

Gastrophysics for pets: Tackling the growing problem of overweight/obese dogs

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ABSTRACT

While the growing global obesity crisis in humans has attracted a great deal of attention from the media and healthcare professionals alike, the rapid increase in weight problems reported amongst pets is now attracting widespread recognition too. In humans, the emerging science of gastrophysics offers a number of concrete suggestions as to how people can be nudged into eating less by means of the enhanced multisensory design of both foods and the environments in which they choose to eat. In this narrative review, the potential relevance of gastrophysics to helping tackle the growing problem of overweight and obese domestic dogs is reviewed. This involves discussion of both the important similarities and difference in the way in which people and their pets perceive food, and the likely role of various product-extrinsic factors on consumption in the two cases. Nevertheless, despite the differences, a number of suggestions for future research are forwarded that may help to address the growing problem of overweight pets, and the behaviours that give rise to it.

1. Introduction

Dogs have been domesticated for more than 40,000 years (Daley, 2017). A large percentage of the population currently own dogs. That said, according to a survey conducted by National Geographic, only 22 of the 60 cultures surveyed considered dogs as pets, and of those, only 7 allowed them to co-habit (see <https://www.nationalgeographic.com/animals/mammals/facts/domestic-dog>). Amongst those cultures, where dogs are considered as pets, ownership has tended to grow steadily. In the United States, for instance, an estimated 68% of households in 2014 had at least one pet (see American Pet Products Association. Pet Industry Market Size & Ownership Statistics; (American Pet Products Association)). What is more, according to the American Pet Products Manufacturers Association (2004), 30–40% of dogs in the United States are overweight. Meanwhile, in the UK, 8.5–9 million dogs were kept as pets in 2017 (PDSA, 2017; PFMA, 2017). A report from the Royal Veterinary College (RVC) in the UK last year reported that one in fourteen of the dogs that veterinarians saw were obese (De Vivo, 2021). The dramatic rise in overweight and obese dogs in recent years presents an important health problem for pets (German, 2006; Lund et al., 2006); See also (Anderson, 1974), for reports of obesity in dogs from almost half a century ago, as well as the observation that obesity is more common in pet dogs than pet cats). In New Zealand, 34% of households owned dogs

in 2020, and 28% were overweight/obese in the North Island according to Gates et al. (2019).

This narrative review (see Furley and Goldschmied, 2021), on the narrative style of review) investigates what can be done to help nudge pets (and their owners) toward being satisfied with a little less (see Seo, 2020), on the concept of sensory nudging). In particular, I want to take a closer look at the various ways in which ‘gastrophysics’ in humans (Spence, 2017b) might be extended to help enhance one’s pet dog’s enjoyment of their food too. In humans, the emerging science of gastrophysics offers a number of concrete suggestions as to how people can be nudged into eating less by means of the enhanced multisensory design of both foods and more specifically the environments in which they choose to eat. However, any simple translation of the insights from human studies to pet dogs is complicated by the very different sensory worlds inhabited by pets as compared to their owners (Muñoz-Prieto et al., 2018). Nevertheless, the new science of gastrophysics can be seen as providing a number of behavioural ‘nudges’ for both pets and their owners to help manage food behaviours more effectively.

1.1. Gastrophysics: The new science of eating

Gastrophysics is the name given to a relatively recent approach to the study of food choice, and food perception in humans (Spence, 2017b).

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The term represents the combination of ‘gastronomy’ and ‘psychophysics’ (the latter the systematic study of human perception).¹ In contrast to more traditional approaches to food science (Heldman, 2006; Potter and Hotchkiss, 1998), where the focus tends to be on the physicochemical structure and shelf stability of foods, the scientific focus in the case of gastrophysics is very much centered on psychological sciences (including psychophysics, cognitive neuroscience, behavioural economics, anthropology, design, etc.; Velasco et al., 2021). While much of the recent popularization of gastrophysics research has occurred in the context of the gastronomic creations of the most innovative chefs, it is worth noting that the optimizing of food, and food experience design is increasingly being taken up by the food industry (e.g., see Spence, 2021a; Spence).

While the majority of the gastrophysics research that has been published to date has involved North American and European participants, there is emerging evidence that many of the same factors influence the food behaviour of populations from a wide variety of cultures/countries (e.g., Velasco et al., 2016; Velasco et al., 2018; Wan et al., 2015). That said, certain of the specific crossmodal associations between, for example, colours, shapes, tastes and flavour have been shown to exhibit some intriguing differences (e.g., Blank and Mattes, 1990; Bremner et al., 2013; Raevskiy et al., 2022). It is currently unclear whether there would also be cross-cultural differences in the food-related correspondences of dogs (though see Korzeniowska et al., 2022), for evidence of crossmodal correspondences in domesticated dogs). As gastrophysics aims to expand our knowledge on the phenomena observed in relation to gastronomy, a growing number of researchers are also interested in evidence-based solutions to urgent human and planetary health issues. The hope is that at the intersection of science, technology, and design it will be possible to foster awareness, behavioural change and inspire novel strategies for innovation in the food industry that are so urgently needed.

When it comes to considering the characteristics of pet food that matter most to dog owners, one online study administered via email to 2181 dog owners by North American researchers revealed that health and nutrition, quality, ingredients, and freshness were ranked as most important (Schleicher et al., 2019). Intriguingly, the majority of the pet owners who responded reported giving either equal weight (53.1%) or greater priority (46.3%) to buying healthy food for their pets as compared with themselves. At the same time, however, Schleicher et al. also highlighted how many pet owners report finding it difficult to know what the optimal diet to feed their pets might be. Indeed, according to online reports, many dog owners would welcome information regarding how best to meet the nutritional requirements for their pets (PetFood Industry. Survey confirms that pet owners need pet nutrition education, n.d.; Phillips-Donaldson, 2013).

1.2. Factors contributing to obesity/overweight status in dogs

There is already rich published literature concerning the various factors that contribute to obesity/overweight status in dogs (see Endenburg et al., 2018), for a review). Significant risk factors that have been identified for overweight status by previous research include orthopaedic diseases (and thus decreased activity; McGreevy et al., 2005), type of diet (Kienzle et al., 1998), change of lifestyle (Robertson, 2003), neuter status (Lafamme, 2005), body condition score (BCS) of the dog as judged by its owner (Kienzle et al., 1998), breed/genetic background (Jeusette et al., 2004), and the socioeconomic status of the owner (McGreevy et al., 2005); see also (Courcier et al., 2010), although it is apparently independent of the economic status of the country (Torda Orsolya et al., 2020). Meanwhile, according to Ronja and Kölle (2021), it is not only the management of feeding that contributes to the

development of obesity in pets, but also genetics, age and gender as well as specific primary diseases which may exert a significant influence on weight gain. Additionally, medical treatment and the relationship between the owner and their pet may also increase the risk for obesity.

2. Multisensory flavour perception in dogs

There are a number of important similarities and differences in the ways in which dogs and their owners experience food (see also Pogány et al., 2018; Tvarijonavičiute et al., 2020). So, for example, it has been suggested that our own transition from four legs to two may have led both to a reduction in our olfactory abilities, and to a concomitant increase in our visual acuity, as our eyes moved further above the olfactorily-rich ground (though see Porter et al., 2006), for evidence that humans can also follow a scent trail in the grass much like dogs; And see (McGann, 2017), on the story of how scientists were misled into believing that the sense of smell in humans is so bad.). At the same time, however, it has also been suggested that the fact that we had to tilt our heads forward as a result of this change to an upright posture may have given rise to a shortening of the distance between the back of the nose and mouth (Shepherd, 2012, p. 26; See also Craven et al., 2010; Ni et al., 2015). This, in turn, may have led to the development of the retronasal sense of smell, according to the eminent North American neuroscientist, Gordon Shepherd. Retronasal olfaction occurs when volatile aromas are pushed out of the nose from the back of the oral cavity when people chew and swallow (Rozin, 1982; Wilson, 2021). This increase in retronasal olfactory contributions to flavour perception in humans really matters, given that it has been estimated that something like 75–95% of what we think we taste (i.e., as a result of the stimulation of the gustatory receptors) may actually be information detected via the retronasal sense of smell instead (see Spence, 2015b), for a review). The percentages are, however, likely to be quite different (and presumably much lower for retronasal olfaction) in the case of dogs, though objective figures are not currently available. See Maier and Elliott (2020) for recent research assessing the relative contribution of olfactory and gustatory cues to flavour perception in non-verbal animals (and for methods to assess food preferences in dogs, see Tobie et al., 2015).

More than a century ago, the Nobel-prize winning Russian psychologist Ivan Pavlov first discovered that dogs would salivate whenever they heard the sound of the bell (actually a tuning fork) signalling that it was time to eat (Pavlov, 1927). It has been suggested that we may be much the same, at least for the section of the population who happen to salivate when they see something like a sour lemon being sliced (see (Spence, 2011b; Spence et al., 2011). Hence, while there are undoubtedly a number of important differences in the way in which dogs and their owners combine the senses as far as multisensory flavour perception is concerned, there are also likely to be a number of similarities in the way that food-extrinsic sensory factors influence consumption behaviour in the two groups.

2.1. Taste and smell

Unlike cats, who lost the ability to taste sweetness, dogs are sensitive to all five of the basic tastes (Biello, 2007; Finlay, 2017; Fregly, 1980; Kumazawa and Kurihara, 1990; Kumazawa et al., 1990). That said, dogs are not particularly sensitive to the taste of salt, given that meat, which would have figured heavily in their ancestral carnivorous diet, would naturally have been high in sodium (e.g., Coile, 2020; Kitchell, 1978). In general, dogs have far fewer taste buds than do humans—about 1700 in the average dog as compared to something like 9000 in humans (Coren, 2011; Spence, 2022). Unlike many humans, though, dogs do not acquire a liking for bitter tastes (Lei et al., 2015). This is despite the fact that they have sophisticated sensory capabilities, as well as the capacity to learn about the physiological consequences of the foods that they consume. That said, dogs are also slower than both humans and cats to learn to avoid those foods that have previously made them ill (Rathore, 1984).

¹ Though see Hinchliffe (2015) and Pedersen, Hansen, and Clausen (2021) for a couple of other uses of the term.

Dogs apparently also have special receptors on the tip of their tongue that enable them to detect water (Liljestrand and Zotterman, 1954). Though, as Bradshaw (2006) notes, in dogs: “it is still unclear how the information from the taste buds is integrated into the brain or translated into feeding behaviour.”

Dogs undoubtedly have a much more developed sense of smell than do humans (Willis et al., 2004). To put the difference in the chemical senses between dogs and humans into perspective, it has been estimated that dogs have something like one-sixth the ability that humans have to taste (that is to detect, sweet, bitter, salty, sour, and umami on the tongue, and elsewhere in the oral cavity; see Spence, 2022), whereas the ability of dogs to smell (primarily orthonasally – i.e., from the outside in when sniffing) is said to be as much as one million times better than that of humans. It is perhaps surprising, therefore, to learn that untrained dogs are unable to discriminate between more versus less food solely on the basis of olfactory cues (Horowitz et al., 2013). According to the latter researchers, olfactory cues are not primary for domestic dogs (the study involved a mixture of 34 mixed breed dogs, and 35 purebreds; it is though important to acknowledge potentially important between-species differences here), and they may not attend to odours as much as a result. That said, dogs are able to analyse the components in odour mixtures in a way that humans simply cannot do (Gazit et al., 2021). Given such insights, the question then becomes one of how pet foods should be designed in order to engage a dogs’ superior orthonasal sense of smell (Bradshaw, 1991; Chen et al., 2016; Yin et al., 2020).

In terms of food odours, preferences amongst dogs tend towards the meaty end of the spectrum (Hall et al., 2017), with most dogs preferring beef and pork over chicken and lamb. It has been suggested that dogs may have specific gustatory receptors tuned to the taste of meats, fats, and other meat-related chemicals (Bradshaw, 2006; see also Boudreau et al., 1985; Boudreau and White, 1978). That said, olfaction also plays an important role in food selection, given that anosmic dogs (i.e., those without a functioning sense of smell) exhibit a significantly reduced ability to discriminate between different types of meat (Houpt et al., 1978). Dogs tend to seek out, and to prefer, the taste of those foods that contain meat, or at least flavours that have been extracted from meat. However, by themselves, the presence of meaty odours, will not help sustain a dog’s interest in an otherwise bland diet (Houpt et al., 1978). It is therefore interesting to consider the role that a dog’s taste preferences might play in the emerging obesity epidemic amongst pets (Houpt and Smith, 1981).

It has been suggested that dogs prefer warm, moist foods over foods that are cold and dry, perhaps once again reflecting the evolutionary gorging on fresh kill by wolves, the ancestors of dogs. That said, questions have been raised over the appropriateness of raw meat diets for dogs and cats (Davies et al., 2019; Freeman et al., 2013; Jackson, 2022; Kidsley et al., 2020). An advert from the Gaines Research Kennels (Gaines Research Kennels, 1952) that appeared in Life magazine promoted the desirability of ‘the crunchy little nuggets’ in their homogenized dog food.² There is, however, little empirical evidence to support the claim that domestic dogs do, in fact, like crunchy (i.e., noisy) foods. Humans, by contrast, are attracted to noisy foods, at least as far as our consumption of snack foods and fresh produce is concerned (Spence, 2015a).³ Intriguingly, numerous patents have been awarded over the last half century concerning the optimization of the sensory qualities of pet foods (e.g., Boudreau and White, 1981; Chen and Trivedi, 2005;

Greenberg and Spiegel, 1973; Shi et al., 2008), hinting at the size and value of the market for pet food. For reference, according to the Statista Pet Food in the US report (Statista), consumers there spent an average of \$194 per year for pet food in 2013. According to estimates, in 2018, there were an estimated 370 million pet cats and 470 million pet dogs worldwide, together consuming \$134 billion of food each year (Knight et al., 2022). And the pet food market continues to grow. In the UK, it rose 17 per cent in the five years to 2019 (Lawton, 2022).

2.2. Do dogs eat first with their eyes?

It has long been claimed that humans eat first with their eyes (Apicius, 1936; Spence et al., 2016). One might therefore naturally wonder whether or not the same is true for dogs. However, the first thing to bear in mind here is that the visual abilities of dogs are typically much worse than those of humans. For example, it has been estimated that dogs are four to eight times worse than humans in terms of their visual acuity (i.e., when it comes to perceiving the details of an object; see Pongrácz et al., 2017). What is more, colour vision in dogs is similar to that in those people (mostly males, as it happens) who happen to be red-green color blind (see Fig. 1). Red-green colour blindness tends to make food less visually appealing to humans, and one might wonder whether the same is also true in dogs (Siniscalchi et al., 2017; Spence and Piqueras-Fiszman, 2014). Nevertheless, according to Beck (2021), dogs appreciate food more when it has a lighter/brighter appearance. In the survey of 2181 pet owners reported by Schleicher et al. (2019) mentioned earlier, colour was one of the least important characteristics of pet food amongst pet owners. As one researcher puts it: “for most pet dogs, the selection of food provided by humans is based upon its appearance, odor, flavour, and texture.” (Bradshaw, 2006, p. 1928S). However, seemingly contradicting such a view, the survey of 2181 pet owners reported by Schleicher et al. (2019), had appearance being rated as one of the least important characteristics of pet food amongst pet owners, whereas health and nutrition, quality, ingredients, freshness and taste were rated as being most important.

Humans perceive there to be more food when it is served on a small rather than large plate (see Fig. 2; though see also Rolls et al., 2007). Similarly, serving food in a rimless bowl can also make it look like there is more food than when exactly the same portion of food is served in a bowl with a rim instead (e.g., Holden et al., 2016; Petit et al., 2018). Relevant specifically to the case of pet food, researchers have demonstrated that untrained dogs can discriminate visually between bowls containing more versus less food (Araujo and Milgram, 2004; Horowitz et al., 2013; Prato-Previde et al., 2008); See also (Agnetta et al., 2000; Ward and Smuts, 2007). Although I am not aware of any research specifically on the issue, dogs are susceptible to a number of visual illusions. That said, they tend to show assimilation rather than contrast in the case of the Delboeuf illusion (contrast being the typical response in humans), this the most relevant illusion as far as explaining the plate-size/rimmed bowl effect on food consumption is concerned (Byosiére et al., 2017; see also Miletto Petrazzini and Wynne, 2016).⁴ Such size/volume illusions may be especially important for those breeds of dog (e.g., beagles) that tend to overeat by a factor of between two and five (Mugford, 1977), a habit perhaps originating from the tendency for wolves to gorge-feed on kills (see (Bradshaw, 1991).

The blue dog bowl shown in Fig. 3 was created in an attempt to nudge pets toward slower consumption (and hence, possibly, eating less). It has long been anecdotally suggested that blue plateware is off-putting to humans. Indeed, back in the 1920’s Depression Era America, saloon owners figured that their customers ate less if served from blue trays (this was known at the time as the so-called ‘blue tray meal

² As the strapline of the ad put it: “You can SEE, FEEL, SMELL the difference! It’s **HOMOGENIZED!**” (Gaines Research Kennels, 1952).

³ At the same time, however, the results of a North American study in which people were invited to taste a range of pâtés, one of which was actually made from blended dog food, revealed that the human tasters did not pick out the pet food from the other four store-bought pâtés. That being said, the blended dog food didn’t score particularly highly in terms of liking amongst the human participants (Bohannon et al., 2009).

⁴ This, then, contrasting with the behaviour of certain reptiles, such as tortoises, whose food consumption is influenced by the Delboeuf illusion in much the same way as in humans (Santacà et al., 2019).

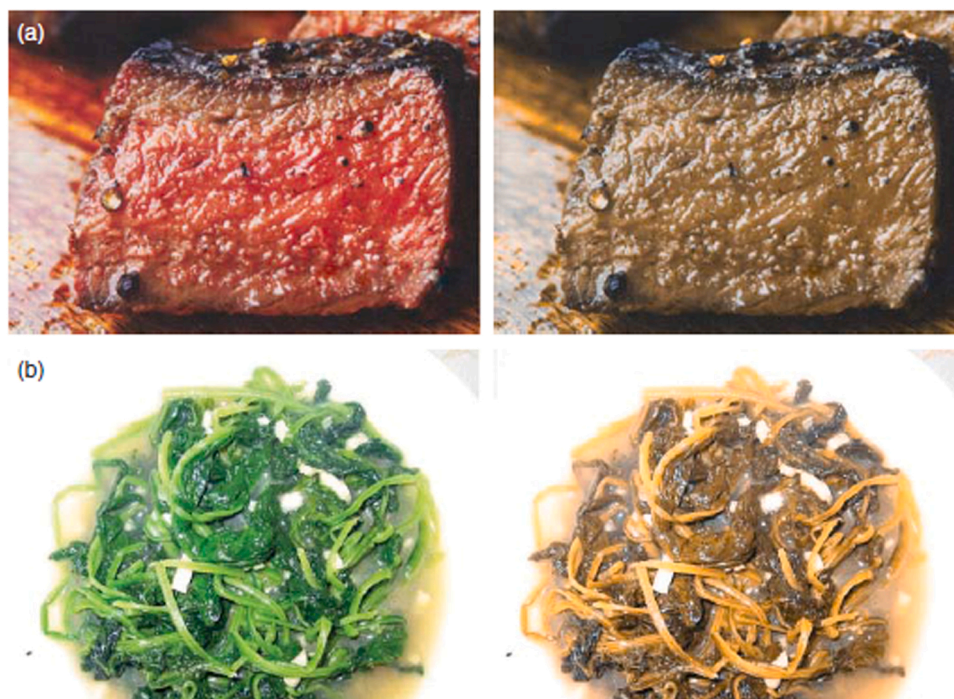


Fig. 1. A rare steak for a normal-sighted person on the left, compared to how a red/green colour-blinded person would see the same steak (i.e. as well cooked) on the right. (b) A plate of cooked spinach for a normal-sighted person (on the left) compared to how a green colour-blind diner might see it (as a meat stew, perhaps?). Note that dogs are red-green colour blind. [Figure reprinted from Spence and Piqueras-Fiszman, (Figure 8.3) (Spence and Piqueras-Fiszman, 2014).].



Fig. 2. In humans, serving food from a smaller plate or bowl can give the illusion that there is more food. Would the same illusion also help your pet to be satisfied with less? Relevant here, it has been suggested that dogs use bulk as the main cue for meal size (Janowitz and Grossman, 1949). [Figure reprinted from Spence and Youssef (2016b)].

deal'; Crumppacker, 2006; Spence). However, given that dogs have poorer vision than humans, such manipulations of plateware colour are less likely to work in canines. At the same time, however, notice how the bowl's protruding dimples will likely make it harder for a pet to consume the food served from such a bowl (thus likely slowing the rate of consumption), regardless of its possibly off-putting colour. A number of designers have designed plateware to make it appear visually as though there is more food than is actually the case for humans (e.g., see Spence, 2018b), though in neither case is there any peer-reviewed evidence to determine whether this kind of nudge actually works to limit the consumption (of either human or animal participants). However, given that dogs have no real interest in what food looks like, it probably really doesn't much matter what colour a dog's bowl happens to be (Thixton, 2009; See also <https://dogcare.dailypuppy.com/matter-dogs-eat-dark-light-6349.html>).



Fig. 3. Pet food bowl designed to reduce consumption. But just how easy is it to transfer insights from the gastrophysics of human nutrition to the case of pet food?

2.3. Sensory dominance, sensory overload, and multisensory flavour perception in dogs

When it comes to integrating the different sensory cues regarding food at mealtimes, it is perhaps worth noting that the research, more generally, shows that dogs exhibit visual dominance over hearing. For example, just think about how a dog may growl viciously, but if their tail is wagging, other dogs' behaviour is dominated by what they see, and consider that it's time to play (rather than reading the multisensory cues as indicating aggressive intentions, as per the growling; Partan and Marler, 1999). Visual cues also dominate over auditory and olfactory cues when it comes to a dog's awareness of people (Fukuzawa and Watanabe, 2017). In fact, according to Adachi, Kuwahata, and Fujita (2007), dogs can even recall their owner's face on hearing the sound of

the latter's voice. That said, olfaction dominates over vision in the responses of trained dogs' to explosives (Gazit and Terkel, 2003), while in the context of food, it has been observed that adding a strong odour that was either unpleasant, or non-food related, to food, reversed the normal preference domestic dogs exhibit to approach the bowl with more food (see Fig. 4; Horowitz et al., 2013).

At the same time, however, dogs, just like humans, may suffer from 'sensory overload' if they are overstimulated (on sensory overload in humans, see Malhotra, 1984); On sensory overload in dogs, see <https://wagwalking.com/condition/sensory-overload>). People's ability to taste is influenced by the level of background noise. Loud noise suppresses the ability to taste sweet and sour (Spence, 2014; Woods et al., 2011; Yan and Dando, 2015). Intriguingly, background noise results in rats liking sweetness more, perhaps as a way of dealing with the sensory stress/overload (Kupfermann, 1964). At the same time, however, the smell of vanilla has been shown to calm both dogs and humans at mealtimes (Binks et al., 2018; Rain, 2004; see also Graham et al., 2005), on the excitatory effect on movement and barking of the dogs housed in an animal shelter on being exposed to the scent of peppermint and rosemary).⁵

Intriguingly, the latest research demonstrates that dogs make some of the same surprising crossmodal associations, e.g., between the pitch of a sound and the size of an object that have previously been documented in people (Korzeniowska et al., 2022; though see Faragó et al., 2010; Von Hornbostel, 1931), this is just one example of so-called crossmodal correspondences (Spence, 2011a). There is growing interest in 'sonic seasoning' (a particular type of crossmodal correspondence), where music and soundscapes are used to enhance people's experience of food and drink. So, for example, one Beijing café deliberately played 'sweet' music (i.e., music that is tinkling, high-pitched and consonant) all day long, the idea being that they could reduce the sugar in their drinks while keeping the perceived sweetness level the same (Blecken, 2017). In humans, tinkling higher-pitched music tends to be associated with, and actually to enhance, the perceived sweetness of food and drink. By contrast, very low-pitched music (i.e., music that is heavy on the bass), tends to bring out bitterness instead; this, remember, a taste that, unlike humans, dogs do not



Fig. 4. Dog paradoxically approaching the plate with less food when a strong odour (of vinegar, lavender, or mint) had been added to the plate with more food. [Figure reprinted from Horowitz et al. (2013); (Figure 7).].

⁵ Note that the dogs tested in Binks et al.'s (2018) study were in an animal shelter, a likely stressful, though potentially sensorially understimulating, environment, according to the study's authors. The scents of vanilla, coconut, ginger, and valerian all exerted an effect on the dogs' behaviour.

(learn to) like. Humans eat and drink more when exposed to loud, fast music (see Spence et al., 2019, for a review). It is currently an open question as to whether dogs' behaviour when feeding might also be entrained to the musical beat (though see Fitch, 2013, on whether sonic seasoning could work to enhance the meatiness of a meal for pets, say (cf. Spence and Youssef, 2016a, on the use of animal sounds to enhance people's experience of a duck dish)?

Separate from this question, though, there is also an emerging literature on the use of classical and other types of music to help /soothe dogs (as measured by activity level/time spent sleeping, vocalizing, and/or body shaking, no matter whether they are in the home environment, kennelled, or in an animal shelter (Bowman et al., 2015, 2017; Gabbard, 2017; Kogan et al., 2012; Leeds and Wagner, 2008); though see also MailOnline Reporter, 2017). As yet, however, I am unaware of anyone having looked at the question of whether classical (or, for that matter, any other kind of) music influences the feeding behaviour of dogs under different environmental conditions/contexts (and see Snowden et al., 2015, on species-appropriate choice of music in cats). It is, however, worth bearing in mind that the dogs habituated to the music after a few days, suggesting that any beneficial effects might be short-lived. Changing the music on a regular basis may help to reduce the speed at which habituation occurs.

Elsewhere, Schipper et al. (2008) have demonstrated the beneficial effect of feeding enrichment toys on the behaviour of kennelled dogs. Specifically, the behaviour of eight laboratory dogs was observed in their home cage pre-toy, during interaction with the toy ('Kong extreme™'; a rubber dog toy stuffed with dog treats), and post-toy. During the trial where the dogs interacted with the toy stimulated appetitive behaviours and increases the dogs' level of activity (exercise), when compared to a sham-treated control group. Indeed, more generally, it is important to consider how pets are often given treats as a reward to enhance the efficacy of training and/or to show affection. Depending on how often they are given out, such treats may also make a not inconsiderable contribution to an animal's overall energy intake thus potentially also making a significant contribution to the growing obesity crisis amongst pets (Forrest et al., 2022). More generally, there is also growing interest in the effects of environmental enrichment on dog behaviour (Hunt et al., 2022). Nutritional enrichment, also called feeding enrichment, is where animals are encouraged to perform natural foraging and feeding behaviours with the use of food rewards (Young, 2003).

3. On the relation between what we feed ourselves and what we feed our dogs

The majority of dog-lovers say that they want to give their pets the best, but report that they sometimes find it hard to distinguish what is best for them (Russell and Buchanan, 2021). Pet owners often struggle to separate what looks/tastes good to them, from what may appeal to the rather different sensory world in which their pet dogs undoubtedly live. At the same time, however, researchers have also documented a correlation between obesity in dogs and their owners, perhaps hinting at the intriguing relation between what we choose to feed ourselves and what we choose to feed our pets (Linder et al., 2021; See also Kienzle et al., 1998).⁶

In humans, eating and drinking are primarily social activities (Jones, 2008; See also Spence et al., 2019). By contrast, dogs evolved from competitive pack-hunting ancestors, namely the wolf *Canis lupus* (Bradshaw, 2006), and hence do not savour their food in quite the same way that either cats or humans do. Dogs tend to eat only during daylight (Mugford, 1977), with their feeding occasions influenced by an endogenous rhythm (Ozon et al., 1986), and distinguished by large infrequent

⁶ That said, walking one's dog, might be expected to have a beneficial effect on the health/weight of both the pet and its owner.

meals. Nevertheless, according to the latest research, it may be beneficial for the health of pet dogs to be fed only once a day (see Le Page, 2021).

We would find it very boring were we to eat the same food for every meal, unless perhaps we happen to be talking about breakfast, where different rules seemingly apply (Spence, 2017a; Spence, 2021b). There is some suggestion that a varied diet is also beneficial, and possibly liked more by dogs, as they seek to meet their nutritional requirements (Bradshaw, 2006; Postins, 2022). According to Kuo (1967), ensuring a varied diet early on is likely to help a pup respond positively to a varied diet later on in life. That said, in the survey of 2181 pet owners reported by North American researchers, ‘variety’ was ranked as somewhere between a slightly- and moderately-important characteristic of pet food amongst pet owners (Schleicher et al., 2019). At the same time, however, it is interesting to note how adding unpredictability to the presentation of food (i.e., by hiding small amounts of food) has been shown to positively influence the food behaviour (i.e., behavioural diversity) of small cats in confined environments (Stepherdson et al., 1993; cf. Clarke et al., 2005).

One area of rapidly-growing interest concerns the place of entomophagy in insect-based pet foods (Hall, 2021). According to estimates from Rabobank, a Dutch multinational, the insect-based pet food market could increase 50-fold by the year 2030, when it is projected that half a million metric tons will be produced (de Jong and Nikolik, 2021). Currently, animal meals are made from crickets, mealworms and black soldier flies. Crucially, however, insect-based pet food is typically more expensive than traditional pet food (Hall, 2021). However, the question is whether the same constraints on what the owner would be happy to consume also influence their choice of what to feed their pets. At present, the higher price of insect-based pet foods is still a barrier to wider uptake. Notice how much the same question arises when pet owners struggle with the question of whether to serve their pets natural or organic dog food (Simonsen et al., 2014). Recently, it has been suggested that switching one’s pet to a vegan diet might, perhaps counterintuitively, provide a number of health benefits (Knight et al., 2022). According to a report from The Insight Partners (The Insight Partners, 2021), the market for vegan pet food was worth an estimated USD 8.7 billion globally in 2020, and its forecast valuation by 2028 has been estimated at USD 15.7 billion.

So, do pet owners make the same kind of food decisions for themselves as for their pets? According to the results of a North American online survey of almost 200 dog owners (Tesfom and Birch, 2010), they are much more serious about buying healthy food for their dogs than they are for themselves. They also tend to be more loyal to pet food brands, as well as more price sensitive when it comes to pet food than their own food (see also Jyrinki, 2006). Certainly, it is interesting to consider the role played by dog owners’ commercial food choices as far as the growing problem of overweight dogs is concerned (Suarez et al., 2012).

One might also consider enrichment and use of varied commercial and home-cooked diets making it difficult for owners to determine the appropriate amount of food and caloric intake (see Pedrinelli et al., 2017). Intriguingly, according to the press, one pet food company (Purina) has recently started trialling smart dog bowls that can measure what pets consume and make nutritional recommendations accordingly (Best, 2021), thus potentially helping to address this problem.

4. Conclusions

Ultimately, our (human) appreciation of food is heavily influenced by what it looks like, by the aroma (both orthonasal, but also the retro-nasal contribution to flavour), and even by the appealing sound of noisy foods. By contrast, dogs have little interest in what food looks or sounds like and while they have vastly superior orthonasal olfactory abilities as compared to humans, it has been suggested that their retro-nasal olfactory abilities may be much reduced. The fact that humans

and their pets live in such different sensory worlds can make it challenging to optimize the food offering for one’s pet, even though a surprisingly large number of pet owners report prioritizing their pet’s nutrition over their own (Schafer, 1978).⁷ Nevertheless, there are a number of directions for gastrophysics-type research (see Spence, 2017b) that will likely help pet owners to make their pets’ mealtimes more enjoyable, and possibly also help to nudge their pets toward a healthier and more sustainable food future. These suggestions are built on the recognition of the salient differences between the multisensory experience of food; Orthonasal olfactory cues and temperature cues appear to be especially important, whereas visual appearance, sound, and texture of food appear to be much less important than for their owners. The potential influence of ambient contextual cues, such as noise, music, and background scent should also be considered, while, at the same time, watching out for the dangers of sensory overload which has been shown to affect dogs much like their owners. Variety in food appears to be much more important to humans. The growing interest in insect-based pet food, and even the rise of vegan alternatives raise the possibility that the food that is served to our pets may increasingly come to diverge from what we feed for ourselves in the coming years (Southern, 2022). As has been reviewed here, the gastrophysics-inspired approach to tackling the growing obesity/overweight problems amongst pet dogs provides a number of suggestions for ways in which an animal’s behaviour may be modified, including various aspects of food selection (amongst both pets and their owners), as well as various multisensory associations that may potentially influence food choice.

Conflict of interest

The authors confirm that there are no conflicts of interest, either real or perceived, in this review article.

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⁷ Given that similarities in smell and taste preferences in couples increase with relationship duration (Groyeck et al., 2018), one might wonder whether the same holds true between owners and their pets (e.g., in terms of a preference for organic food, say).

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