusions

In summary, we argue that the potential for multi-component foods to affect eating behaviour is an important but under-researched topic. This is because, given our discussions around food variety and perceived complexity, and preliminary evidence from the relevant extant literature, it is likely that multi-component foods are a driver of food intake. Moreover, a potential overlap between multi-component foods and ultra-processed foods may compound such effects. From a health perspective, if these effects were capitalised on to increase consumption and liking for low energy density and high micro-nutrient dense foods then this could help prevent under-nutrition. However, if foods with these properties are also high energy density and low micro-nutrient dense then this may drive over-eating and obesity. We suggest that research in this area has been hindered by methodological barriers, in particular, around test food production. It does seem that there are promising approaches to systematically examining the effects of multi-component foods (e.g., further developed versions of heterogenous model foods as used by Aguayo-Mendoza et al. 2021). Researchers conducting studies in this area might consider multi-disciplinary collaborations in order to capitalise on such food technology innovations, as well as methodologies that facilitate a pragmatic way of conducting studies with resource intensive test-foods.

Footnote:

[1] We acknowledge contemporary commentary on the difficulty of quantifying supra-additive effects (when the whole is more than the sum of its parts), and adopt the suggestion of referring to cooperative effects, defined as a combined effect that is greater than the individual effect of each factor (for review see Geary, 2013).

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