CROSSMODAL CORRESPONDENCES AND ATTENTION IN THE CONTEXT OF MULTISENSORY (PRODUCT) PACKAGING DESIGN

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"The unity of the senses reveals itself in a variety of ways: in sensory processes, where the psychophysical behaviour of different senses shows marked similarities; in perceptual processes, where the different senses provide common information about the world and where characteristics of sensory experience resemble one another; and in cognitive processes, where verbal metaphors describe or suggest similarities among sensory phenomena." (Lawrence Marks, 1978, p. 182).

"Synesthetic design has the goal of achieving the optimal figuration of objects based upon the systematic connections between the senses." (Michael Haverkamp, 2014, p. 15).

Declaration

I hereby declare that this work has not been submitted previously as an exercise for a degree at this or any other university, and that it is entirely my own work.

Carlos Velasco

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This thesis is dedicated to my parents Carlos J. Velasco and Ana I. Pinzón, my sisters Diana and Cristina Velasco, and my partner Emley Kerry.

In memory of my grandmothers.

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Note for the reader

Twenty experiments are presented in this thesis. Fifteen of those experiments are presented in the main body of the text, and five further experiments are presented in the appendices. Experiments 8 and 10 were led by Dr. Muriel Jacquot (University of Lorraine, Nancy, France) and Dr. Xiaoang Wan (Tsinghua University, Beijing, China), respectively. That said, I was involved in the conception of the idea, data collection, analysis, and manuscript drafting. A number of pilot and/or complementary experiments are also presented throughout the manuscript. The contents of this thesis are, in part, based on preprints and accepted versions of the articles included in the section "Publications", for which the author gives full acknowledgement.

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Short abstract

Thesis title: Applied crossmodal correspondences

By Carlos Velasco, Pembroke College, D.Phil. Student of Experimental Psychology, Michaelmas 2015.

The term 'crossmodal correspondence' refers to the tendency for people to match information across the senses. In this thesis, the associations between taste/flavour (tastants and words) information with shapes and colours is investigated. Furthermore, such correspondences are addressed in the context of multisensory packaging design. The focus in this thesis is on the way in which taste/flavour information can be communicated by means of the visual elements of product packaging. Through a series of experiments, I demonstrate that people associate tastes and the roundness/angularity of shapes, and that taste quality, hedonics, and intensity influence such correspondences. However, packaging roundness/angularity does not seem to drive these associations. Additionally, I demonstrate that culture and context systematically influence colour/flavour associations. Importantly, the results reported in this thesis suggest that taste/shape correspondences can influence taste expectations as a function of the visual attributes of product packaging. The results reported here also reveal that colour can influence the classification of, and search for, flavour information on a product's packaging. It turns out that the strength of the association between a flavour category and a colour is crucial to such an effect. The implications of these findings are discussed in light of the theories of crossmodal correspondences, its applications, and directions for future research.

Extended abstract

Thesis title: Applied crossmodal correspondences

By Carlos Velasco, Pembroke College, D.Phil. Student of Experimental Psychology, Michaelmas 2015.

In this thesis, the crossmodal correspondence between taste/flavour and visual information is investigated. In particular, the focus is on clarifying whether people match tastes and shapes and flavours and colours consistently, and the potential mechanisms that may explain these matches. Moreover, I also assess the way in which such matchings influence both visual search for flavour information in product packaging and taste perception. In the first chapter, a general framework for crossmodal correspondences, that is, the tendency to match information across the senses (Marks, 1978; Spence, 2011), is presented (Section 1.1). Next, the available literature on taste-flavour/shape correspondences (Section 1.2), and colour/flavour associations (Section 1.3), as well as the relevant literature on the influence of such correspondences on flavour information search in product packaging is reviewed (Section 1.4). In each of these sections, the review of the literature is framed in the context of the design of product packaging. The argument is made that this provides an interesting means for assessing correspondences between taste/flavour and visual information given that most foods and drinks are packaged (Garber et al., 2001).

Chapter 1 reviews the literature showing that people match both taste and flavour[1] stimuli to the roundness/angularity dimension of shapes (Ngo et al., 2013; Spence & Deroy, 2013), and to packaging shapes (e.g., Smets & Overbeeke, 1995). Importantly, while such associations have previously been documented, the mechanisms that explain them are still unknown, and are tackled in this thesis. Based on research from the olfactory domain, it is hypothesized that certain amodal attributes, namely, taste and shape hedonics and intensity may mediate the association between tastes and the roundness/angularity of shapes (e.g., Deroy et al., 2013; Hanson-Vaux et al., 2013). In addition, it is hypothesized that such mechanisms may differ for packaging shapes, as in that context, there are specific conventions to be found in different product categories (Crilly et al., 2004; Schoormans & Robben, 1997).

The literature on colour/flavour associations is reviewed taking into account the role of culture and context. Several studies are presented in which it is shown that colour associations can vary from culture to culture (Madden et al., 2000) and from context to context (Garber et al, 2000). I hypothesize that the statistical regularities of specific environments and the semantic associations people build from them could perhaps explain such crossmodal associations. With that in mind, although variations may be found across countries and contexts, certain natural pairings found in the environment may therefore be shared in different populations (e.g., Piqueras-Fiszman et al., 2012). A hedonic account is not ruled out for these correspondences though, since in recent years several studies have documented that a similar account can perhaps also explain

[1] People often confuse tastes and flavours. Note that tastes refer to the specific gustatory sensations that arise from the stimulation of receptors in the tongue (e.g., bitter, sweet, salty, sour), while flavours are the product of a combination between taste, (retronasal) olfaction, and trigeminal sensations (Prescott, 1999).

crossmodal matching of polar dimensions involving colours (Palmer et al., 2013; Schifferstein & Tanudjaja, 2004). The chapter ends by suggesting that, while the literature on colour/flavour associations makes specific claims about how and why they should influence information processing (e.g., based on the strength of the association; Berthet et al., 2011), it is less clear how and why taste/shape correspondences may influence visual and taste perception (see Liang et al., 2013). Specially, because the same food or drink can come in a number of different shapes, which differs from the co-occurrence of colours and tastes/flavours in the environment.

The focus in Chapter 2 is on taste/shape correspondences, and the hypothesis suggesting that people match information in those senses as a function of stimulus hedonics and intensity is tested. Experiments 1-3 demonstrate that people match sweet tastes to round shapes, and the other four basic tastes (bitter, salt, sour, umami) to more angular shapes instead. The results of Experiment 4 provide some of the first evidence to suggest that taste hedonics might explain part of the variance of the roundness/angularity ratings. In Experiment 5, the concentration of the tastant is manipulated. The results reveal that not only does taste hedonics, but also taste quality and concentration, influence the roundness/angularity matchings. Notably, this research suggests that shapes can be categorized in both hedonic and intensity-related dimensions, with round shapes being preferred over angular shapes (Bar & Neta, 2006), and the latter being perceived as more potent than the former (Lyman, 1979). Taken together, these results suggest that such properties that can be perceived across all the senses matter when it comes to taste/shape correspondences.

In Chapter 3, an experiment is presented that was designed to assess the way in which people match abstract shapes (on the design of product packaging) and packaging image

moulds to taste words. When using abstract shapes, the results obtained were similar to those presented in Chapter 2. However, that said, the roundness/angularity dimension appeared to be less critical when matching concrete packaging shapes to taste words. These results therefore suggest an additional mechanism when it comes to packaging moulds. The role of conventions (semantic knowledge) and product categorization is discussed. Familiarity with particular products may, instead, guide taste/packaging associations (Felcher, Malaviya, & Mcguill, 2001; Schoormans & Robben, 1997).

The experimental designs from Chapters 2 and 3 are extended to typefaces in Chapter 4. Typefaces undoubtedly constitute an interesting stimulus set for research on crossmodal correspondences since they can convey meaning over-and-above the semantic content of the words (Doyle & Bottomley, 2004; Morrison, 1986; Tannenbaum et al., 1964). The results presented here also reveal that people matched round typefaces to sweet and angular typefaces to the other taste words (bitter, sour, and salty). Crucially, as typefaces roundness/angularity also convey emotional meaning similarly to the way in which shapes do (e.g., Salgado-Montejo et al., 2014), the mechanism discussed in Chapter 2 are extended to the results from Chapter 4.

In Chapter 5, the role of culture and context in colour/odour and colour/flavour correspondences is assessed across 3 experiments. The results demonstrate that, while differences are observed, specific colour/flavour associations can be found across cultures (Experiments 8-10). In particular, those associations that correspond to natural pairings that might be found in the environment (e.g., cucumber and green) are found to be consistent across cultures (at least across those cultures tested in the present thesis). In addition, the results reveal that the context (e.g., packaging or receptacle type) in which foods or drinks are presented interacts with the country of the participants when matching

colours and flavours. These results suggest that context can also influence such associations. The semantic knowledge about specific objects, which can vary from culture to culture and context to context, may influence such mappings (Elliot & Maier, 2012).

Chapter 6 builds on the results presented in Chapter 5 by creating congruent and incongruent colour/flavour word combinations in product packaging. Those combinations are then used in go/no go and visual search tasks. The results show that a product's packaging colour can influence the classification and search of written flavour information on it. In particular, congruent stimulus combinations lead to faster reaction times and less errors than incongruent stimulus combinations (Experiments 11-12). Moreover, the strength of the association between a flavour word and a colour is demonstrated to be a critical factor in the aforementioned congruence effect (Experiment 13). In other words, when a flavour is strongly associated with a colour, incongruent colours interfere more with the search for flavour information. Such results reveal a Stroop-like interference effect (MacLeod, 1991). It is possible to suggest that the colour associated with a flavour may therefore be represented in working memory while searching for a specific flavour label (cf. Eimer, 2014), and potentially, those flavour labels that are presented in a manner that is consistent with the statistical regularities of the environment (see Parise & Spence, 2013, and Spence, 2011), such as cucumber in green, may be easier to classify and search for.

In the last experimental chapter reported in the main part of this thesis, (Chapter 7), the influence of taste/shape correspondences on packaging classification and taste perception is evaluated. In Experiment 14, the different design elements used in Chapters 2-4 are utilized in a classification task. The results demonstrate that people categorize as sweet a product's packaging whose design elements (packaging shape, sound-symbolic name,

and typeface) are consistently round, and as sour when those elements are angular. In addition, such classification is also influenced by the pitch of a task-irrelevant sound; that is, a low-pitched sound increased the likelihood of a product being categorized as sweet, whereas a high-pitched sound increased the likelihood of a product being categorized as sour instead. On the other hand, in Experiment 15, the results failed to reveal any influence of shape on taste perception. The results reported in this chapter therefore suggest that these correspondences may act at higher, as compared to lower, levels of information processing.

In the final chapter of the thesis, the results reported in the experimental chapters are summarized and reviewed in light of the theories of crossmodal associations. Each of the chapters is reviewed and the idea that the different putative mechanisms for crossmodal correspondences (Marks, 1978; Spence, 2011) should not be considered as mutually exclusive is highlighted (Parise & Spence, 2013). Moreover, based on the literature and the experiments reported in this thesis, it is possible to think that crossmodal associations in the context of product packaging may be explained by two parallel and interacting processes that include a concrete semantic space which deals with learnt crossmodal semantic knowledge and a more abstract semantic space that built from abstract, commonly called, amodal features.

CHAPTER 1

Assessing the role of crossmodal correspondences in human information processing

This dissertation reports a series of experiments designed to understand the various ways in which people associate tastes/flavours and visual information. In addition, the way in which these associations, namely crossmodal correspondences, influence human information processing is also assessed. The implications of these studies for the design of product packaging are explored. Specifically, the focus will be on taste/shape and colour/flavour correspondences, and their influence on stimulus classification and visual search. Such correspondences are considered in the context of product packaging, since the latter provides an interesting means of evaluating expectations, classification, and the search for tastes/favours as a function of specific visual attributes. In recent years, a number of developing economies are facing the challenge of introducing a number of new products (and thus flavours) to the international market (Ngo et al., 2013; Salgado-Montejo, Velasco, & Spence, 2013; 2014). A key aspect of this process refers to the way in which both packaging colour and shape can convey information about the likely flavour of a product. With that in mind, one of the aims of this thesis is to approach such a challenge from the literature and experimental methods concerning crossmodal correspondences.

In this introductory chapter, a theoretical framework in which to understand crossmodal correspondences and human information processing is presented. The main focus is on tastes/flavours and shapes, and tastes/flavours and colours. This thesis extends previous

research on the topic and a number of theoretical gaps in the literature are filled in along the way. After providing a conceptual framework, 15 experiments are presented in the main body of the thesis (Chapters 2-7). These experiments are designed to systematically assess the aforementioned correspondences, some of their possible mechanisms (Chapters 2-5), and their influence on classification and visual search (Chapters 6-7). Five additional experiments are presented in Appendices A-C. Whilst these experiments relate to my long-term interests in applied crossmodal perception, and were developed during the course of my D.Phil. research, they are included as Appendices since they are not central to the main objectives of my thesis. Note that throughout this document I will also point the reader to other studies developed throughout my D.Phil. research, which relate to the specific topics covered in this thesis.

1.1 What are crossmodal correspondences?

The concept of crossmodal correspondences (e.g., Spence, 2011, 2012; Spence & Deroy, 2013), sometimes referred to as synaesthetic correspondences or synaesthetic associations (e.g., Marks, 1978; Marks & Mulvenna, 2013), describes the fact that people associate information across the senses (often in ways that may initially seem surprising, hence, the link to synaesthesia). The idea that our brains unite information from the different senses has received attention both from scientists and practitioners in a number of fields including marketing, design, and human-computer interaction. This fascinating topic has attracted attention because it deals with fundamental questions concerning human perception and experience (e.g., Marks, 1978; Spence, 2011) but also because the specific

ways in which the senses relate to one another can inform the design process in many applied contexts (e.g., Haverkamp, 2014; Spence, 2012).

The idea of the "unity of the senses" can be traced back to the first Western philosophers and the topic has long been studied by researchers from a range of disciplines (see Marks, 1978, for a historical overview). In his seminal work "The Unity of the Senses", Marks (1978) described five major scientific doctrines that have dealt with cross-sensory correspondences. The first one, the Doctrine of Equivalent Information, can be found in Aristotle's *sensu communis.* Here, it is suggested that the human senses can provide information about the same characteristics of objects in the environment, that is, there are certain properties of objects that are amodal. For example, while it is possible to visually perceive the spiky shape of an object, it is also possible to do so via the sense of touch[2]. The second, the Doctrine of Analogous Attributes and Qualities, suggests that there are a number of attributes of sensation that are suprasensory in that they may apply to more than one sensory modality. So, for example, information presented to any sensory modality can be described in terms of its intensity, its spatial positions, temporal alignment, and perhaps also its hedonic value (see Chapters 2-5).

The third doctrine, that of Common Psychophysical Properties, builds on the first two and suggests that there are common psychophysical relations between the senses between the attributes suggested by the first two doctrines (e.g., Melara, Marks, & Lesko, 1992). The fourth doctrine, the Doctine of Neural Correspondences, indicates that the first three doctrines have a neural equivalent. Finally, the Doctrine of the Unity of the Senses,

[2] See Appendix A for a series of experiments developed during the course of my D.Phil. thesis, in which evidence is provided for the idea that temperature can also be perceived through audition, which makes one think that this may also be an amodal property.

constructs an integrative interpretation of the crosstalk between the senses by incorporating and extending the other 4 doctrines. According to Marks (1978), the first four doctrines should not be considered as mutually exclusive, but rather as complementary. Importantly, when the fifth doctrine was proposed, Marks (1978) was aware that although such an integrative doctrine would not fully explain the richness of human multisensory experience, and that much work was still needed in order to provide a comprehensive explanation for the unity of the senses. The Unity of the Senses, however, provides an interesting framework that points to some of the key mechanisms putatively driving the way in which the information from different senses may be experienced as united (see Martino & Marks, 2001; Marks, 2013, for reviews on later developments of this approach).

More recently, Spence (2011) forwarded a model that aimed to explain potential mechanisms for, and types of, crossmodal correspondences (see also Parise & Spence, 2013). According to Spence's proposal, crossmodal correspondences include statistical, structural, and semantic varieties. Statistically mediated correspondences are those related to the internalization of the statistical regularities of the environment (e.g., think only of pitch and elevation, see Parise, Knorre, & Ernst, 2014). Structural correspondences result from underlying similarities in the neural coding of different kinds of sensory stimuli (e.g., loudness and brightness, see Marks, 1989). Semantically mediated, or linguistic, correspondences are those that are based on nonredundant stimulus information (and which emerge in language, e.g., a high musical note and a high aroma note, see Deroy, Crisinel, & Spence, 2013). Note here that semantic matching is different from semantic congruence, where stimuli in two sensory modalities such as vision (e.g., the sight of a dog) and audition (e.g., the bark of a dog), belong to the same

object (see e.g., Chen & Spence, 2010, and thus reflect a common identity or meaning). Parise and Spence (2013) argue that semantic congruence generally refers to redundant information about the same object in the environment, while crossmodal correspondences generally refer to complementary (non-redundant) cues. As such, they may reflect the apparently arbitrary associations people make across the senses. Importantly, however, a number of researchers have suggested that such semantic mapping also reflects the correspondences that exist between the senses (Piqueras-Fiszman & Spence, 2011; Piqueras-Fizman, Velasco, & Spence, 2012). If that were the case, it is not clear whether they would differ from other processes such as semantic knowledge (e.g., Humphreys & Forde, 2001). With these points in mind, one may refer to the first as linguistic or lexical correspondences, as suggested by Walker (2012) and Parise and Spence (2013), and to the second as semantic correspondences.

Parise and Spence (2013) acknowledge that the aforementioned correspondences should not be considered as mutually exclusive but rather as complementary, in that one may pick-up the statistical regularities of the environment, which may later be coded in language, and then, over the long term, become structural once the organism evolves. On the available scientific evidence, Spence (2011) suggested that both structural and statistical correspondences could impact perceptual and decisional levels of human information processing, whereas linguistic correspondences would, more likely, primarily have an effect at the decisional level.

Intriguingly, a fourth type of cross-sensory correspondence has also been proposed, namely affective correspondences (e.g., Collier, 1996, Deroy et al., 2013; Kenneth, 1923, for some examples), which Spence (2011) also recognised, though he gave little space to discussing. The idea here is that certain cross-sensory matches may be based on a

common feeling elicited by the information presented to two different senses (for example, music and colours, see Palmer, Schloss, Xu, & Prado-Leon, 2013; or odours and colours, Schifferstein & Tanudjaja, 2004). This idea can be found in the early theories such as the physiognomic hypothesis (e.g., Werner, 1934, 1957) in which it was theorised that affect may be common to the different sensory systems, and that sensory information can produce specific physiological responses that may explain the way in which the senses interact (Marks, 1996; Martino & Marks, 2000). Whilst interesting, this hypothesis has received far less attention than the other accounts of crossmodal correspondences that have been put forward to date. Nonetheless, it has been argued that affect is key to crossmodal associations in that both uni- and multi-sensory stimuli evoke characteristic affective states (e.g., Collier, 1996; Royet et al., 2000). In Chapter 2, this hypothesis is tackled in the context of taste/shape correspondences, which will be later explained in more detail (see Section 1.2.1).

Both Spence (2011), and Marks (1978), primarily focused on audiovisual crossmodal correspondences, since the vast majority of the research that has been published to date has been devoted to these two senses, and their interaction. Therefore, although much work has been conducted on the correspondences between the different senses in recent decades (e.g., Deroy et al., 2013, for a review on the crossmodal correspondences between olfaction and audition), additional research is still needed in order to evaluate other correspondences such as those between gustation and vision (e.g., O'Mahony, 1983), as well as the influence of those associations on visual information processing (e.g., expecting, classifying, attending)—in other words, how these associations influence the way in which tastes/flavours are approached in the world. In addition, while most of the research on crossmodal correspondences has been conducted in the laboratory,

researchers have only recently started to evaluate the way in which this knowledge can be extended to various applied contexts (e.g., Becker, van Rompay, Schifferstein, & Galetzka, 2011; Spence, 2012).

In the following subsections of Chapter 1, the literature on crossmodal correspondences between taste/flavour and visual attributes is presented. In particular, in Section 1.2, the evidence concerning the existence of crossmodal correspondence between taste and shape is reviewed. It is at this point that product packaging is introduced as one way to understand these correspondences. Besides, the way in which such understanding can inform applied contexts such as marketing and design is discussed. After that, crossmodal correspondences between taste/flavour and colour are presented (Section 1.3) and some the available literature on these correspondences and human information processing is summarized (Section 1.4), as a function of the specific aims of this thesis. As colour/flavour correspondences have been more broadly studied, the focus here is the role of context (e.g., packaging) and culture. Chapter 1 ends with a detailed description of the aims of the experiments reported in the thesis.

1.1.1 Interim summary

For a long time now, scientists have wondered how and why humans tend to associate information across the senses. In this chapter, crossmodal correspondences (i.e., the tendency to match information across the senses), and their potential underlying mechanisms are introduced. Specifically, based on the framework laid out be Spence (2011), as well as later developments (Deroy et al., 2013), it is possible to argue that four

types of non-mutually exclusive correspondences — structural, statistical, linguistic, and affective can potentially explain the way in which people match information across the senses. Moreover, the literature on crossmodal correspondences between tastes/shapes (abstract and concrete, packaging) and tastes-flavours and colour are presented and discussed. This chapter will also build on a framework that may account for the influence of these correspondences on human information processing and will outline the general and specific aims of this thesis.

1.2 Associations between taste/flavour and shapes

1.2.1 Crossmodal correspondences between tastes/flavours and abstract shapes

People associate tastes with a variety of information from other sensory modalities (e.g., Knöferle & Spence, 2012; O'Mahony, 1983; Tomasik-Krótki & Strojny, 2008; Wan et al., 2014a). To date, a variety of crossmodal correspondences have been documented between tastes/flavours and colours (e.g., Koch & Koch, 2003; Piqueras-Fiszman & Spence, 2011; Piqueras-Fiszman, Velasco, & Spence, 2012), pseudo-words (Ngo, Velasco, Salgado, Boehm, O'Neill, & Spence, 2013; Spence, 2012), and shapes (Deroy & Valentin, 2011; Overbeeke & Peters, 1991; Smets & Overbeeke, 1995; Spence & Deroy, 2013). The latter correspondence (tastes/flavours-shapes) is particularly intriguing in that many foods or ingredients are presented in a variety of different shapes (or forms), depending on the culinary ingredients, preparation, packaging, or marketing. This in turn, make it less clear as to whether such correspondences can be explained in terms of just their co-occurrence (of features) in the environment.

Spence and Deroy (2013) highlight the fact that crossmodal correspondences between flavours and shapes also surface in language, with adjectives such as ‘round’ and ‘sharp’ being used to describe certain foods and drinks (e.g., wine; Lehrer, 1975, 2009). Indeed, roundness and angularity appear to play an important role in these intuitive associations between tastes and shapes (see Spence, 2012), which should certainly not be thought of as only being restricted to the few reported cases of taste/flavour-shape synaesthesia (see Cytowic, 2003; Cytowic & Wood, 1982; Spence & Deroy, 2013, for reviews), as they also occur in the population at large. In point of fact, synaesthetic metaphor, or the emergence of crossmodal metaphor in language (i.e., just think of phrases such as “a sharp taste” or a “bright sound”), has been reported elsewhere in the literature (e.g., Marks, 2013; Williams, 1976).

Using shape stimuli similar to those originally described by Köhler (1929), Spence and Gallace (2011) reported that certain foodstuffs (and their oral-somatosensory characteristics), such as, for example, sparkling water and Maltesers (a form of honeycomb-centred chocolate confectionary), were associated by people (i.e., normal adult participants) with angular shapes, whereas others, like Brie (a soft French cheese) or chocolate-covered caramel, were better associated with rounded shapes instead. Meanwhile, Spence, Ngo, Percival, and Smith (2013) assessed shape associations to different cheeses’ olfactory, gustatory, and oral-somatosensory properties and demonstrated that people consistently matched different shapes to specific cheeses, and that such matchings were based mainly on the cheese’s taste attributes. Chocolate samples with different cocoa contents are also reliably matched to different shapes varying in angularity, with those with a higher cocoa content being matched to more angular shapes (Ngo, Misra, & Spence, 2011), at least in Western populations (see Bremner et al., 2013,

for an exception). Similar associations have been reported between other foods and beverages and shapes (see Spence & Ngo, 2012, for a review). Crucially, these correspondences are also observed when participants are given a wide range of different shapes to choose from (e.g., Deroy & Valentin, 2011; Seo et al., 2010), thus demonstrating that they do not only appear under conditions of limited restricted forced choice (e.g., between two options). Likewise, crossmodal correspondences have also been documented between angularity and bitterness and between roundness and sweetness (see Spence & Deroy, 2013, for a review).

It appears that some of these correspondences can be observed across cultures, as shown by Ngo et al.'s (2013) study in which both in Colombia and the UK sweeter fruit juices were associated with rounder shapes whereas sourer-tasting juices were matched with more angular shapes instead (though see Bremner et al., 2013, for a cross-cultural study suggesting differences between cultures in the case of people matching chocolate and carbonation to shape, see also Experiment 10 in Chapter 5).

Over-and-above the aforementioned crossmodal correspondences that have been documented to date, it is still an open question as to why the roundness/angularity of shapes would be associated with tastes/flavour in the first place, and, in particular, (how and why) to "basic tastes" (see Spence & Ngo, 2012).[3] One suggestion which has emerged from the study of those crossmodal correspondences that involve olfactory stimuli (e.g., Hanson-Vaux et al., 2013; Seo et al., 2010, see also Kenneth, 1923, for an early proposal), and which is in line with the physiognomic hypothesis presented in the previous section

[3] The ongoing debate as to whether there are 'basic' tastes, and how they should be defined (see Delwiche, 1996; Erickson, 2008), will not be discussed here.

(e.g., Marks, 1996), is that participants tend to match pleasant odours to rounder shapes, while matching unpleasant (or less pleasant) odours to more angular shapes instead (see also Guerdoux, Troutillet, & Broulliet, 2014, for the role of pleasantness in olfactory-visual correspondences, and Appendix B, for a study conducted during my PhD in which such an account is furthered in the context of odour/music correspondences). This may be related to the idea that people generally prefer curved over angular visual objects (Bar & Neta, 2006; Collier, 1996; see also Salgado-Montejo, Velasco, Olier, Alvarado, & Spence, 2014, for a study on this observation, that I developed during my D.Phil. research). This type of explanation could certainly generalise to basic tastes as well, since our reactions to taste stimuli certainly have an affective component—that is, humans react more positively to sweetness while bitter tastes elicit more negative affective reactions (e.g., Steiner et al., 2001). In other words, it may be the case that when matching tastes and abstract shapes, people may rely on the affective properties of such stimuli.

Further research is, however, still needed in order to systematically assess the relationship between basic tastes and the curvature of shapes, and to evaluate whether stimulus hedonics influences the way in which people match tastes and shapes. In Chapter 2, five experiments are presented where the crossmodal correspondence between basic tastes and curvature is empirically assessed and the question of whether taste hedonics can be used to predict shape curvature matchings is evaluated. While previous research has focused on more complex foodstuffs (and flavour is a complex multisensory construct, see Auvray & Spence, 2008; Prescott, 1999; Spence, Smith, & Auvray, 2015), I start by understanding these associations in relation to simpler taste stimuli.

In the following section, I move on to introduce the concept of crossmodal correspondences in the context of multisensory packaging design. Product packaging

constitutes a particularly intriguing marketing stimulus since foods and drinks generally come packaged (Hine, 1995) and its visual features can be experimentally manipulated. This, in turn, offers the possibility of assessing the crossmodal correspondence between taste/flavour and shape as a function of packaging design in that one can manipulate the different visual attributes of product packaging and therefore assess how that changes its taste associations.

1.2.2 Crossmodal correspondences between tastes/flavours and packaging shapes

Researchers and design and marketing practitioners[4] have recently started to realize just how important the study of the different sensory features of a product's packaging can be in terms of engaging their consumers, enhancing the perception of the product, and building brand value (see Krishna, 2012; Spence, 2012). Just imagine the packaging of a product, composed of various sensory features such as colour, shape, the graphemes, and typographies of any text that might be present on the label. Not only that but the feel of the packaging, and any sound that it makes when the consumer picks it up and interacts

[4] It is many years now since the packaging of food and beverage products was thought of merely in terms of portion control, and protecting and conserving the product (see Hine, 1995, for an entertaining history of product packaging). Nowadays, innovative design is increasingly all about using the packaging as a powerful marketing tool in order to more effectively capture the attention of the consumer in the store, communicate with them, and then, ideally, provide the product with a competitive advantage, as compared to other products in the marketplace (see Azzi, Battini, Persona, & Sgarbossa, 2012; Rundh, 2005). Indeed, the last few years have shown how innovative packaging can be used to enhance the consumers' perception of a variety of food and beverage products, help build brand value, and even persuade the consumer to select one brand over another (Orth & Malkewitz, 2008; Prendergast & Pitt, 1996; Rundh, 2009; Schoormans & Robben, 1997; Silayoi & Speece, 2007; Underwood & Ozanne, 1998; Vernuccio, Cozzolino, & Michelini, 2010).

with it can also help to convey a particular message regarding the likely sensory attributes of the packaging's contents (e.g., Spence, 2012; Underwood, 2003).

The idea that different sensory features of a product's packaging may convey information about the attributes of a product may be explained in terms of the notion of crossmodal correspondences as discussed above. A number of published studies have already documented the existence of crossmodal correspondences that may be used to convey information about the taste of a product based on its other features. For example, people associate tastes/flavours and colours (Piqueras-Fiszman & Spence, 2011; Piqueras-Fiszman et al, 2012), sounds (e.g., Knöferle & Spence, 2012; Knöferle, Woods, Käppler, & Spence, 2015), shapes (e.g., Deroy & Valentin, 2011; see also Westerman et al., 2012), and words (Spence & Gallace, 2011; see also Deroy & Spence 2013; Spence, 2012; Spence & Ngo 2012, for reviews). While interesting, one may also wonder whether more basic taste/shape affective correspondences can be generalized to the context of, for example, packaging shapes, since the existing conventions in the marketplace (thus semantic associations) may also play a role in guiding the way in which tastes and packaging design elements are matched (e.g., Moreau, Markman, & Lehman, 2001). In the next section, I critically evaluate the literature on the relationship between packaging shapes and design elements on the one hand, and tastes on the other.

1.2.2.1 Taste and packaging shapes

People make particular associations between abstract/concrete shapes and other sensory stimuli (this area of research is typically referred to as shape symbolism, see Crisinel & Spence, 2012a; Okamoto & Dan, 2013; Spence, 2012). In other words, the shape of a package may evoke specific associations about the sensory attributes of the contents.

Overbeeke and Peters (1991) conducted one of the first studies in this area to investigate whether various packaging shapes would be matched to particular tastes. The participants in their study had to match different desserts (pudding, mousse, tiramisu, and sour cream) to various packaging shapes. The various packaging designs were associated with the desserts in the way that the designers had intended. The authors interpreted these results as reflecting the ability to express and perceive synaesthetic-like relationships (e.g., reflecting some kind of inner connection between taste and shape), though they acknowledge that the idea of people being able to understand specific conventions could not be ruled out (see also Smets, Overbeeke, & Gaver, 1994).

Furthermore, Smets and Overbeeke (1995) reported four experiments designed to assess whether tastes could be expressed by means of product packaging. In their first study, their participants matched specific tastes such as vanilla pudding, yoghurt, and macaroon custard with specific packaging shapes. In their second study, the participants had to complete the same task when the shapes were blurred (in order to investigate the associations between colours and flavours). In their third experiment, the colour was removed from the packaging in order to investigate the effect of shape in driving the matches that their participants made. In their final experiment, Smets and Overbeeke had both experts (designers) and non-experts assess any potential differences between the groups in terms of how packaging shapes convey information about the taste of a product. Their results revealed that people do indeed match particular designs with specific tastes and interpreted the results in terms of the theory of direct perception originally proposed by Gibson (1979, see Section A.1 in Appendix A, for a more detailed explanation of Gibson's theory). The authors suggested that designers are able to express "behavioural

meaning", through their designs. However, the specific way in which Gibson's theory would explain those associations was not detailed.

Additionally, Smets and Overbeeke (1995) did not discuss in detail the fact that their findings may potentially have resulted from both participants and designers acknowledging the conventions of the marketplace (though they did in another of their studies, Smets, Overbeeke, & Gaver, 1994). Nonetheless, it is interesting to note that their results demonstrated that both colour and shape convey information about the taste of a product in packaging, possibly, in a way that reflected the semantic associations that exist between conventional packaging shapes and their contents instead. From this study it was also suggested that there are differences between designers and non-designers in the aforementioned results, with the former being more 'precisely' (based on the intended association) able to match shapes with tastes. Perhaps designers may simply have a richer imagination when it comes to visualizing crossmodal associations (Rader & Tellegen, 1987; Spence & Deroy, 2013), or they may possibly have a better intuitive feel for what constitutes the consensual response of people to such questions (see Koriat, 2008).

Taken together, then, these studies provide some of the first evidence to support the claim that certain tastes/flavours may be associated with the design of product packaging. However, it is not clear whether they rather reflect the conventions of the marketplace, that is, consumers match the packaging shapes and tastes as a function of product-category schemes or semantic knowledge (e.g., Schoormans & Robben, 1997; Stayman, Alden, & Smith, 1992). Certain packaging shapes or image moulds (see Meyers, 1981, on the powerful notion of the image mould; and Spence & Piqueras-Fiszman, 2012, for a more recent summary of this notion) might be linked to specific desserts because that is the convention present in the marketplace, and both designers and consumers' may pick

up on these regularities. In addition, it should be noted that Overbeeke and Peters (1991) and Smets and Overbeeke (1995) both used relatively small sample sizes (i.e., no more than 10-15 participants per study). Likewise, the researchers typically did not draw any generalizations concerning how particular basic features of shapes (i.e., angularity vs. roundness, what some refer to as curvature) can be matched to taste (cf. Seo et al., 2010).

Becker et al. (2011) conducted a study in which they assessed the influence of packaging design on people's perception of flavour. They found that the shape of the packaging shown to their participants (on a computer screen), which included both round and angular designs, influenced the perceived intensity of the flavour of a product. The angular packages increased perceived intensity as compared to the round packages. They concluded that visual parameters can enhance a consumer's expectations about the flavour of a food product, at least in those who were sensitive to design (which was assessed with a standardized questionnaire designed to assess individual differences as a function of visual aesthetics appreciation).

By understanding how information from the different senses is matched crossmodally, it is theoretically possible to influence a consumer's perception of taste and flavour (however, it is not yet clear under which circumstances). For example, by designing packages with visual elements that take into account how tastes and other sensory features are mapped onto one another (Spence, 2012, 2014). While the results of Becker et al. (2011) complement those early studies of Overbeeke and Peters (1991) and Smets and Overbeeke (1995), the fact that designers were more sensitive to the influence of a packaging's shape on the perceived flavour of a product may, once again, reflect the fact that they are more sensitive to the conventions (e.g., concrete packaging shapes may tend to be used for specific product categories) and potentially had specific expectations.

However, it is important to highlight the fact that flavour intensity was affected by the curvature of the shape which, presumably, may be one such feature that guides crossmodal matching to tastes and flavours. The hypothesis here is that, when consumers match tastes/flavours to packaging shapes, they may rely on both crossmodal correspondences and design conventions (semantic knowledge).

Apart from the few studies that have been published on packaging design and taste/flavour, a large and growing number of studies on the topic of crossmodal correspondences have recently appeared in the literature that shed light on how particular tastes/flavours and shapes are matched in the general population (see Section 1.2.1). But why should people match shapes with tastes in the first place? Could it be that here, once again, hedonics plays a role (e.g., Deroy et al., 2013)? That said, it is not known whether hedonic matching may account for the association between tastes and abstract shapes and whether that extends to concrete packaging shapes. The latter question will be assessed in Chapter 3, in which both abstract shapes and concrete (packaging) shapes are used in order to assess the way in which participants' match them to taste words.

It is reasonable to expect that the mechanisms that explain associations between tastes and abstract shapes (without a particular meaning or association) differ from those between tastes and concrete shapes (that have a specific function, identity and/or meaning, e.g., Mervis & Pani, 1980; Rosch et al., 1976; Tyler et al., 2013). The association between tastes/flavours and packaging shapes may be influenced by the fact that specific product categories (categorical knowledge about the object) sometimes use similar packaging image moulds (Spence, 2012; Warlop, Ratneshwar, & Van Osselaer, 2005). Indeed, when matching packaging shapes and tastes, the simple fact of having packaging shapes may create a context that gives rise to an association between a specific

flavour, or class of product (e.g., canned products, cereals, yoghurts), and a particular packaging image mould. More specifically, the different shapes that are used on a product's packaging may be crossmodally matched to a variety of tastes, and may also provide relevant information about the taste of the product (in the case of food and beverage items), over-and-above the concrete knowledge people have about the product that relates to such packaging. Shape attributes are not only found in the form of a package but also on design elements on the packaging such as logos, images, typefaces, and even the sounds that are produced when people interact with a package. Research on the association between these elements and taste/flavour information is presented below.

1.2.2.2 Taste and typefaces

Ngo, Piqueras-Fiszman, and Spence (2012) have suggested that different typographies on the packaging of products may be capable of conveying meaning over-and-above the actual semantic content of whatever it is that happens to be written in those various typographies. It is, then, possible to think about typographies that may convey information about a product and influence both brand and product perception (Childers & Jass, 2002; Doyle & Bottomley, 2006). However, to the best of my knowledge, little research has been conducted to date concerning how different typographies can potentially be mapped onto sensory attributes in other modalities such as, for example, onto tastes (or can be used to help convey information about them). As typefaces can vary in a number of attributes such as curvature, thickness, and orientation, it seems reasonable to expect that people would match them to specific tastes as a function of such features (see Section 1.2.1). In Chapter 4, a study on typefaces and taste words is presented, and the mechanisms underlying the possible relationships between taste and typeface features discussed.

1.2.2.3 Taste, names, and sounds

The associations between speech sounds and tastes have been studied recently and it has been suggested certain speech sounds convey meaning (e.g., think of the name of a product or brand on a packaging). This idea can be traced back to the seminal early research conducted by Sapir (1929), who is considered to be the founding father of sound symbolism research (though see also Uznadze, 1924, 1927). He was certainly one of the first to demonstrate that speech sounds can convey information about the likely size of their referents (e.g., 'mil' for small, and 'mal' for big, see also Ramachandran & Hubbard, 2001). Based on the literature on sound symbolism (e.g., Hinton, Nichols, & Ohala, 1994, for a review) it is, then, possible that specific names that are selected for a product convey information about the sensory features of the product with their names (see Abel & Glinert, 2008; Favalli, Skov, Spence, & Byrne, 2013; Klink, 2000, 2001, 2003) and influence consumers' judgments (Yorkston & Menon, 2004; see Spence, 2012, for a review).

Since Sapir's (1929) seminal proposal, a number of studies have been conducted in order to try to assess how different speech sounds convey information about tastes and other product attributes (Spence, 2011); for instance, it has been proposed that 'soft' and 'rounded' sounds of nonsense words such as 'bouba' or 'maluma' may be better matched to sweet tastes (see Gallace, Boschin, & Spence, 2011; Spence, 2012, 2014), while the 'sharper' speech sounds that are present in words such as 'kiki' or 'takete' may be better associated with sour tastes instead (Ngo et al., 2013). Note, here, that the fact that those words have also been mapped onto shapes with 'kiki' being associated with angular shapes and 'bouba' with round shapes (e.g., Lindauer, 1990). This is interesting for any theoretical proposal regarding crossmodal correspondences because it may allow one to

make predictions about the way in which information is associated. For example, if a sensory stimulus 'A' is associated to two other stimuli in different modalities, namely 'B' and 'C', would that lead to an association between 'A' and 'C'? While this has been found for audiovisual correspondences (e.g., Walker, 2012), further research is undoubtedly needed for the case of taste and olfaction (Deroy et al., 2013).

Furthermore, the idea that people exhibit a tendency to match certain speech sounds to a variety of basic tastes has also been investigated using non-speech sounds. Crisinel and Spence (2009) documented the existence of crossmodal correspondences between tastes and pitch, and found that higher pitched sounds were better associated with sour tastes, while lower-pitched sounds were more naturally associated with bitter tastes instead (note that taster status did not have an effect in such results, see Tepper, 2008, for a review on taster status). Certain mappings (e.g., between bitter tastes and lower pitched sounds and between sweet tastes and higher pitched sounds), however, appear, at least at first glance, to be somewhat inconsistent. So, for example, while Crisinel and Spence (2009, 2010a) both reported that both sour and sweet tastes are associated with high-pitched sounds, Simner, Cuskley, and Kirby (2010), found sweet tastes to be mapped on to low-pitched sounds. Simner et al. suggested that the differences found between studies might be attributable to the different methodological approaches used in the various studies; however, in a later study, Crisinel and Spence (2010b) confirmed Crisinel and Spence's (2010a) results suggesting that sweet and sour tastes may indeed be associated with low-pitched sounds. Further evidence has been provided to support the idea that that sweet tastes tend to be associated with lower pitched sounds, as compared to sour (e.g., Ngo et al., 2013). It would therefore seem fair to say that further research is needed in order to clarify whether sweet tastes are crossmodally matched to lower or higher pitched sounds

(see Knöferle & Spence, 2012, for a review). In Experiment 14, a study that includes pitch as a factor contributes additional evidence to this discussion.

1.2.3 Interim summary

Section 1.2 presented the literature on the crossmodal correspondence between visual and auditory design elements and tastes (Section 1.2.1) and their role in the context of product packaging emphasized (Section 1.2.2). In seems reasonable to expect that taste/abstract shape associations may be based on a hedonic mechanism, while taste/packaging shapes may change as a function of the regularities of the marketplace. They may interact though, in conveying taste/flavour information. These points are assessed experimentally and developed in Chapters 2-4. In the next section, I move on to present the literature on flavour/colour correspondences.

1.3 Cognitive influences on taste/flavour and colour correspondences

1.3.1 Tastes/flavours and colour

We typically perceive foods visually before we eat them (Michel, Velasco, Gatti, & Spence, 2014). It has been proposed that the appearance of food and drink items (not to mention their other sensory features) convey a variety of useful information about taste/flavour (e.g., Delwiche, 2012; see Spence, Levitan, Shankar, & Zampini, 2010, for a review). Just imagine yourself at a supermarket trying to figure out which fruits would be best for a meal. What kind of features would you look for? Information such as the

colour and shape of the fruits is critical not only in determining the identity of the food but also in assessing its quality, potential flavour, and/or ripeness (e.g., Koch & Koch, 2003; Ngo et al., 2013; Shankar, Levitan, & Spence, 2010a; Shankar et al., 2010b; Verhagen & Engelen, 2006; Zampini, Sanabria, Phillips, & Spence, 2007).

A number of studies have been conducted in order to assess how the (multi-) sensory attributes of foods and drinks influence consumers' flavour expectation and discrimination (e.g., Auvray & Spence, 2008; Hoegg & Alba, 2007; Levitan, Zampini, & Spence, 2008; Spence, 2012). For example, Zampini et al. (2007) demonstrated that certain colours tend to be associated with specific flavours, and that flavour discrimination can be impaired by colouring flavoured solutions with incongruent colours; that is, colours that do not necessarily match the flavour (i.e., just imagine an orange juice presented as a blue solution; see Spence et al., 2010, for a review).

The concept of congruence (e.g., between a flavour and a colour) has been proposed as a key aspect of multisensory learning since it can influence both uni- and multisensory information processing. Congruency can be understood as the association that people make between information presented in different sensory modalities that is consistent with relationships between the senses found in nature (Shams & Seitz, 2008). Note that congruence not only applies to colour/flavour associations but also to other associations such as those between shapes and tastes. Congruence becomes potentially interesting when people search for foods and food products in the environment, since those multisensory properties of an object that are congruent may be represented in people’s minds while searching for a target food item.

In the context of colour/flavour associations, congruence may be influenced by peoples' previous experiences in that it has been suggested that the same colour can convey different meanings depending on the context in which it is presented (e.g., Elliot & Maier, 2012; Gimba, 1998; Wan et al., 2014a). That said, the main focus and novel approach of this thesis consists of extending previous research that assessed the cross-cultural and context-related (packaging) differences that may arise in colour/flavour associations.

A hedonic mechanism may not be ruled out though, as people's liking of a taste or flavour, and a colour, may indeed be a product of the context in which taste preferences are developed. In fact, previous research has documented that hedonics may also mediate the association between chemosensory and visual information (e.g., Schifferstein & Tanudjaja, 2004). One possibility here is that that stimulus hedonics and the co-occurrence of specific pairs of colour/flavour stimuli interact. Below, I present colour/flavour associations with a specific emphasis on packaging.

1.3.2 Correspondences between tastes/flavours and colour in product packaging

There can be no doubt that colour plays an essential role in consumer behaviour. In fact, it is perhaps the single most important cue, one that can potentially convey a variety of relevant information to the consumer (i.e., concerning flavour, quality, etc. in the food and beverage sector). Colour cues contribute to product differentiation (e.g., Labrecque & Milne, 2013) and undoubtedly influence consumer behaviour (e.g., Singh, 2006). Many researchers have indeed demonstrated that colour plays a key role in determining whether a consumer attends to a product or brand, and how they subsequently perceive it (e.g., Bagchi & Cheema, 2013; Bottomley & Doyle, 2006; Boudreaux & Palmer, 2007; Dichter,

1964; Favre & November, 1979; Labrecque & Milne, 2012; Labrecque, Patrick, & Milne, 2013). In effect, there are patterns of colour use (what one might call 'colour conventions') that vary by product category. So, for example, it is common for financial products/services to use blue in their brand logos, and for the logos of entertainment brands to use black and white (see Labrecque & Milne, 2013). Importantly, while the rational it not apparently clear, it has also been suggested that food-related product categories also use specific colours in their packages, as it is the case of crisps (see Garber, Hyatt, & Starr, 2000; Piqueras-Fiszman et al., 2012). While initially interesting, one may wonder how stable and robust such colour conventions are.

Although there is general agreement concerning the relevance of colour in communicating brand and product information to consumers, it is important to note that one and the same colour can carry different meanings, or associations, in different cultural contexts (e.g., Gimba, 1998; Madden et al., 2000; Taft, 1997). Thus, understanding how colour-meaning and associations change as a function of culture[5] will be potentially helpful for those companies wanting to develop more effective international communication strategies. By so doing, the hope is that it will increase the likelihood of their conveying the intended meanings in different marketplaces.

Suggestive evidence in this regard comes from a study by Madden et al. (2000). These researchers conducted an experiment designed to assess any differences, or similarities,

[5] Culture is undoubtedly a complex construct, one that researchers have struggled to define (see Greenwood, 1999; Kroeber & Kluckhohn, 1952; Kurtiş & Adams, 2013). Nonetheless, in the context of marketing communications, the concept is typically used to refer to a particular geographical region (e.g., country; see Jacobs, Keown, Worthley, & Ghymn, 1991; Madden et al., 2000, for published examples). Throughout this document, the concept "culture" will be referred to as in the later definition and will be used interchangeably with the word "country".

concerning colour preference and meaning in eight countries spanning East Asia, North America, Europe, and South America (see also Grossman & Wisenblit, 1999). Madden et al. found that in some cases colour preference and meaning were shared across cultures. For instance, their participants liked and associated similar meanings (peaceful, gentle, and calming) with blue, green, and white regardless of the culture that they came from. However, the meaning associated with some colours differs as a function of culture: while black was associated with "formality" in Brazil, Colombia, mainland China, and Taiwan, it was associated with "masculine" in Austria, Hong Kong, and the United States (though it was consistently perceived as "sad" and "stable" across cultures). These results also suggest that a colour can have more than one association and that its meaning can be polysemous and influenced by a variety of contextual variables.

Colour can be used to convey information about product attributes such as the taste/flavour of food and beverage products and can influence product taste evaluation when they are part of a product's physical appearance (e.g., Zampini et al., 2008) and/or when associated with its packaging (Becker et al., 2011; Smets & Overbeeke, 1995). Previously, researchers have demonstrated the existence of robust explicit and implicit colour-flavour associations in product packaging (e.g., in the crisps, or potato chips, category; Piqueras-Fiszman & Spence, 2011; see also Ngo et al., 2012). It would therefore appear that certain crossmodal associations or correspondences may be consistent across cultures (Piqueras-Fiszman et al., 2012).

In particular, Piqueras-Fiszman et al. (2012) assessed the nature of any implicit and explicit crossmodal associations between colour and flavour in the packaging of crisps amongst British and Colombian participants. These researchers found that people from both countries responded more rapidly when they had to pair "natural" labelled crisps

with blue, and "lemon" flavour with green, as compared to "cheese and onion" with blue, and "salt and vinegar" with green (a typical association in the UK marketplace). Furthermore, in an explicit task in which the participants had to come up with colours for particular flavours of crisps, certain associations were shared across cultures while others were found to be more idiosyncratic (though still being shared within a culture). For instance, tuna & mayo labelled crisps were associated with the salmon, cream, and pink colours in both countries, but also with light blue amongst the British participants.

Piqueras-Fiszman and her colleagues (2011, 2012) suggested that people may associate colours and flavours as a function of either the arbitrary associations that have been learnt through repeated exposure to a given brand in the marketplace, and/or by the colour of the primary ingredients by which the product happens to be known (when it comes to crisps, this tends to be the colour of the key flavour components). Although interesting, the aforementioned results included both complex and uncommon colours and flavours, thus making it difficult to generalize from Piqueras-Fiszman et al.'s findings. In addition, a number of intriguing and open questions remain, such as which associations are consistent across cultures, and the potential mechanisms that may explain them.

When it comes to the colour-flavour expectations, significant cross-cultural differences in colour-flavour correspondences do indeed exist. Shankar et al. (2010a) conducted a study designed to assess the flavour expectations elicited by specific beverage colours in British and Taiwanese participants. Red, green, yellow, blue, orange, brown, and clear drinks were presented to the participants who were simply required to report the flavour that first came to mind on seeing them. Cross-cultural differences were documented for the yellow, blue, orange, and brown drinks. For example, the British participants

associated the brown drink with cola, whereas the Taiwanese participants who took part in the study associated it with grape flavour instead (see also Chapter 5).

As mentioned before, there is now a growing body of empirical research demonstrating the existence of significant cross-cultural differences in the meaning of both food and beverage product and packaging colour. However, that said, it is important to highlight the fact that it is still unclear whether there are different types of colour-flavour correspondences (e.g., structural, linguistic, affective, and/or statistical), or conventions (semantic knowledge), and if there are, whether (and how) they interact. In Chapter 5, three experiments are presented in which the cross-cultural differences between flavour related elements, namely, flavour words and smells, are assessed. One of those experiments assesses common edible- and nonedible-related odours and colour associations. Odours are used here too since odours provide some of the first cues about food before people eat, and are consistently matched to colour cues (Maric & Jacquot, 2013) and specific food objects (Shankar et al., 2010a). The potential mechanisms for such correspondences and cross-cultural differences are critically evaluated.

1.3.3 Interim summary

As it is the case of taste/shape associations, specific tastes/flavours and colours are matched in specific ways that may be culturally and context-dependent. While one may be tempted to think that the crossmodal correspondence between colour and flavour is statistically mediated, previous research has also pointed to the idea that not only can colour convey meaning in a context-dependent fashion but also the hedonic value of both colours and flavours may change as a function of context. In the following subsection

(Section 1.4), the way in which these correspondences may influence information processing is discussed. It is important to note that the focus of colour/flavour correspondences will be the flavour labels that food products tend to use on their packages. In Section 1.4.2, this claim is further developed.

1.4 The role of congruence on human taste and visual information processing

1.4.1 Taste-shape correspondences and information processing

Recent evidence suggests that the associations between basic tastes and shapes can influence information processing. For instance, Liang et al. (2013) have assessed the influence of shapes on people's sensitivity to sweetness using near-threshold sucrose solutions. In their study, they reported that people rated round shapes as more pleasant and that presenting a round shape before a sweetness solution could enhance sweetness sensitivity, as compared to when an angular shape was presented (see also Gal, Wheeler, & Shiv, 2007; Stewart & Goss, 2013; though see also Piqueras-Fiszman, Alcaide, Roura, & Spence, 2012). On the other hand, as was already mentioned, Becker et al. (2011) provided evidence for the idea that the curvature of a package can influence the perceived intensity of a taste. Researchers such as Liang and colleagues have interpreted their findings as pointing to the idea that a visual cue, such as a round shape, that has a higher hedonic rating, can thus enhance sweetness expectations. While this points to the idea that these correspondences may influence information processing at the perceptual level, no additional evidence has developed in line with this hypothesis.

In other words, to date, there have not been many studies that have attempted to investigate the implications of these crossmodal associations between shapes and tastes for information processing, in particular as related to the way in which people classify and search for visual representations of taste/flavour. A key question here refers to whether taste/shape correspondences influence information processing at a perceptual or decisional level. The aim of the experiments reported in Chapter 7 was to evaluate whether the design elements of a packaging influence the way in which people classify them as a function of different taste qualities. Additionally, the chapter will assess whether results such as those from Liang and her colleagues would also extend to the other basic tastes, across a range of more everyday suprathreshold stimulus intensities.

1.4.2 Taste/flavour-colour correspondences and visual information processing: The case of flavour labels

According to Garber et al. (2000), most food brands utilize colour in one way or another in order to indicate the flavour of the products they sell. Indeed, when it comes to food, vision, together with orthonasal olfaction, are thought to provide the majority of the information that is available to people before they eat and drink (see also Hutchings, 1977; Shankar et al., 2010a; Stevenson, 2009). Colour, in particular, may be one of the most important cues in guiding people's flavour expectations, classification, search, and perception (see Garber et al., 2000; Garber et al., 2001; Piqueras-Fiszman & Spence, 2011; Spence et al., 2010; Spence, Velasco, & Knoeferle, 2014; Stillman, 1993; Velasco, Jones, King, & Spence, 2013).

Flavour information is also often conveyed by means of other design elements on food products (Garber et al., 2000). For example, the name of the flavour written on the package, or flavour label, can be important when it comes to deciding which product to buy, since colour schemes vary as a function of brand, product category, and country (e.g., Madden et al., 2000; Piqueras-Fiszman et al., 2012). Notably, it has been highlighted that the congruency (e.g., consistency of the information in terms of consumers' prior experience) between the elements of marketing communications can be critical since congruent (e.g., tomato and red) and incongruent (e.g., tomato and blue) information may have different effects on consumer behaviour (Heckler & Childers, 1992; Mandler, 1982; Miller & Kahn, 2005; Peracchio & Tybout, 1996; Schoormans & Robben, 1997).

People have been shown to match both flavour names (e.g., Piqueras-Fiszman & Spence, 2011; Wan et al., 2014a) and actual flavours (e.g., Wan et al., 2014b; Zampini et al., 2007) to colours in specific ways. Notably, the specific ways in which colours and flavours are associated are sensitive to a number of contextual variables (e.g., Shankar et al., 2010a). This, presumably, is attributable to the internalization of the statistical regularities of the environment (Spence, 2011, 2012). Such an idea may explain why it is that certain associations, such as, for example, tomato with red or cucumber with green (natural pairings), are consistent across countries, whereas others are not (lemon refers to lime in Colombia and thus is tends to be associated with green, while in China and the UK with yellow, see Chapter 5). A key question here concerns whether colour-flavour associations (and the strength of the association) influence the classification and search for products with specific flavour labels, since the same product/flavour can often be presented in

different colours, even in the same country (not to mention new products or colours that are introduced to market).

The literature on the Stroop effect demonstrates that when a word (colour name) does not match the (semantically-related) colour in which that word is presented, people take longer and make more errors when trying to name the colour of the word (Stroop interference, see MacLeod, 1991, for a review). Importantly, previous studies have demonstrated that the strength of the association between a colour and a word can influence the magnitude of interference (Berthet, Kop, & Koudier, 2011; Klein, 1964; Klopfer, 1996; Proctor, 1978; Scheibe, Shaver, & Carrier, 1967), which may extend to associations between colours and flavour words. The strength of the association between colour and flavour words is crucial in the context food products as some flavours may have a stronger colour identity (e.g., strawberries) than others (e.g., chicken), which in turn, may depend, for example, on the product category (e.g., an actual chicken has a colour, which may be different when used in crisps).

Relevant to the context of the present study, a reverse Stroop effect, in which colour has been shown to interfere with the reading of the word (e.g., Durgin, 2000), has also been documented. Moreover, this effect has been observed in relation to food names and colours. For example, Nijboer, van Zandvoort, and Hann (2006) conducted a study in which they assessed colour priming in a lexical decision task that used a colour patch or word (i.e., a red patch or red word) in order to prime colour-related ('tomato') and colour-unrelated words ('timato'), as well as congruent (i.e., red) vs. incongruent colours (i.e., blue). In Nijboer et al.'s study, colour facilitated participants' decisions regarding those words that were semantically related to the colour, as compared to incongruent words. In other words, colour can influence decision processes and bias them towards related

objects/words (see also Heurley, Brouillet, Chesnoy, & Brouillet, 2013). With this in mind, if, say, a flavour label and a colour do not match with a consumers' previous experiences, some kind of interference can be expected when classifying and searching for a product's flavour information.

A similar colour-flavour congruency effect may be expected in the context of visual search for flavour information on a product's packaging. The way in which people attend to the world around them depends on at least two attentional mechanisms: bottom-up (stimulus-driven) and top-down (goal-driven; e.g., Spence & Driver, 1994). The latter implies that, by modulating the sensitivity of the brain mechanisms that represent information (top-down processing), it is possible to more efficiently explore and select one kind of stimulus over another (Knudsen, 2007; Wolfe & Horowitz, 2004). People's goals (e.g., searching for a flavour label) can act as a filter to facilitate selective attention to a subset of all of the visual information (i.e., colour) competing for an observer's attention in the world (e.g., in the supermarket). A particular colour-related word or colour can activate related representations that may then exert a top-down influence that favours semantically-related information. Indeed, knowing (or expecting) the colour of a target can reduce search latencies (Eckstein, 2011; Theeuwes, 2010).

In Chapter 6, three experiments are conducted in order to assess whether the congruence between colour and flavour words would influence information processing, in particular, a go/no go task and a visual search task are used. The proposal that will be forwarded here is that Stroop-like tasks in the context of classification and search can provide useful information as to which colours and flavours are more strongly related.

1.4.3 Interim summary

In Section 1.4, relevant literature on the influence of tastes and shapes and colours and flavour information congruence on information processing was introduced. Not much evidence is available on how taste/shape correspondences may influence information processing of visual representations of taste. On the other hand the literature on colour/flavour associations allows one to make specific predictions about flavour label processing on product packaging and the role of colour. Specifically, by taking into account the Stroop interference literature as well as the studies on colour/flavour congruence in flavour perception. In Section 1.5, the aims of the present thesis are stated.

1.5 Aims and outline of the following chapters

In the following chapters, empirical evidence will be provided with the aim of responding the different questions raised in this introductory chapter. In particular, the general aims here concern how and why people match taste/flavour information (either taste or flavour words or tastants) and visual information, and how do those associations influence information processing. In Chapter 2, the focus is on taste/shape correspondences, and a hedonic and intensity mechanism for such correspondences will be assessed. Chapters 3 and 4 extend the results of Chapter 2 to the context of packaging shapes, and packaging design elements. In Chapter 5, the role of culture and context in colour/flavour and colour/odour correspondences is assessed, and Chapter 6 and 7 explore these correspondences in both classification and search tasks. The final aim consists of providing a comprehensive framework for the evidence presented, and to discuss the potential limitations and future studies that may follow this dissertation. It is hoped that

the present thesis contributes to the understanding of the different correspondences that have been presented in Chapter 1, and also that it provides new insights for practitioners interested in the growing field of ‘synesthetic design’ which aims to translate the research on multisensory processes to human experience design (e.g., Haverkamp, 2014).

CHAPTER 2

Crossmodal correspondences between tastes and abstract shapes

2.1 Introduction

Over-and-above the various correspondences between tastes and shapes that have been documented in the literature to date (see Sections 1.2.1 and 1.2.2), it is still an open question as to how and why the roundness/angularity of shapes should be associated to tastes/flavours in the first place, and why, in particular, they should be associated with "basic tastes" (see Spence & Ngo, 2012). In this chapter, I test the suggestion emerging from the literature on crossmodal correspondences that involve olfactory stimuli (Crisinel & Spence, 2012b; Deroy et al., 2013; Hanson-Vaux et al., 2013; Kenneth, 1923; Seo et al., 2010; Velasco, Balboa, Marmolejo-Ramos, & Spence, 2014[6]), in which it has been suggested that participants would match pleasant odours with rounder shapes, while matching unpleasant odours with more angular shapes.

Again, as mentioned before, this may be the case because people generally prefer curved over angular visual objects (e.g., Bar & Neta, 2006). What is more, our reactions to basic tastes certainly have a fundamental affective component with humans reacting more

[6] See Appendix C, for this study in which I assess the crossmodal effect of music and odour pleasantness in olfactory quality perception, which was also developed through my D.Phil. research. This study also points to hedonic-related correspondences in the case of olfaction.

positively to sweetness while bitter tastes elicit more negative affective reactions instead (e.g., Steiner et al., 2001). Note that previous research has suggested that people tend to match round shapes and sweet flavours (Ngo et al., 2013). Furthermore, based on the evidence to suggest that taste intensity may be an important factor when it comes to shape influences on taste perception (Becker et al., 2011), such variable is also studied in this chapter.

Five experiments are reported here in which the associations between basic tastes (both taste words and actual tastants) and roundness/angularity (Experiments 1-3), and the role of taste liking (Experiments 3-5) and concentration in these associations (Experiment 5) were assessed. If both taste liking and taste concentration contribute to the way in which people match tastes and shapes, that would make one wonder, from a theoretical perspective, how and why such unisensory stimuli interact when people match them.

2.2 Experiment 1: Crossmodal correspondences between taste names and roundness/angularity in abstract shapes

2.2.1 Methods and materials

2.2.1.1 Participants

Twenty-six participants (17 females, mean age = 26.3 years, SD = 6.5) took part in the study. All of the experiments reported in this thesis were reviewed and approved by the Central University Research Ethics Committee at the University of Oxford. The participants in all of the experiments reported in this thesis also signed a standard consent form. This experiment lasted for approximately 5-8 minutes.

2.2.1.2 Apparatus and materials

The experiment was designed and conducted using the E-Prime 2.0 software (Psychology Software Tools, Inc.). The participants were seated approximately 60 cm in front of a 17 inch CRT-monitor, with a resolution of 1024 x 768 pixels, and a screen refresh rate of 60 Hz, in a darkened, sound-proofed experimental booth.

The taste words ('bitter', 'salty', 'sour', and 'sweet') were presented on the monitor in Courier New, font size 20. The participants' task consisted of rating those taste names along shape scales anchored with angular or rounded shapes (see Figure 2.1). Those shapes have previously been used in various studies that have assessed crossmodal correspondences between tastes and shapes (e.g., Spence, & Deroy, 2013; Spence & Ngo, 2012, for reviews) and some were taken from the original studies conducted by Köhler (1929). Each pair of shapes, shown in Figure 2.1, was used as the anchors for one of the four different visual analogue scales (VAS), ranging from 0 to 100. Pairs A and D were anchored with the rounded shape on the left side and the angular shape on the right, while pairs B and C were anchored with the angular shape on the right and the rounded shape on the left instead. This counterbalancing of position was incorporated into the experimental design in order to avoid any lateralized anchor position effects. That is, in order to avoid that having the same shape on either the right or left side would bias participants' responses. The four taste names were paired with each of the four scale combinations and each pairing was shown twice, giving rise to a total of 32 trials. The trial order was randomised across participants.

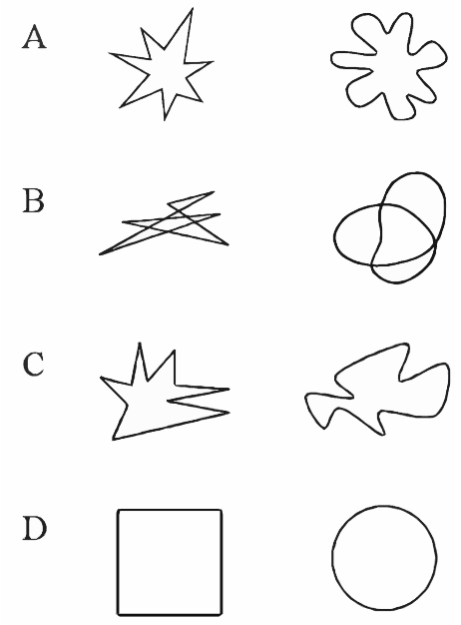


Figure 2.1. The four pairs of angular and rounded shapes used as anchors for the different scales in Experiment 1.

2.2.1.3 Procedure

In each trial, the participants were asked to think of a food that has the taste presented in the trial, and to try to match it to a point on the scale. Analysis of the data was carried out using in SPSS (IBM, Chicago) and R statistical software (R Core Team, 2013) and the ggplot2 package (Wickham, 2009).

2.2.2 Results and discussion

Preliminary analysis revealed a very similar pattern of results for the 4 scales. Consequently, the scales were collapsed into a broader category of shape roundness/angularity in order to assess any difference in taste-shape correspondences as

a function of the taste word under consideration. A one-way repeated measures analysis of variance (RM-ANOVA), using the Greenhouse Geisser correction, revealed a significant effect of taste word, $F(1.857, 46.422) = 17.508$, $p < .001$, $\eta^2_{partial} = .412$. Pairwise comparisons (Bonferroni corrected) revealed that sweet taste was rated as rounder than any of the other tastes ($p \leq .001$, for all comparisons, see Figure 2.2).

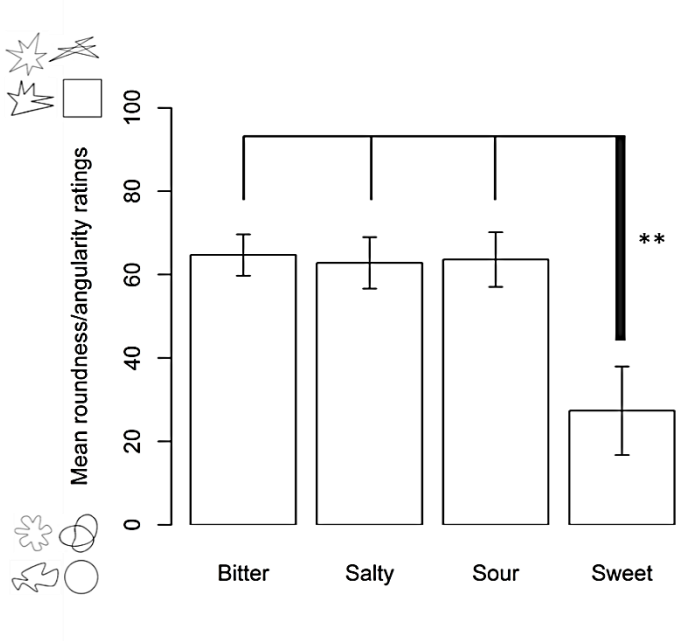


Figure 2.2. Mean roundness/angularity ratings for each taste in Experiment 1. The thicker line indicates the taste being compared and the asterisks highlight the ratings that were significantly different for sweet as compared to the other tastes ($p \leq .001$). The error bars represent 95% confidence intervals.

In addition, one-sample t-tests were performed in order to determine whether the ratings on each taste differed from the mid-point of the scale (50). This analysis revealed that participants rated bitter, $t(25) = 3.711$, $p = .001$, salty, $t(25) = 3.257$, $p = .003$, and sour, $t(25) = 2.921$, $p = .007$, significantly toward the angular end of the scales, whereas sweet responses fell significantly toward the round end of the scales, $t(25) = -5.421$, $p < .001$.

These results therefore suggest that rather than there being taste specific associations to roundness/angularity, the correspondence between shape and taste only seems to capture the distinction between sweetness and the other three most commonly mentioned basic tastes (namely bitter, salty, and sour). In order to confirm and extend this finding, the same design was implemented in an online study in Experiment 2, thus allowing my colleagues and I to test a larger and more varied sample of participants compared to the Oxford University students used in my first study.[7]

2.3 Experiment 2: Crossmodal correspondences between taste names and roundness/angularity in abstract shapes: An online replication

2.3.1 Methods and materials

2.3.1.1 Participants

One hundred and one participants (40 females, mean age = 32.84 years, SD = 9.23 years) from the United States took part in the study online through the Adobe Flash based Xperiment software (http://www.xperiment.mobi). All of the participants were recruited using Amazon's Mechanical Turk in exchange for a payment of 1.25 USD and all were based in the USA. All of the participants agreed to take part in the study after reading a standard consent form. The experimental procedure used in Experiment 1 (Section 2.2) was also utilized here.

[7] See Henrich, Heine, and Norenzayan (2010), on the limited scope of research that only tests WEIRD participants, that is, participants from Western, Educated, Industrialized, Rich, and Democratic societies.

2.3.2 Results and discussion

Once again, the ratings across the 4 scales were collapsed in order to assess any difference in terms of taste-shape correspondences as a function of the taste word under consideration. A one-way RM-ANOVA using the Greenhouse-Geisser correction revealed a significant difference between the shape ratings associated with taste names, $F(2.404, 240.398) = 73.639$, $p < .001$, $\eta^2_{partial} = .424$. Pairwise comparisons (Bonferroni corrected) were performed and the results revealed that the "sweet" taste word was rated as rounder than any of the other taste names ($p < .001$, for all comparisons, see Figure 2.3).

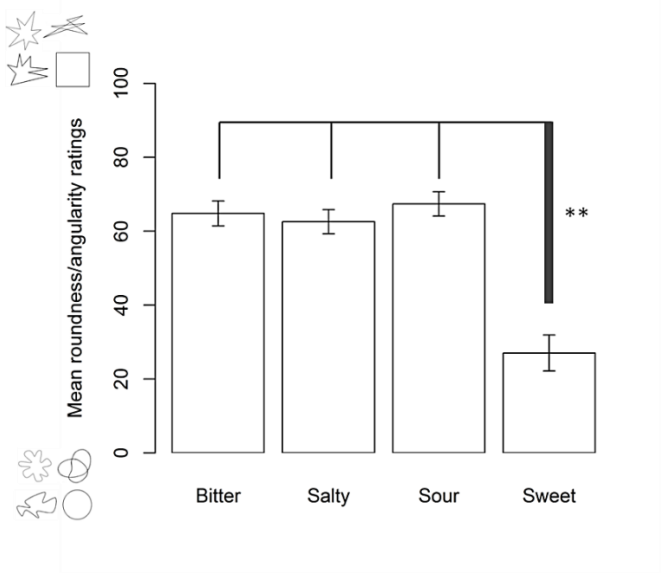


Figure 2.3. Mean roundness/angularity ratings for each taste name in Experiment 2. The thicker line indicates the taste being compared and the asterisks highlight the significantly different ratings for sweet as compared to the other tastes ($p < .001$). The error bars represent 95% confidence intervals.

One-sample t-tests revealed that the participants rated bitter, $t(100) = 6.898$, $p < .001$, salty, $t(100) = 6.105$, $p < .001$, and sour, $t(100) = 7.854$, $p < .001$, as significantly more toward the angular end of the scales, whereas sweet was rated as significantly toward the round end of the scales, $t(100) = -11.140$, $p < .001$. As in Experiment 1, it would appear that people tend to match roundness to sweetness while the other tastes do not differ in terms of their shape associations, and all are matched with shapes that fall toward the angular end of the shape scale.

At a more fundamental level, one can ask why is it that people match shape roundness/angularity to taste names in the first place? In Experiments 3-5 (Sections 2.4 and 2.5, respectively), the role of taste (words and tastants) liking in taste-shape associations was assessed in order to evaluate whether the hedonic properties of a stimulus might play an important role in explaining the way in which people form these associations (e.g., see Crisinel & Spence, 2012b; Spence & Deroy, 2014).

2.4 Experiment 3: Roundness/Angularity and liking: An online study on taste (names) and their shape associations

2.4.1 Methods and materials

2.4.1.1 Participants

Sixty five participants (14 females, mean age = 28.24 years, SD = 7.51) from the United States took part in the online study, again run with the Xperiment platform. All of participants were recruited using Amazon's Mechanical Turk in exchange for a payment of 0.60 USD.

2.4.1.2 Apparatus and materials

Two visual roundness/angularity scales were designed based on the results of Experiments 1-2. The scales were as follows: A single shape was presented on the screen which could be morphed by the participant dragging their mouse up and down the screen. This was achieved by rapidly moving between a sequence of 100 images that morphed gradually. Two pairs of shapes were used as the anchors and 100 images that represented the variation from one anchor (round) to another (angular) were created in order to represent a visual scale of roundness/angularity. Dragging the mouse fully to the bottom/top of the screen morphed the shape entirely into one of the anchor images.

To generate a linear sequence of morphed images between the two original images, the original jpg-format images were first converted into vector images using Adobe Illustrator's trace feature, and then these vectors were imported into Adobe Flash Professional CS 5.5. The software's Shape Tween tool was used to morph one image into the other over a series of 100 frames, and then exported these series of still-images (see Figure 2.4).

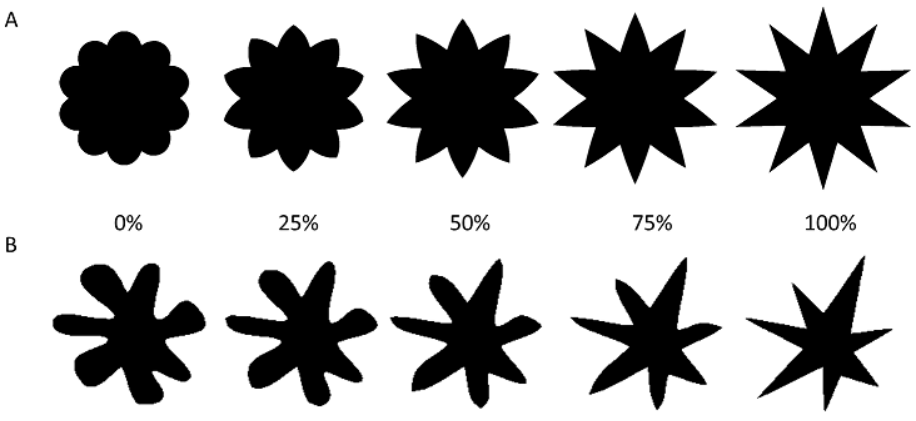


Figure 2.4. Two morphed scales (A and B) created for Experiment 3. The figure presents five states of each scale corresponding to 0%, 25%, 50%, 75%, and 100% angularity (0% roundness).

2.4.1.3 Procedure

The words “sweet”, “sour”, “bitter”, and “salty” were presented randomly twice, once for each roundness/angularity scale. Each trial started with a blank screen with the instructions to hold down the left mouse button (upon which an image for the scale was shown, specific to the mouse location on the screen) and to move the mouse up or down in order to morph the shape. The participants were instructed to press the Space bar on the keyboard in order to continue on to the next trial once they were happy with the modified shape. At the end of the experiment, the participants were also presented with a drag and drop task almost identical to that reported in previous experiments. Here the participants had to arrange each taste word according to the extent that they liked each taste relative to the others.

2.4.2 Results and discussion

The dependent variable was the image number that the participants chose to represent each taste-word. As the images were arranged in a sequence of gradually morphing images from an angular to a smooth shape, this number reflects how round/angular the chosen image was. First, a repeated measure ANOVA with factors scale (2 levels) and taste (4 levels) was performed in order to assess any effect of scale type, taste, or the interaction between these factors. This analysis revealed a significant main effect of taste, $F(2.341, 149.804) = 13.084$, $p < .001$, $\eta^2_{partial} = .170$, while no effect of scale type or the interaction between scale and taste was found. Pairwise comparisons revealed that the

participants rated the word sweet as being significantly rounder than the other three taste words ($p < .001$, for all comparisons, see Figure 2.5A).

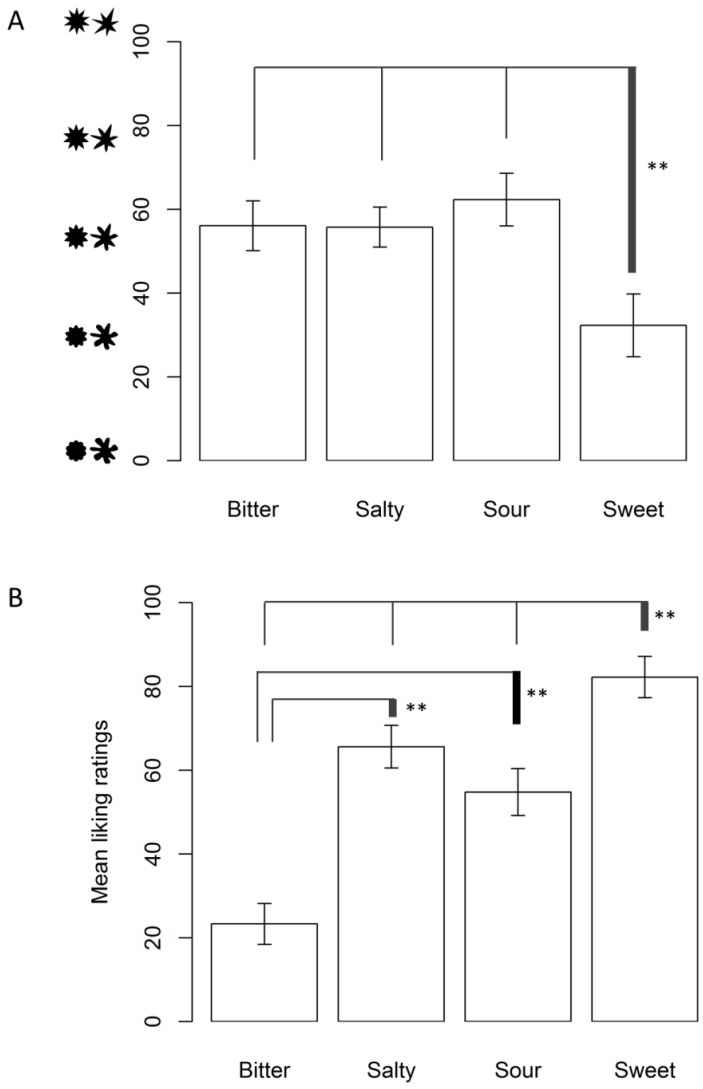


Figure 2.5. Mean roundness/angularity (A) and liking (B) ratings for each taste word in Experiment 3. The thicker line indicates the taste being compared and the asterisks highlight the significantly different ratings for sweet as compared to the others ($p < .001$). The error bars represent 95% confidence intervals.

Since no effect was found for scale type, both scales were collapsed into one measure of roundness/angularity. One-sample t-tests revealed that the participants associated sour with the angular shapes, $t(64) = 3.402$, $p = .001$, while associating sweet with rounder shapes, $t(64) = -4.913$, $p < .001$. A borderline significant effect was found for the bitter ($p = .079$), and salty ($p = .066$) tastes toward the angular shapes. The liking ratings for the taste words were assessed by means of a RM-ANOVA. The results revealed a significant difference in liking ratings, $F(2.647, 169.399) = 67.641$, $p < .001$, $\eta^2_{partial} = .514$ (see Figure 2.5B). The participants reported liking the sweet taste more than any of the other tastes ($p < .001$, for all comparisons), and salty and sour tastes more than the bitter taste ($p < .001$, for both comparisons). No correlation was found between the participants' liking of the tastes and the roundness/angularity ratings (see Figure 2.6).

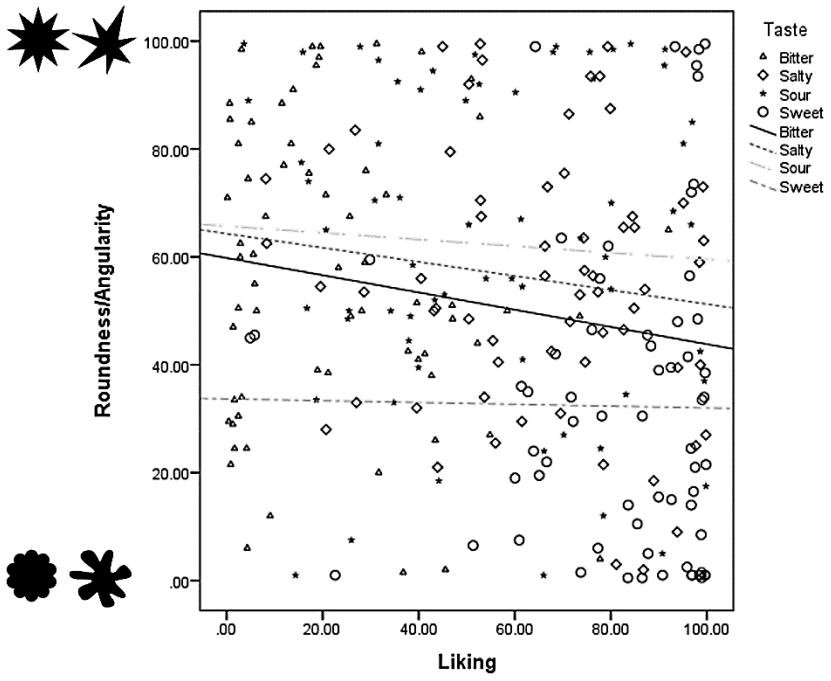


Figure 2.6. Scatterplot and regression line for the liking and roundness/angularity as a function of taste ratings in Experiment 3.

The results of Experiment 3 therefore both replicated and extended those reported in Experiments 1 and 2. They also demonstrate that people seem to have a stronger preference for sweet and salty tastes than for the other tastes. In addition, this study suggests that, regardless of a shape's identity (note that one set of shapes were symmetrical and the other asymmetrical), varying its roundness/angularity dimension can potentially provide similar information to that from a matching task.

Experiments 1-3 relied on taste words rather than real tastants, which has previously been highlighted as a potential limitation in taste research (see Simner et al., 2010). Indeed, although the participants were instructed to imagine a food with the taste in each trial, taking into account the literature on sound symbolism (Marks, 1978; Parise & Spence, 2012; Sapir, 1929), one may wonder whether the sound of the words themselves may have influenced participants' performance in the matching task. In other words, would such as sweet would be more associated with a taste due to its phonetic sound rather than the actual taste object to which it refers to?. In addition, tastants can also be controlled for in terms of their intensity, something that is probably unachievable when working with imagined tastes. In Experiment 4, actual tastants were therefore used, including the taste of umami, which is widely considered to be the fifth basic taste (e.g., Kawamura & Kare, 1987; Kurihara, 2009; Mouritsen & Styrbaek, 2014).

2.5 Experiment 4: Crossmodal correspondences between basic tastants and visual roundness/angularity: The role of liking

2.5.1 Methods and materials

2.5.1.1 Participants

Twenty participants (12 females, mean age = 23.80 years, SD = 5.38) took part in the study through the desktop Adobe Air based version of Xperiment (http://www.xperiment.mobi). Before the experiment started, participants completed a questionnaire designed to make sure that they did not have any potential sensory dysfunction (visual or gustatory). The participants were instructed not to wear any fragrances on the day of the sessions and not to have a meal, coffee, or to smoke at least 30 minutes before the experimental session.

2.5.1.2 Apparatus and materials

Solutions of the 5 basic tastes, including sweet (sucrose, 24.00 g/L), sour (citric acid, 1.20 g/L), bitter (caffeine, 0.54 g/L), salty (sodium chloride, 4.00 g/L), and umami (monosodium glutamate, 2.00 g/L), were prepared in accordance with Hoehl et al. (2010). Each taste stimulus was prepared as an odourless and colourless solution (distilled water, ReAgent, Runcorn, Cheshire, UK) as specified by ISO 3972. The participants received 20 ml of each stimulus in a 40 ml transparent cup.

The experimental design of Experiment 2 was modified in order to present the ‘taste’ blocks in a random order. In each taste block, the participants responded to the different shape scales for a particular taste. These scales were randomly presented within each block of trials. In addition to the shape scales, a liking scale was also included in each

block in order to assess the participants' liking for the basic taste solutions. In a final block, participants' liking of the different shapes included in the study was assessed by having participants arrange the stimuli as a function of how much they liked them by dragging and dropping each into a box (from 0 to 100) anchored with 'not at all' and 'very much' on the left and right respectively. Each taste was coded with a three digit number that was visually uninformative to the participants. The codes were as follows: 523 for sweet, 991 for sour, 414 for salty, 346 for umami, and 382 for bitter.

2.5.1.3 Procedure

Before the experiment started, the participants were given 20ml of distilled water to rinse their mouth and then instructed to expectorate it into a disposable cup. Next, a taste code appeared on the computer monitor; the participant informed the experimenter of the number, and the appropriate tastant was then given to the participant. The participants were instructed to hold the tastant in their mouth for approximately five seconds, and then to expectorate the liquid into a glass. After responding to the different scales for a particular taste, the participants were instructed to cleanse rinse their mouth again before moving on to the next trial.

2.5.2 Results and discussion

A one-way RM-ANOVA, using the Greenhouse Geisser correction, revealed a significant difference between the shape ratings of tastes ($F(4, 76) = 6.511$, $p < .001$, $\eta^2_{partial} = .255$). The results of pairwise comparisons (Bonferroni corrected) revealed that the sweet taste

was rated as rounder than any of the other tastes ($p \leq .02$, for all comparisons, see Figure 2.7A).

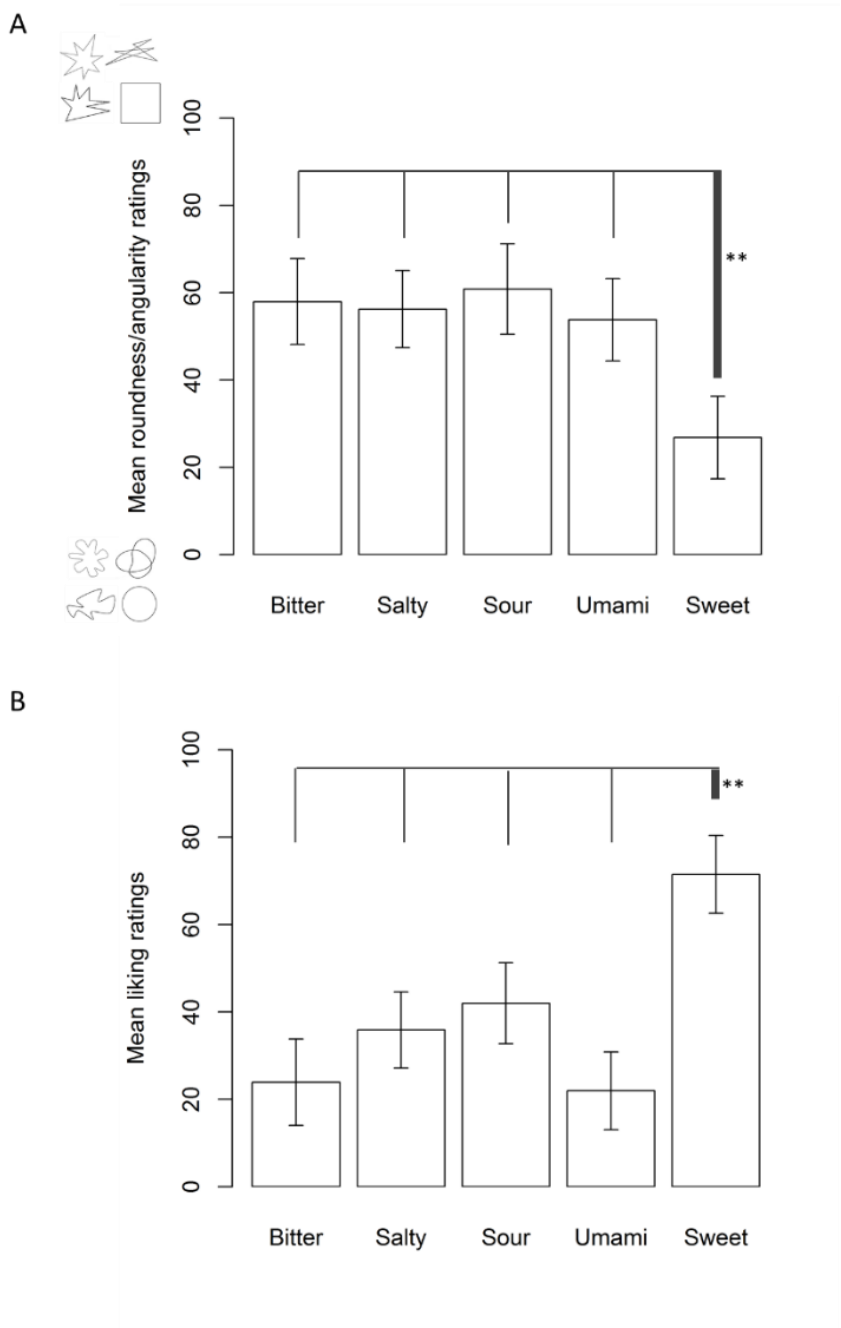


Figure 2.7. Mean roundness/angularity (A) and liking (B) ratings for each tastant in Experiment 4. The thicker line indicates the taste being compared and the asterisks highlight the significantly different ratings for sweet as compared to the other tastes ($p < .001$ for roundness/angularity and $\leq .002$ for liking). The error bars represent 95% confidence intervals.

One-sample t-tests revealed that the only value that differed significantly from the mid-point of the scale was sweet which deviated significantly toward the round shapes, $t(19) = -5.283$, $p < .001$. For the sour taste, a borderline significant effect was found, $t(19) = 1.909$, $p < .072$ (see Experiment 5, for evidence that this association can reach significance). Once again, the results of Experiment 4 confirmed that the participants associated sweet tastes with rounded shapes, not only when a taste word is presented but also when responding to an actual tastant. Participants' liking of the tastes was assessed by means of a RM-ANOVA. A significant difference between ratings was found ($F(4, 76) = 14.557$, $p < .001$, $\eta^2_{partial} = .434$). Pairwise comparisons revealed that the participants liked the sweet taste more than any of the other tastes ($p = .002$, for all Bonferroni-corrected comparisons, see Figure 2.7B).

In order to assess any relationship between participants' roundness/angularity and taste liking ratings, Pearson correlations with one-tailed (based on the literature review in the Introduction Section, a negative correlation was expected) significance tests were performed. A significant negative correlation was observed between taste liking and roundness/angularity for bitter ($r = -.742$, $p < .001$), umami ($r = -.530$, $p = .008$), and sweet ($r = -.632$, $p = .001$). Although the correlations were not significant for salty and sour, a borderline significant trend was found ($p = .075$, and $p = .071$, respectively, see Experiment 5, for further development). These correlations suggest that the more a taste was liked, the more it was associated with one of the rounded shapes, whereas the less a taste was liked, the more it was associated with an angular shape instead. Figure 2.8 shows a scatterplot in which roundness/angularity and liking are presented, together with a regression line for each of the tastes, in which the latter point is illustrated.

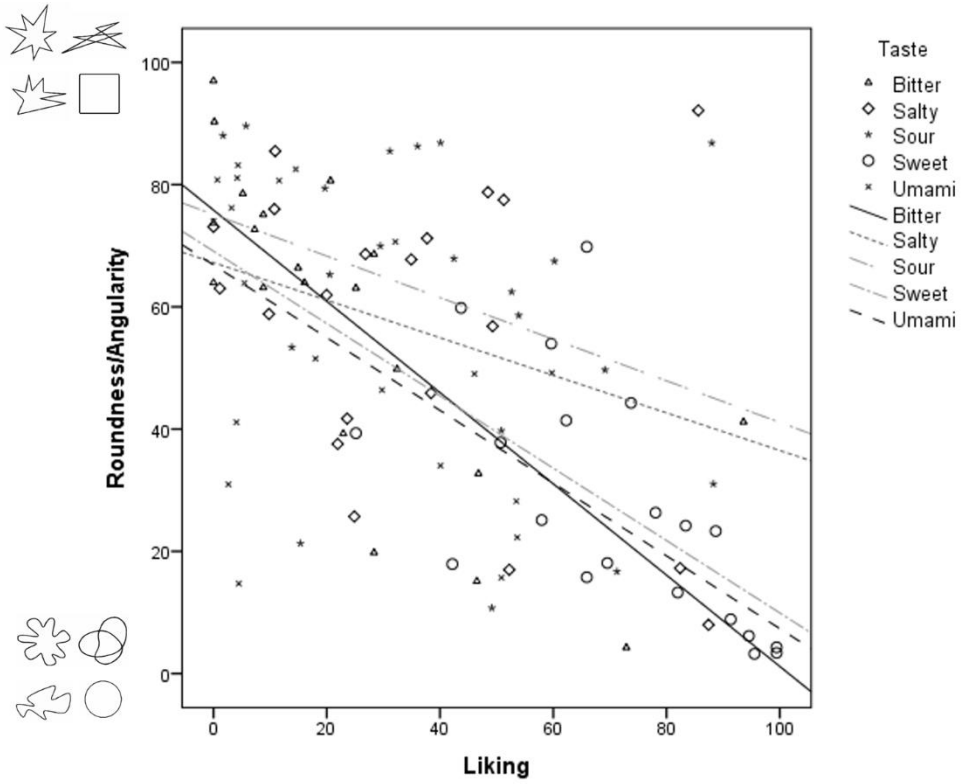


Figure 2.8. Scatterplot and regression line for the liking and roundness/angularity as a function of taste ratings in Experiment 4. Note that taste liking predicted significantly roundness/angularity ratings for bitter, sweet, and umami. A trend was also observed for the salty and sour tastes.

A simple linear regression analysis was used to test whether taste liking predicted roundness/angularity ratings for those tastes in which a significant correlation between liking and roundness/angularity was documented. The results of the regression analysis indicated that for bitter, liking explained a significant proportion of the variance, R^2 = 0.550 (adjusted R^2 = 0.525), $F(1,19) = 21.986$, $p < .001$. Liking significantly predicted taste roundness/angularity, β = -0.742. For umami, liking also explained a significant proportion of the variance, R^2 = 0.281 (adjusted R^2 = 0.241), $F(1,19) = 7.019$, $p = .016$. Once again, for umami, liking significantly predicted taste roundness/angularity, β = -0.530. Finally, liking explained a significant proportion of the variance of the roundness/angularity ratings for the sweet tastant, R^2 = 0.400 (adjusted R^2 = 0.366),

$F(1,19) = 11.977$, $p = .003$. Liking ratings for the sweet tastant significantly predicted taste roundness/angularity, $\beta = -0.632$. Taken together, then, these results provide some of the first evidence in support of the idea that participants' liking of taste is an important factor when it comes to the crossmodal matching of tastes to shapes.

In order to assess any differences in the angular vs. round shapes, the scores of the task in which the participants rated how much they liked each of the shapes used to anchor the scales, were collapsed. A paired-sample t-test revealed that the participants in Experiment 4 liked the round shapes (M = 64.18, SD = 13.49) significantly more than angular shapes (M = 39.18, SD = 16.61), $t(19) = 4.132$, $p = .001$), thus adding further weight to the claim that people prefer round over angular shapes (Bar & Neta, 2006; Lyman, 1979; Westerman et al., 2012).

The results of Experiment 4 revealed that the hedonic account of cross-sensory correspondences (e.g., Barbiere, Vidal, & Zellner, 2007; Guerdoux et al., 2014; Palmer et al., 2013; Schifferstein & Tanudjaja, 2004) can in fact be extended to the case of correspondences between taste and vision. Experiment 4 provides some of the first empirical evidence to support the idea that taste hedonics can be an influential factor in the correspondence between shape roundness/angularity and tastants. In Experiment 5, I aimed to replicate these results and also to assess whether taste concentration (or objective intensity) may play a role in such associations. As pointed out in Chapter 1, intensity has been proposed as an amodal attribute that is perceivable in each of the senses and which may explain cross-sensory associations. Indeed, research in the olfactory domain provides support for the idea that more intense odours have a tendency to be associated with more angular shapes, whereas less intense odours tend to be associated with rounder shapes

instead (e.g., Hanson-Vaux et al., 2013, see also Becker et al., 2011, for some indirect evidence in the case of taste and angularity).

2.6 Experiment 5: Crossmodal correspondences between basic tastants and visual roundness/angularity: The role of liking and intensity

2.6.1 Methods and materials

2.6.1.1 Participants

30 participants (19 females) aged 18-41 years (M=22.7, SD= 5.5) took part in the experiment through the desktop Adobe Air based version of Xperiment (http://www.xperiment.mobi). The data from one participant was excluded from the analyses due to a hardware related data recording problem. The experiment lasted for approximately 20-25 minutes and the participants were compensated with 5 pounds in return for their time.

2.6.1.2 Apparatus and materials

Two taste solutions (one weaker and the other stronger) of each of the five basic tastes were used (bitter, sour, salt, umami, and sweet). These solutions included caffeine at 0.27 and 0.54 g/L (bitter), citric acid at 0.60 and 1.20 g/L (sour), sodium chloride at 2.00 and 4.00 g/L (salt), monosodium glutamate at 1.00 and 2.00 g/L (umami), and sucrose at 12.00 and 24.00 g/L. The preparation of the mixtures followed the procedure suggested by Hoehl et al. (2010; see also Experiment 4). Each taste stimulus was prepared as an

odourless and colourless solution (distilled water, Life, Paisley, Renfrewshire, UK) as specified in Experiment 4, and presented between the keyboard and the screen of the computer arranged from left to right in front of a numeric three digit code that was visually uninformative to the participants. The codes for each weak and strong solution were as follows: 143 and 215 for bitter, 244 and 384 for sour, 455 and 466 for sweet, 506 and 618 for salty, and 688 and 712 for the umami solution.

2.6.1.3 Procedure

Before the experiment started, the participants were asked to take a sip of water from a glass of purified water in order to rinse their mouth out and then to expectorate into a disposable cup. At the start of each block a taste code appeared on the computer monitor. The participants had to find the corresponding labelled solution, pour it into their mouths, hold it there for approximately five seconds (or until they got a sense of what the solution tasted like), and then expectorate the liquid into the disposable glass. Over a pair of trials, the participant's rated the taste solution along two shape scales anchored with angular or rounded shapes (see Figures 2.1A and B, e.g., Spence & Deroy, 2013; see Experiment 4), and along two liking and intensity VAS anchored with "not at all" and "very much". Trial order was blocked into pairs according to each tastant, with taste block order and pair order fully randomised over participants (that is, a given pair of trials in a taste block were always shown one after the other in random order, at a random time during the study). Note that one of the scales always had the angular shape anchored to the left and the round shape to the left, while the other scale was presented with the anchors reversed in order to avoid any lateral bias in responding from influencing the results. Before moving on to the next tastant, the participants had to rinse their mouth out again with water.

2.6.2 Results and discussion

A one-sample t-test was conducted on each variable (roundness/angularity, liking, and perceived intensity) as a function of concentration and tastant in order to assess which values differed from the mid-point of the scales (see Table 2.1 for a summary of the results). The results from this table show that the participants associated sweet tastes with round shapes, and sour tastes with angular shapes, regardless of the concentration of the solutions (weak or strong). Moreover, the participants associated the weaker salty tastant with angular shapes. It is worth mentioning that the p vales of the one sample t-tests are based on a two-tailed test. With that in mind, if one takes into account the results of Experiment 4, one may simply apply a one-tailed p value to the roundness/angularity ratings and bitter and salty in their stronger concentrations would also become significant in terms of ratings falling towards the angular end of the scales. While the sweet solutions were liked, the other tastants were all disliked. Most of the weaker solutions (all but umami, which presented a trend) were rated closer to ‘not at all intense’, and the stronger sour solution was rated closer to ‘very much intense’.

Table 2.1. Separate one-sample t-tests performed in order to evaluate which ratings differed from the mid-point (50) of the scales in Experiment 5. The significant values are highlighted in bold.

Concentration	Taste	Roundness/angularity		Liking		Intensity	
		t	p	t	p	t	p
Weaker	Bitter	-.998	.327	**-5.224**	**.000**	**-4.476**	**.000**
	Salty	**2.397**	**.023**	**-4.945**	**.000**	**-2.275**	**.031**
	Sour	**6.669**	**.000**	**-2.079**	**.047**	**3.345**	**.002**
	Sweet	**-14.616**	**.000**	**3.435**	**.002**	**-4.943**	**.000**
	Umami	-.715	.481	**-5.300**	**.000**	-1.913	.066
Stronger	Bitter	1.571	.127	**-6.908**	**.000**	-1.194	.243
	Salty	1.618	.117	**-5.844**	**.000**	.675	.506
	Sour	**10.841**	**.000**	**-4.430**	**.000**	**5.702**	**.000**
	Sweet	**-10.212**	**.000**	**4.971**	**.000**	-1.520	.140
	Umami	-.444	.660	**-7.259**	**.000**	-.300	.767

A visualization of the mean roundness/angularity, liking, and perceived intensity ratings is presented in Figure 2.9. A RM-ANOVA with the factors of taste concentration (weaker vs. stronger) and taste (bitter, salty, sour, sweet, and umami) was performed on each of the ratings. The analysis of the roundness/angularity ratings revealed significant main effects of taste, $F(2.692, 75.367) = 58.349$, $p < .001$, $\eta^2_{partial} = .676$ (note that the Greenhouse-Geisser correction was used), and concentration, $F(1, 28) = 5.595$, $p = .025$, $\eta^2_{partial} = .167$. The interaction was not significant. Bonferroni-corrected pairwise comparisons revealed that the participants rated the sweet solutions as significantly rounder than any of the other tastes ($p < .001$, for all comparisons), the sour solutions as significantly more angular than any of the other solutions ($p < .001$, for all comparisons), the umami solutions as significantly less angular than the salty solution (p - .023). Moreover, the stronger concentrations differed from the weaker concentrations in terms of participants' roundness/angularity ratings ($p = .025$).

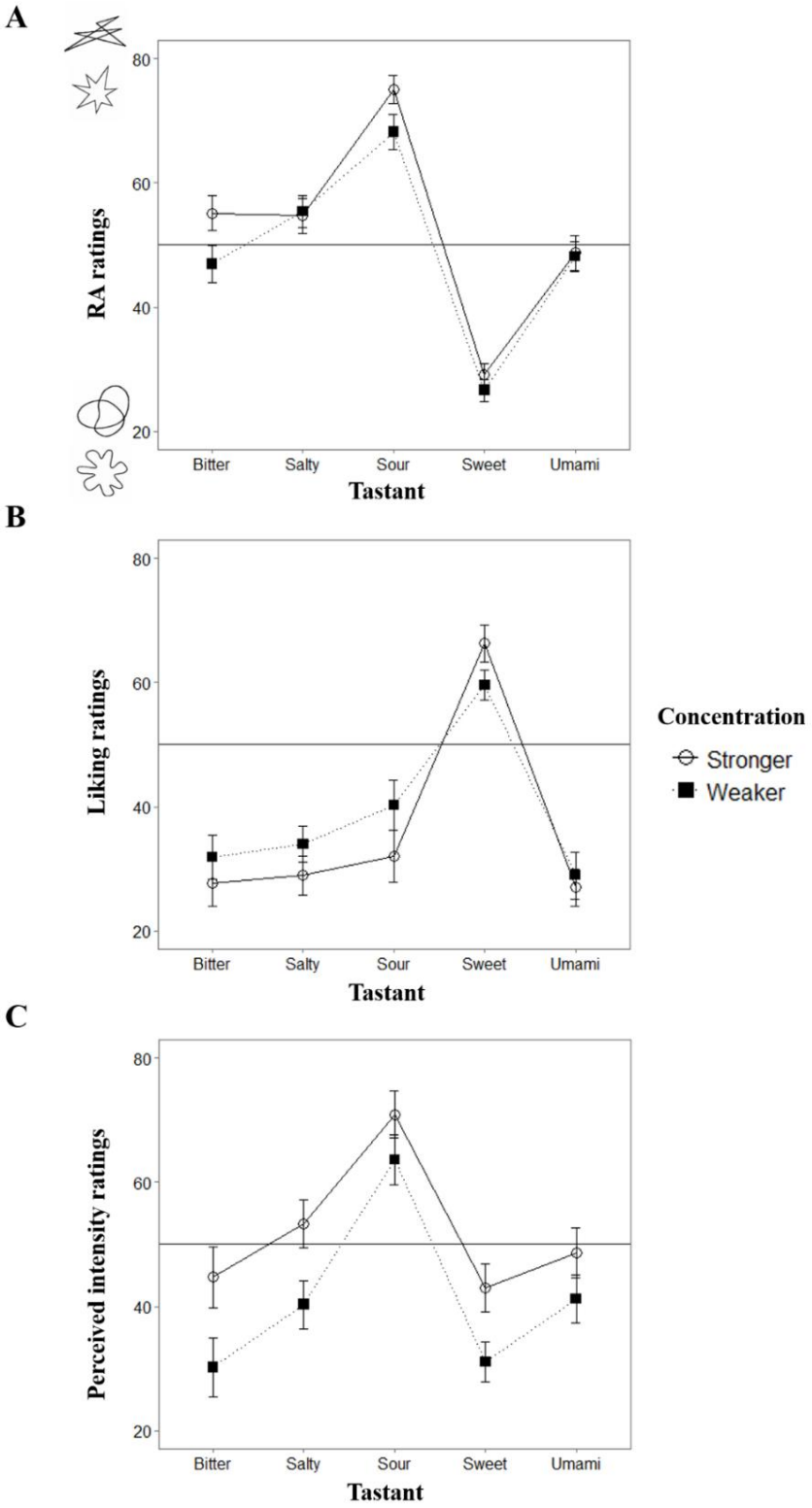


Figure 2.9. Mean roundness/angularity (RA) (A), liking (B), and perceived intensity (C) ratings in Experiment 5. The error bars represent the standard error of the means.

A significant main effect of taste, $F(2.952, 82.651) = 22.562$, $p < .001$, $\eta^2_{partial} = .446$ (RM-ANOVA with the Greenhouse-Geisser correction), and the interaction between taste and concentration, $F(4, 112) = 2.687$, $p = .035$, $\eta^2_{partial} = .088$, was found for the liking ratings (concentration was not significant). The participants liked the sweet taste significantly more than any of the other tastes ($p < .001$, for all comparisons). As for the interaction term, neither of the comparisons reached statistical significance after correcting for multiple comparisons. However, a closer inspection of Figure 2.9B reveals that the participants tended to dislike the higher concentrations (more obviously for salty) in all tastants but sweetness in which the higher concentration seemed to be liked more.

Finally, the RM-ANOVA on the perceived intensity ratings revealed a significant main effect of tastant, $F(4, 112) = 12.536$, $p < .000$, $\eta^2_{partial} = .309$, and concentration, $F(1, 28) = 34.283$, $p < .000$, $\eta^2_{partial} = .550$. The interaction was not significant. The participants rated the sour solutions as significantly more intense than any of the other taste solutions ($p \leq .001$, for all comparisons), and the stronger concentrations as more intense than the weaker concentrations ($p < .001$).

Pearson correlations were performed in order to assess the relationship between taste roundness/angularity, perceived intensity, and liking (see Figure 2.10 for matrices of scatterplots and correlation coefficients). A significant positive correlation between roundness/angularity and perceived intensity was observed for bitter and sour and a borderline significant correlation for salty and umami. Moreover, a negative correlation between taste roundness/angularity and liking was found for all of the tastes, and a

negative correlation between liking and perceived intensity for all the tastants except sweet.

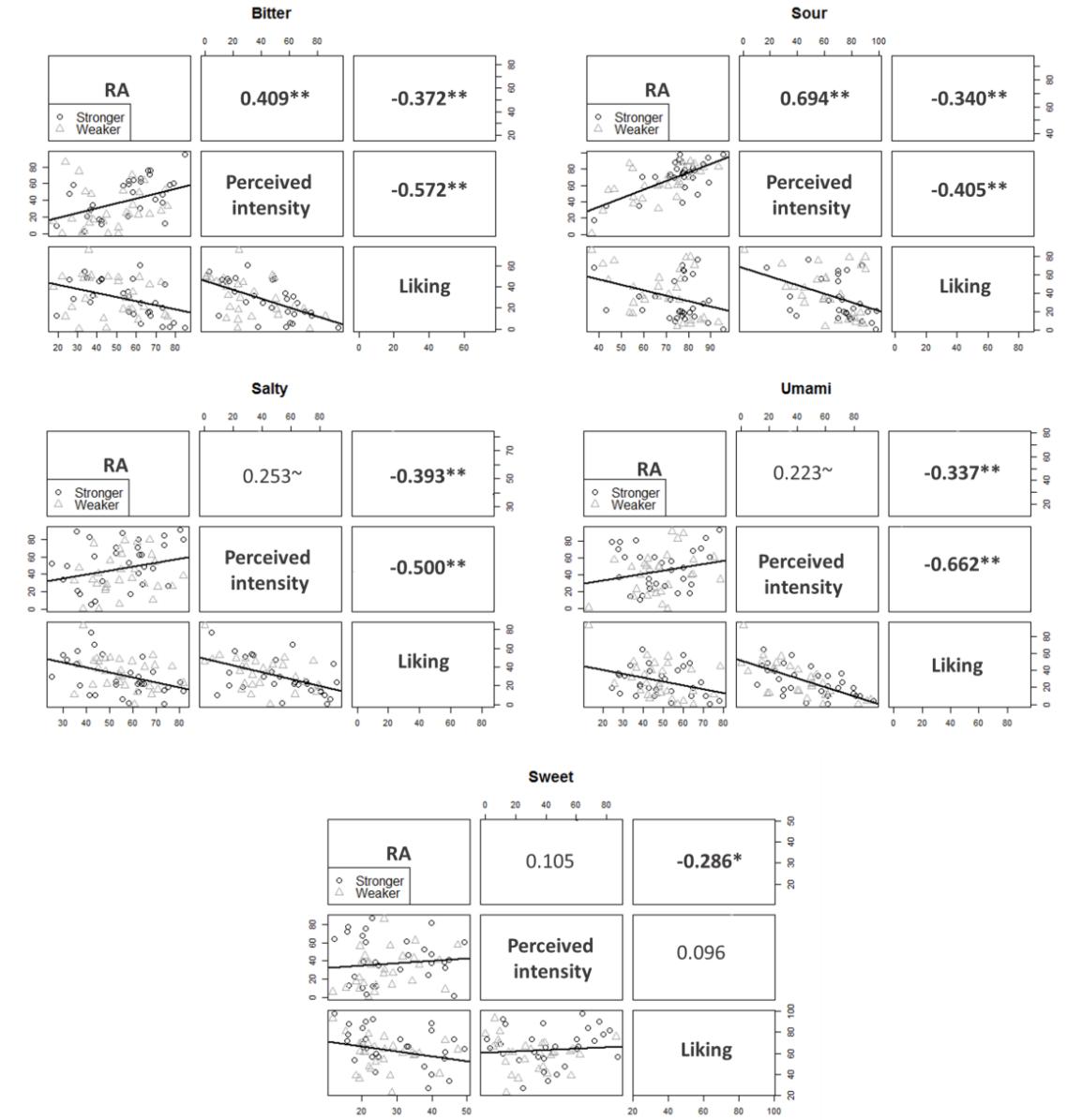


Figure 2.10. Correlation and scatterplot matrices for each tastant used in Experiment 5. Each panel corresponds to a tastant and includes both correlations coefficients between roundness/angularity (RA), perceived intensity, and liking and regression lines between these variables. Note that although the lines were fitted for each tastant, the data points for the weaker and stronger solutions are also visualized. The significant values are highlighted as follows: *** $p < .01$, ** $p < .05$, ~ $p < .1$.

A standard multiple linear regression was used to assess whether the tastants, their concentration, and liking would predict the roundness/angularity ratings of the tastes. The prediction model was statistically significant, $F(6,281) = 65.68$, $p < .001$, and explained approximately 59% of the variance ($R^2 = .589$, adjusted $R^2 = .575$; see Table 2.2 for the regression coefficients). Note that the reference variable for tastant and concentration were the sweet tastant and stronger solution, respectively. The sweet tastant was used as reference variable based on Experiments 1-4, where I demonstrate that it is distinctively associated to roundness (see Experiment 4), a finding that is replicated here.

It is worth mentioning that, after performing the multiple regression diagnostics, the Durbin-Watson test for auto-correlated errors (Fox, 2008), a coefficient of 1.4 was found, and as a consequence, the assumption appears to be violated (though the value is close to the accepted standard). With that in mind, a Gaussian generalized estimating equation analysis (Hardin & Hilbe, 2012) with an exchangeable covariance structure was also used in order to confirm the findings. The results are also presented in Table 2.2, and confirm the results of the multiple linear regression analysis. Additionally, we used the 'calc.relimp' function with the 'lmg' metric from the R statistics package {relaimpo} in order to calculate the relative importance of each regressor (see Grömping, 2006; Lindeman, Merenda & Gold, 1980). Taste quality contributed to 73.3%, taste liking to 25.3%, and taste concentration to 1.4% of the R^2 of the regression model.

Table 2.2. Multiple regression and generalized estimating equations results in Experiment 5.

Variable	Multiple linear regression				Generalized estimating equations			
	Estimate	SE	t value	*p*	Estimate	SE	Wald	*p*
(Intercept)	45.661	3.0688	14.879	**<.001**	45.661	2.903	247.300	**<.001**
Bitter	15.369	2.7342	5.621	**<.001**	15.369	2.616	34.510	**<.001**
Salty	19.154	2.6983	7.099	**<.001**	19.154	2.411	63.120	**<.001**
Sour	36.911	2.6175	14.102	**<.001**	36.911	2.536	211.910	**<.001**
Umami	11.010	2.779	3.961	**<.001**	11.010	2.513	19.190	**<.001**
Taste liking	-0.257	0.0396	-6.495	**<.001**	-0.257	0.041	39.840	**<.001**
Weaker concentration	-3.3428	1.522	-2.197	**0.029**	-3.343	1.499	4.970	**0.029**

These results therefore suggest that tastant, concentration, and participants' liking, predict the roundness/angularity ratings. Specifically, it was observed that the sweet tastant was significantly rounder than the other tastants, and the weaker solutions were significantly rounder than the stronger solutions. Further, taste liking and roundness/angularity have a strong relationship, meaning the more a tastant is liked, the more it is associated to round shapes, while the less it is liked the more it is associated to angular shapes.

The results of Experiment 5 revealed that tastant quality, concentration, and liking all significantly predicted the roundness/angularity that the taste was matched to. Furthermore, the results of Experiment 5 replicated previous findings suggesting that participants' liking for a taste predicted, at least in part, the taste roundness/angularity ratings they made (e.g., Experiment 4), and extend them by documenting the existence of a relationship between perceived intensity and roundness/angularity for every tastant except the sweet solution.

Research in the olfactory domain provides support for the idea that more intense odours have a tendency to be associated with more angular shapes, whereas less intense odours tend to be associated with rounder shapes instead (Hanson-Vaux et al., 2013). In addition,

it has been suggested that angular shapes tend to be associated with attributes denoting intensity such as potency, and that such shapes can influence the perception of taste intensity (e.g., Becker et al., 2011; Schifferstein & Spence, 2008; Poffenberger & Barrows, 1924, see also Obrist et al., 2014).

While it is not altogether clear why one shape should be matched to intensity-related words than others, one possibility is that angular shapes may be more threatening than round shapes due to the sharpness of their angles (cf. Bar & Neta, 2006). In turn, the likely impact of an angular shape on an organism may be more 'intense' than that of a round shape (which is also associated with more positively valenced emotions). This may explain the fact that, overall, the subtle manipulation of taste intensity may have given rise to a difference between the roundness/angularity of the weaker and stronger solutions used in the present study. In other words, people not only match tastes and shapes as a function of their hedonic value (see Experiment 4), but also as a function of their intensity (cf. Marks, 1978; Spence, 2011).

Taking into account Experiment 4, together with Experiment 5, one may wonder to what extent taste/shape correspondences are influenced by what people simply 'think' about the shapes and the tastes or what they actually 'feel' about them. In other words, whether what influences such correspondences is the affective (perceived) quality of both shapes and tastes or an actual affective response to them (cf. Russell, 2003). These points lead to the discussion of whether certain tastes and shapes just share some common dimensions of connotative meaning (Karwoski, Odbert, & Osgood, 1942; Martino & Marks, 2001; Walker, 2012; see also Marks, 1996). As Marks (1996) suggests, the distinction between perceptual experiences from linguistic labels is not always an easy task in the context of crossmodal correspondences. However, a possible way of testing this for a hedonic

account of crossmodal correspondences could be by priming participants with a specific emotional valence (either positive or negative) before a task such as the one used in this study. This way one could test both whether the liking ratings of tastes and shapes and also the correspondences vary.

The results of Experiment 5 provide some of the first empirical evidence to suggest that that perceived intensity (i.e., taste concentration) relates to taste roundness/angularity, but also raise a number of questions as to how and why taste concentration and intensity would be related to taste-shape associations in the first place. For example, one may wonder whether having a larger set of taste concentrations (or actual foods and drinks) would indeed show a clearer effect of concentration on the shape symbolic ratings of the tastes. It has been suggested that the relationship between taste concentration, perceived intensity, and hedonics is complex, being both tastant dependent and subject to individual differences such as taster status and sweetness preference (e.g., Moskowitz, 1971, 1982; Moskowitz, Kluter, Westerling, & Jacobs, 1974; Prescott et al., 1992; Fushan et al., 2009; Yeomans, Tepper, Rietzschel, & Prescott, 2007). Such individual differences may, for example, explain the differences in the umami/angularity association reported in Experiments 4 and 5. That said, the influence of individual differences on roundness/angularity may in turn be multifaceted and thus, further investigation in this area will likely prove fruitful in what taste/shape correspondences concern.

2.7 General discussion and conclusions

In the present chapter, five experiments designed to evaluate the crossmodal correspondence between basic tastes and shape roundness/angularity were reported. The

results of Experiment 1 demonstrated that people consistently match taste words to shapes. These results suggest that there is a distinction between sweetness which was matched to roundness, and the other tastes (bitter, salty, and sour) which were all repeatedly matched with more angular shapes instead. Experiment 2 replicated and extended these results in a more varied population with a larger sample size. Experiment 3 replicated the findings of Experiments 1-2. This experiment also failed to demonstrate any relationship between taste liking and roundness/angularity ratings. In Experiment 4, actual tastants (including umami) were used. The results confirmed the match between sweetness and roundness. However, no particular crossmodal correspondences were obtained for the other four tastants (bitter, sour, salty, and umami). The results of Experiment 4 also demonstrated that taste liking explains part (28%-55%) of the roundness/angularity matchings to tastes. Finally, Experiment 5 replicated the results of Experiment 4, and provided some initial evidence to support the idea that the intensity of the taste may influence tastants' roundness/angularity, at least to a certain degree. Note that there was a tendency for sour to be rated as more angular than the other tastes in both Experiments 4 and 5.

As mentioned in the Introduction of this thesis (see Chapter 1), Spence (2011) presented three (non-mutually exclusive) types of, and mechanisms possibly underlying, crossmodal correspondences: structural, statistical, and linguistic (see also Parise & Spence, 2013). In addition, researchers have suggested that the hedonic character of sensory information may explain the way in which people match information across the senses (Hartshorne, 1934; Kenneth, 1923; Marks, 1978; Osgood, Suci, & Tannenbaum, 1957). Following a proposal initially made by Kenneth (1923), Deroy et al. (2013) put forward the *indirect hypothesis* (see also a review of the physiognomic hypothesis in

Marks, 1996), which states that stimuli in different sensory modalities may be associated, indirectly, over their common hedonic properties (affective correspondences). Whilst certain correspondences such as the one that has been documented between pitch and elevation may be explain by the statistical regularities of the environment (e.g. Parise et al., 2014), it is difficult to think of a statistical explanation for taste/shape correspondences since the same taste may come in a number shapes (e.g., think of sweet and sour fruits, for example). That said, the results lead to the indirect hypothesis in that they demonstrate that the hedonic character of tastes can guided people's associations to shapes, at least, to a certain degree.

An alternative explanation here refers to the idea that tastes and shapes may also share a common meaning. The semantic differential technique which was introduced in the late 1950s (Osgood et al., 1957) with which it was suggested that objects can be categorized through a number of common dimensions/adjectives such as good/bad and strong/weak and that that information across the senses that are categorized consistently in one of those dimensions may tend to go together (Osgood et al., 1957; Snider & Osgood, 1969). This line of thought has been extended by researchers studying crossmodal correspondences (e.g., Karwoski et al., 1942; Martino & Marks, 2001; Walker, Walker, & Francis, 2012). One straightforward future study would aim to assess the extent to which both people's actual feelings and their beliefs about their feelings explain taste/shape correspondences, or whether they are interrelated.

An important point that deserves to be mention is that both, Experiments 4 and 5 provide correlational data in favour of a hedonic and intensity mechanism for such correspondences. Moreover, in such experiments, those tastes that were liked (e.g., sweet), were also associated with roundness, and those tastes that were disliked (e.g., the

others), were preferentially associated with angularity. Further research may be explored in order to assess whether such a premise holds. It would be certainly possible, for example, to think that the inverted U-shaped function between taste concentration and liking that has been previously documented for sweetness can provide an interesting way of assessing the hedonic mechanism of taste/shape correspondences. In other words, would it be the case that sweet becomes angular when the concentration of a sugar solution goes up and participants start disliking it? Furthermore, it has been suggested that there are individual differences in sweet liking. For example, it is known that certain people (sweet likers) have a higher concentration threshold for their liking of sweet solutions than others (sweet dislikers, e.g., Moskowitz et al., 1974).

Taking into account the aforementioned points, an additional experiment was conducted. The aim here was to evaluate whether taste/shape correspondences would change as a function of the concentration of various sweet solutions and between sweet likers and dislikers. Following on from a study conducted by Yeomans et al. (2007), four levels of concentration (0.25, 0.50, 0.75, and 1M, that will be called L1, L2, L3, and L4, respectively) of table sugar were utilized (a pilot study with seven participants was conducted in order to select the appropriate concentrations). Note that the solutions were not increased above 1M taking into account that they become noticeably viscous at higher concentrations. Each solution was presented three times at random to a group of 15 participants (7 females) aged between 19-40 years (mean age = 28.9, SD = 6.7 years). After tasting each stimulus, the participants were presented with 6 scales in a random order, including a Labelled Hedonic Scale (LHS), a General Labelled Magnitude Scale (gLMS; see Lim, Wood, & Green, 2009), as well as the four shape scales used in Experiments 4 (note that instead of a square, the scale with the circle included a triangle).

Based on Yeomans et al. (2007) classification of sweet likers and dislikers, those participants who showed a decline or a rise and decline (e.g., an inverted U-shape function, see also Moskowitz, 1982) in the LHS and who ended in values below the middle point that scale (e.g., dislike), were included into the "disliker" group, while the others were put into the "liker" group. The sweet disliker group included eight participants while the sweet liker group included seven.

Figure 2.11, presents a summary of the mean ratings for each of the ratings scales. Note that, in order to facilitate the interpretation of the data, the higher the value in the angularity/roundness ratings the rounder the taste. Although the sample size for this experiment was fairly small, each variable was analysed following a mixed design ANOVA, with concentration (four levels) as the within-participants factor, and group (liker/dislike) as the between-participants factor. A significant main effect of concentration, $F(3, 39) = 34.300$, $p < .001$, $\eta^2_{partial} = .725$, and group, $F(1, 13) = 7.038$, $p = .02$, $\eta^2_{partial} = .351$, was found. However, the interaction was not significant. Bonferroni-corrected pairwise comparisons revealed that the participants rated L4 as more intense than L1 and L2 ($p \leq .001$, for both comparisons), L3 as more intense than L1 and L2 ($p < .001$ and $p = .053$, respectively), and L2 as more intense than L1 ($p = .001$). Moreover, the sweet dislikers rated the solutions as more intense than the sweet likers ($p = .02$). The analysis on the liking ratings revealed a significant main effect of group, $F(1, 13) = 16.914$, $p = .001$, $\eta^2_{partial} = .565$, and the interaction between concentration and group, $F(3, 39) = 9.052$, $p < .001$, $\eta^2_{partial} = .410$. The sweet likers liked the solutions more than did the sweet dislikers ($p = .001$). As for the interaction term, the sweet dislikers liked L4 less than L1 and L2 ($p = .014$ and $p = 0.40$, respectively). Finally, the analysis on the

roundness/angularity ratings failed to reveal any effect of angularity/roundness, group, or an interaction term (all $F < 1$).

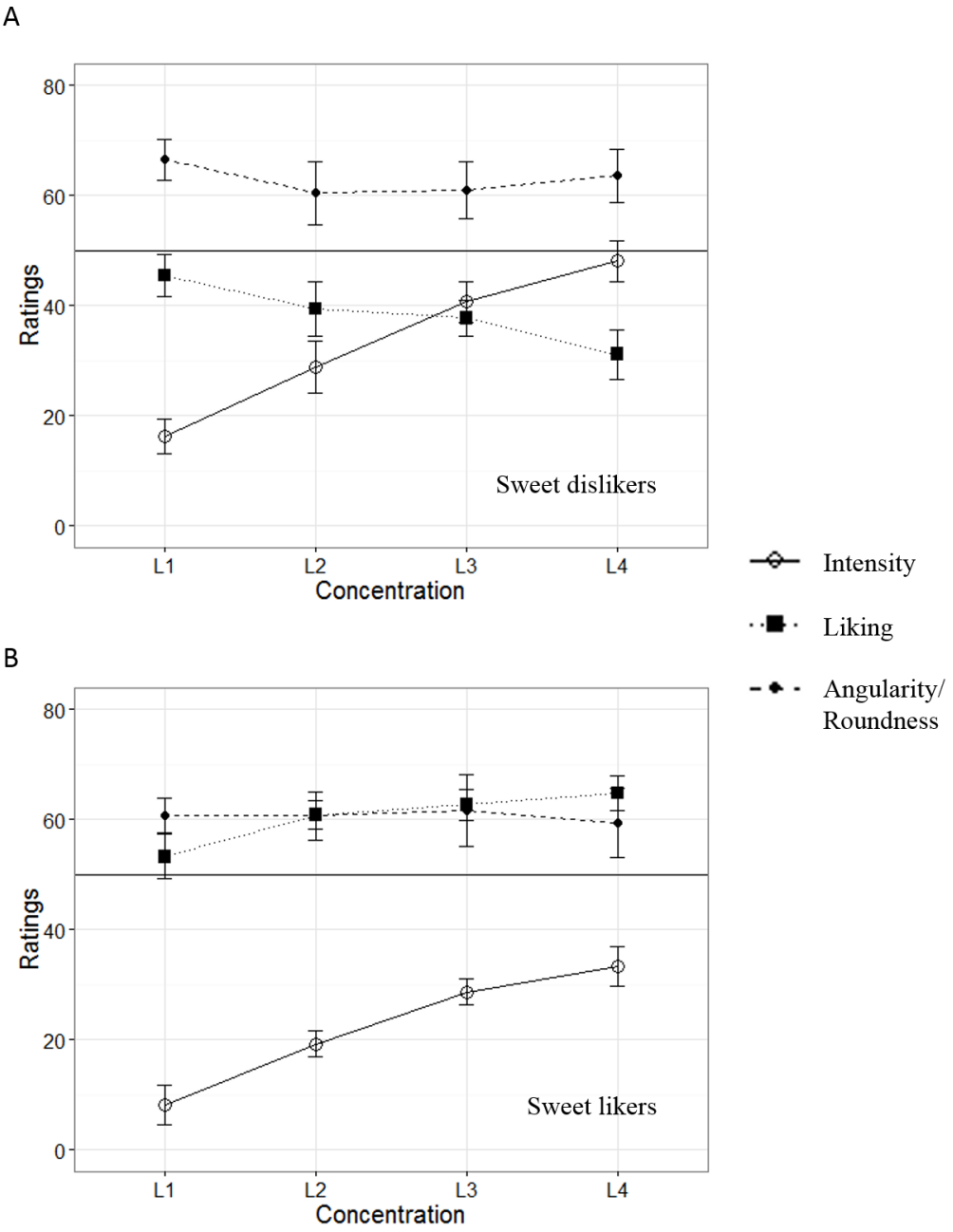


Figure 2.11. Mean ratings of intensity, liking, and roundness/angularity for sweet dislikers (A) and sweet likers (B), as a function of level (L) of concentration. Note that, in order to facilitate the interpretation of the data, the higher value in the angularity/roundness ratings the rounder the taste.

One-sample t-tests were also performed on each variable as a function of concentration and group, in order to assess whether the ratings significantly differed from the mid-point of the scales. A summary of the results is presented in Table 2.3.

Table 2.3. Summary one-sample t-tests performed on the different variables as a function of group and sweetness concentration. Note that the p values presented here have not been corrected for multiple comparisons.

Group	Concentration	Intensity		Liking		Angularity/roundness	
		t	p	t	p	t	p
Dislikers	L1	-14.553	.000	-1.447	.191	3.468	.010
	L2	-4.527	.003	-2.115	.072	1.534	.169
	L3	-2.238	.060	-4.670	.002	2.073	.077
	L4	-.365	.726	-5.036	.002	2.627	.034
Likers	L1	-18.016	.000	1.103	.312	3.041	.023
	L2	-9.033	.000	1.948	.099	2.061	.085
	L3	-5.597	.001	2.259	.065	1.541	.174
	L4	-3.751	.010	2.690	.036	1.324	.234

The results of Table 2.3 provide some interesting evidence to help interpret the different results presented before. Increasing concentrations seems to have made both sweet likers and dislikers rate the solutions as more intense, though neither group consider them above the mid-point of the scale. What is more, while increasing concentration tends to be disliked by the sweet dislikers, it appears that the opposite was true for the sweet likers. The sweet dislikers tended to give angularity/roundness ratings above the mid-point to L1 and L4, while this only happened for L1 and L2 in sweet likers.

It is important to note here that, although sweet dislikers 'disliked' L3 and L4, they still associated L4 with roundness. While this result may provide some initial evidence against the affective hypothesis of taste/shape correspondence, a number of points should be considered before drawing any specific conclusions: 1. The sample size of this experiment is fairly small, which may increase the probability of both false positives and negatives.

2. The p values presented in Table 2.3 only provide an approximation, as no correction has been applied. Obviously, if one were to take into account the fact that 12 t-tests were performed, most of the values would not be significant. 3. Although the difference in liking ratings between sweet likers and dislikers is consistent with previous literature (e.g., Yeomans et al., 2007), one may wonder whether the taste hedonics differences are enough, as they are rather small. Indeed, it has been suggested that crossmodal correspondences are relative to the stimuli used (cf. Parise & Spence, 2013), thus making contrast a key element (see also Chiou & Rich, 2012). While the results of these experiment are not conclusive they do point to the fact that future research will be undoubtedly needed in order to clarify whether the 'special' character of the sweet/roundness association, is only a product of affect, or which other mechanisms may be involved. It is here that becomes important to remember again that Experiments 4 and 5 provided evidence for the fact that taste concentration and liking can only partially explain such correspondences.

In summary, the results that have been reported in this chapter demonstrate that, among the basic tastes, sweetness has a special character in that it is consistently matched with round shapes, which probably derives from human's preference for sweet tastes. In addition, the evidence reported in this chapter supports the idea that taste liking and concentration predict, at least in part, the associations that people make between tastes and shapes (and not taste names and shapes). While these results suggest that taste hedonics contributes to the crossmodal correspondence between tastes and shapes, they also open up a number of interesting questions relating to, for example, other amodal dimensions that may contribute to explain the way in which people match tastes to the roundness/angularity dimension of shapes.

A number of points are raised by the results of the five experiments reported here. First, it is important to note that although a subtle variation in terms of the results obtained can be observed when online and lab-based studies are compared, and when the results from taste words and actual tastants are compared, sweetness was consistently matched with rounded shapes. How can the fact that sweetness is consistently matched to rounder shapes while the other tastes (or taste words) were all associated with either angular shapes or neither rounded nor angular be explained? One explanation concerns the fact that people prefer, or have more positive responses, to sweet tastes, as well as to odours and flavours that have been associated with sweet tastes (Steiner et al., 2001; Stevenson & Boakes, 2004), which gives them a special hedonic character.

How should the finding that liking predicted part of the roundness/angularity ratings with tastants and not with taste words be explained? Presumably, when people are given taste words, they may think of sweetness in a more general fashion. That is, when given a word such as "sweet", those foods having a variety of flavours may come to the participant's mind, while when presenting an actual tastant, people are directly mapping a specific sensation. Alternatively, this results could be related to the different tasks used in Experiment 3 and 4. While, in Experiment 3, the participants had to arrange the taste words in the box ranging from "not at all" to "very much", in Experiment 4, participants responded to each taste on an independent VAS for liking with the same anchors.

After systematically evaluating the way in which people match basic tastes and abstract shapes, I will now move on, in the next chapter, to evaluate the way in which these results extended to the context of product packaging. In Chapter 3, abstract shapes on product packages and packaging shapes are used in order to assess whether people match them to basic taste words.

CHAPTER 3

Crossmodal correspondences between taste and shape: Product packaging

3.1 Introduction

Based on the literature review presented in Chapter 1, and the experiments outlined in Chapter 2, it is possible to assert that people do indeed reliably match shapes with tastes (both when words and actual tastants are used) and that taste hedonics and intensity influence such associations. As suggested before, though, most food products come in a variety of packaging designs which include a number of shapes, words, pictures, and other design elements. Although these elements are used in specific product categories (just think of cans of tuna, or soft drinks), it is sometimes unclear whether the selection of such packaging forms is based on any rational other than merely the conservation and portioning of the product, and perhaps also convention. The idea here is that research on crossmodal correspondences can inform the way in which taste and flavour expectations can be influenced by means of visual attributes. Although it is known, for example, that people can tell whether a packaging form corresponds to a specific kind of product (e.g., Smets, Overbeeke, & Gaver, 1994; Spence, 2012), further research is certainly needed in order to clarify whether common packaging shapes, are associated to foods or drinks with specific taste attributes.

In this chapter, a study that was designed evaluate whether specific packaging moulds (Hine, 1995; Meyers, 1981; Parise & Spence, 2012) and abstract shapes on packaging designs would be matched to specific basic taste words is presented. Basic taste words were used because people rarely experience pure basic tastants in isolation but they can easily generate foods and drinks that contain those tastes (e.g., Lacey & Lawson, 2013). In addition, research has suggested that taste words can activate primary and secondary gustatory cortices, which points to the fact that their meaning is grounded in areas related to taste sensations (e.g., Barrós-Loscertales et al., 2012). Experiment 6 reports an online study designed to assess the way in which people match taste words and packaging shapes, and taste words and abstract shapes on product labels.

3.2 Experiment 6: Crossmodal correspondences between abstract and concrete visual shapes and tastes in product packaging

3.2.1 Methods and materials

3.2.1.1 Participants

The same one hundred and one participants (40 females, mean age= 32.84 years, SD= 9.23) that took part in Experiment 2, participated in this online study using the Adobe Flash based Xperiment software (http://www.xperiment.mobi). All of the participants were recruited using Amazon's Mechanical Turk in exchange of 1.25 USD, and all agreed to take part in the study after reading a standard consent form.

3.2.1.2 Apparatus and materials

Twenty images of abstract shapes from previous research were used as stimuli (Deroy & Valentin, 2011; Ngo et al., 2013; Spence & Gallace, 2011; see also Chapter 2) and are shown in Figure 3.1A. Twenty images of different packaging forms which were based on regular supermarket products such as soft drinks, milk, ice cream, crisps, sauces, canned products, chocolate, and so on were utilized. The packaging images were all presented against a white background (see Figure 3.1B).

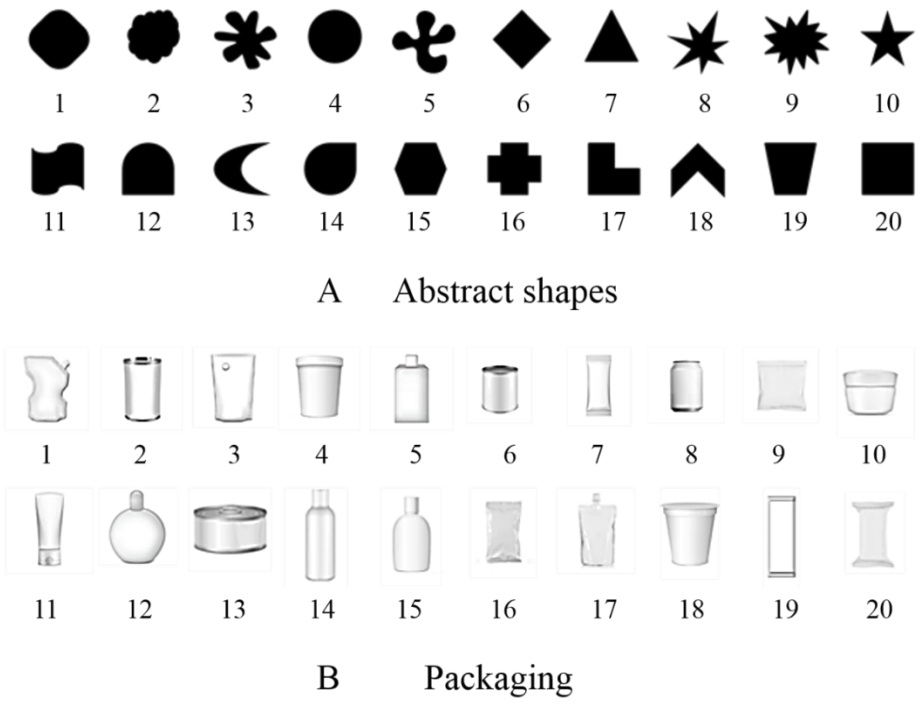


Figure 3.1. Stimuli used in the abstract shape drag-and-drop task (A), and the packaging drag-and-drop task (B) in Experiment 6 (note that the images are not presented to scale).

3.2.1.3 Procedure

The participants were first presented with the general aim of the study. It was mentioned that the experiment was designed to assess the way in which people match information

across the senses. After that, a standard consent form was presented and those participants who accepted to take part continued on with the experiment.

Two tasks were randomly presented to the participants. In the first, the abstract shape drag-and-drop task (see Figure 3.2A), the participants were presented with the twenty images of the same package but with different abstract silhouetted shapes on it (fitted to a 84 x 106 pixel box). The position of the different images on the screen was randomized. The participants were instructed to arrange the shapes in terms of whether they thought the shapes matched bitter, salty, sour, or sweet foods and drinks. The second task, the packaging shape drag-and-drop task (see Figure 3.2B), followed the same approach but instead of abstract shapes, twenty packaging (concrete) forms (fitted to a 75 x 75 pixel box) were presented instead. The order in which the various taste words were presented within each task across participants was randomized.

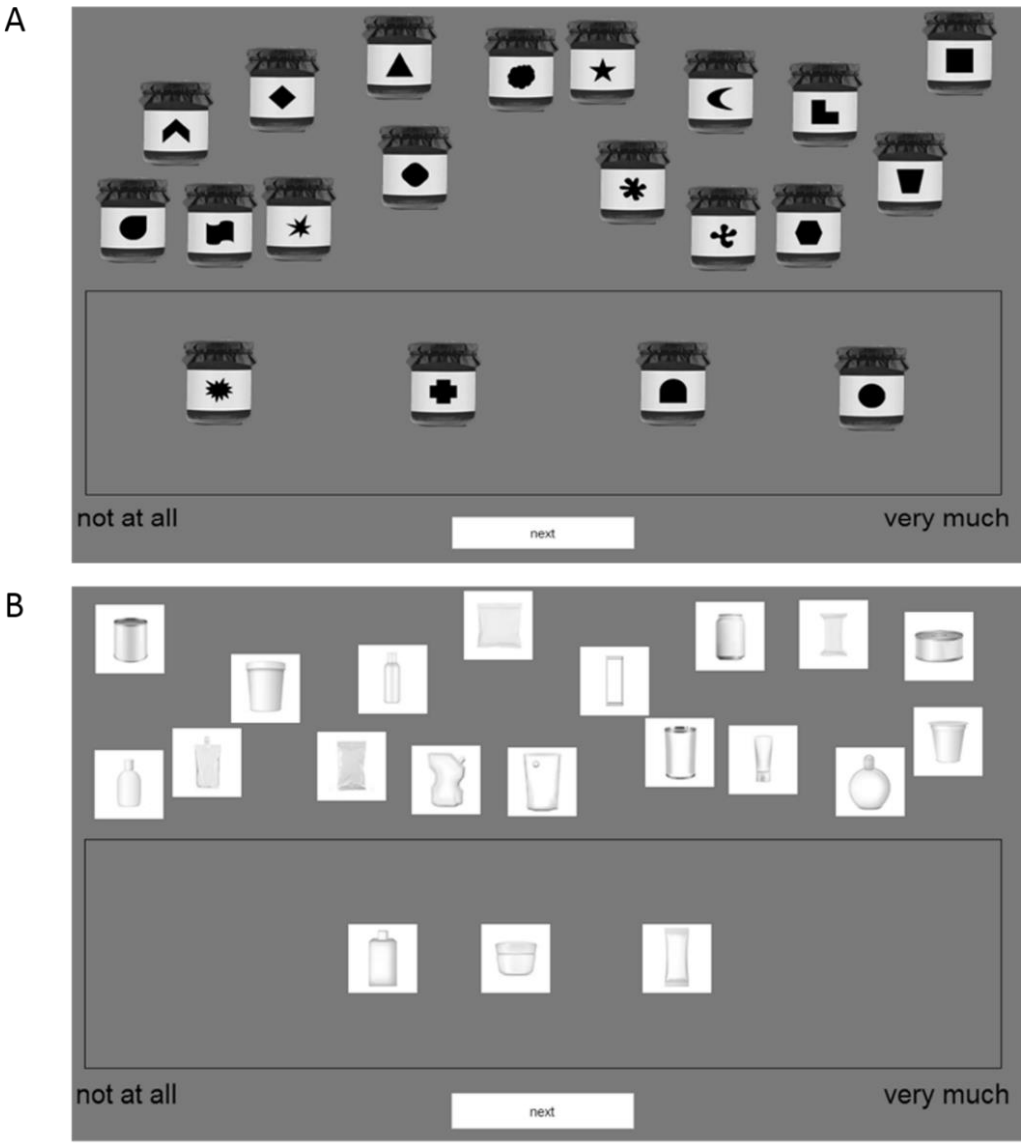


Figure 3.2. Example of an abstract shape drag-and-drop (A), and a packaging drag-and-drop trial (B) in Experiment 6.

At the beginning of each trial, the participants were shown the instructions (i.e., to arrange the abstract shapes/packages according to the extent you think that they represent a 'sweet' food or drink, Times New Roman, font size 22). Next they were shown the different shapes; and a box to which they could drag-and-drop the shapes. Such box acted as a fine-grained 100 point VAS (anchored with 'not at all' and 'very much'). The participants then arranged the different shapes on the screen. Once they had completed a

trial they moved on to the next taste word. After finishing one of the tasks, they continued with the other task.

3.2.2 Results

Due to a number of RM-ANOVA assumptions being violated (e.g., the data was not normally distributed), the rank-based ANOVA-type statistic (ATS) was used to analyse the results (see Noguchi, Gel, Brunner, & Konietschke, 2012, for details). The taste words (i.e., bitter, salty, sweet, and sour) and packaging shapes (shapes 1~20) variables were submitted as within-participants factors to the ATSs performed for both the packaging and the abstract shapes drag-and-drop tasks.

Abstract shapes drag-and-drop task. A 4 (taste words) × 20 (packaging shapes) ATS revealed a significant main effect of shape, F_{ATS} (8.57, ∞) = 17.40, p <. 001, and an interaction between taste words and shape, F_{ATS} (16.77, ∞) = 12.83, p < .001. The ATS did not reveal a main effect of taste word. Multiple pairwise comparisons of shapes were submitted to the percentile bootstrap method ($\hat{\psi}_{PB}$). This method adjusts the p-values by using the sequential rejection method (see Wilcox, 2005, p. 313). Figure 3.3 presents the median ratings for the main effect of shape. Since the main aim of the present study was to study the interaction between taste quality and shapes, pairwise comparisons are presented in section 3.2.4, Table 3.3, with additional materials from this experiment.

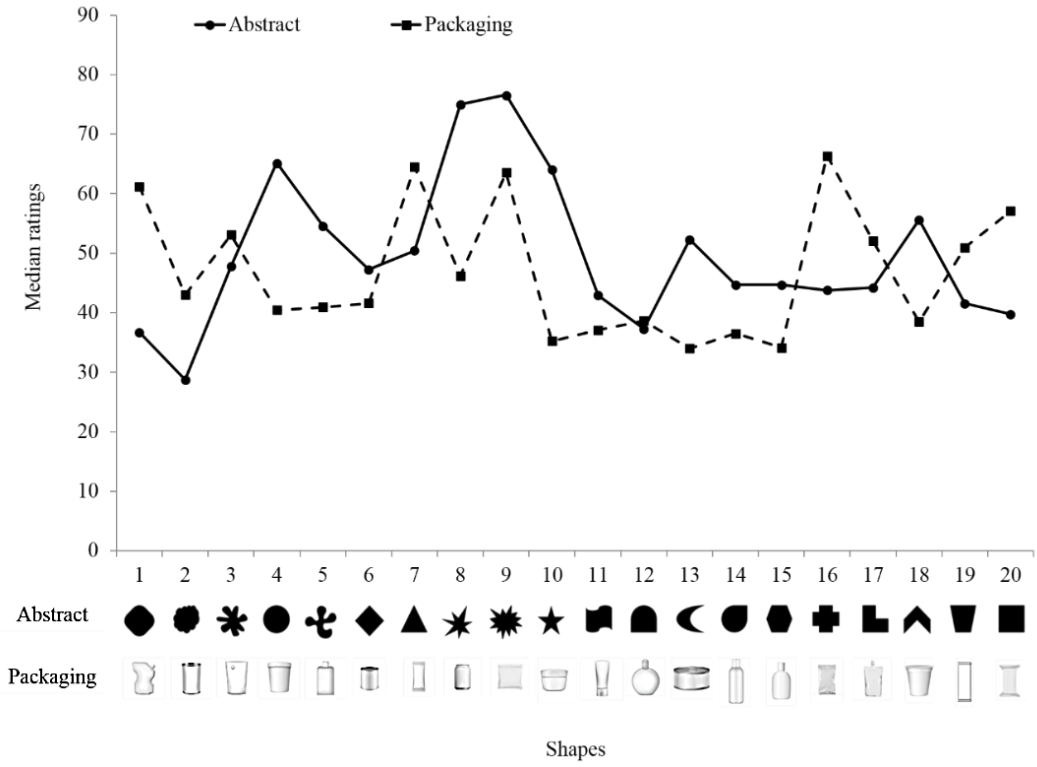


Figure 3.3. Median (Harrell-Davis-type; see Vélez & Correa, 2014) ratings of abstract and packaging shapes in relation to taste words in Experiment 6. The higher the median rating, the higher the taste ratings for the abstract or concrete shape.

A summary of the results of the interaction are shown in Figure 3.4A. Friedman tests were performed in order to further explore the interaction between taste word and shape. Significant differences among the packages were found for bitter, χ^2 (19, n=101) = 151.537, p < .001, sour, χ^2 (19, n=101) = 384.927, p < .001, salty, χ^2 (19, n=101) = 119.409, p < .001, and sweet, χ^2 (19, n=101) = 207.343, p < .001. These results corroborate what is illustrated in Figure 3.4A, namely that while certain shapes were rated higher after a specific taste word (e.g., shape 9 | sour taste), others shapes were rated lower (e.g., shape 2 | sour taste). A summary of the pairwise comparisons can be found in Table 3.1 (Siegel & Castellan, 1988).

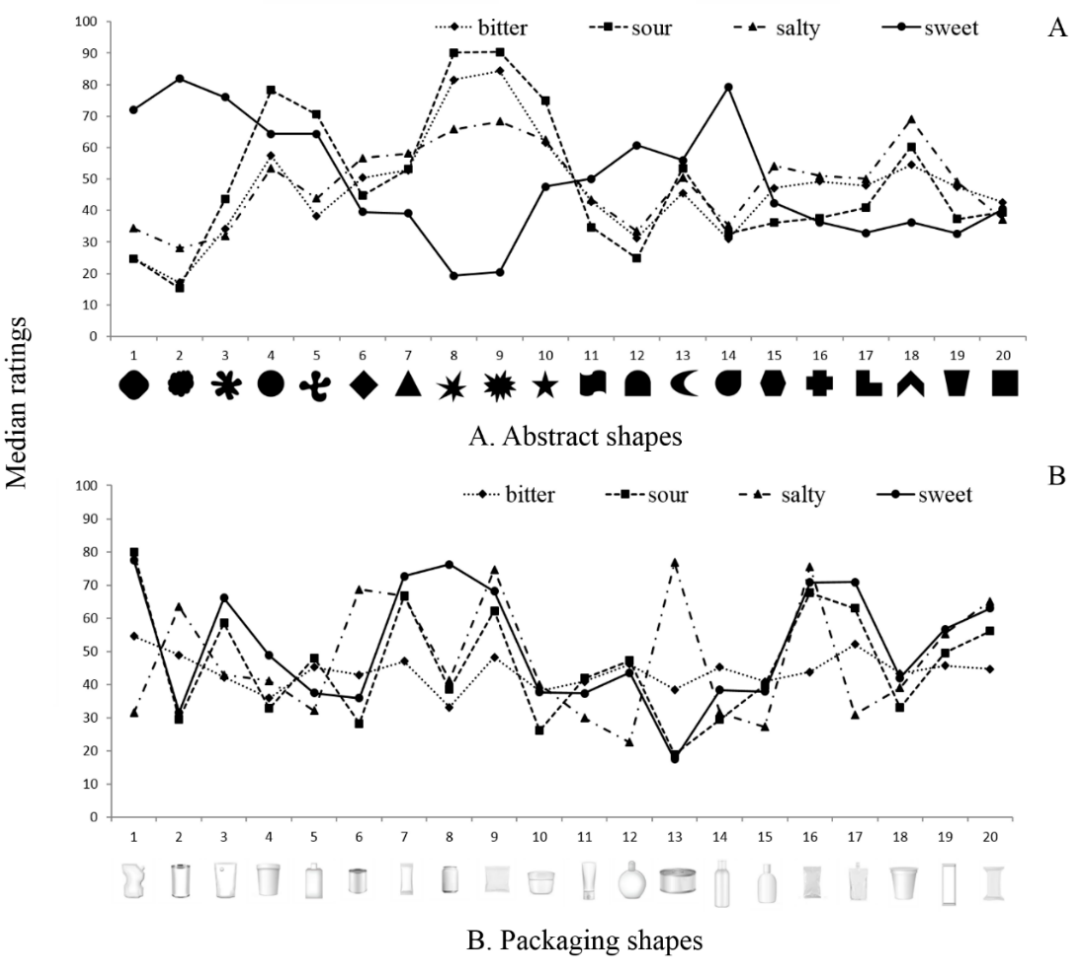


Figure 3.4. Interaction between taste and shape in both abstract and packaging drag-and-drop tasks in Experiment 6. While panel A shows that the participants tended to associate the word "sweet" with more rounded abstract shapes, and the other tastes with more angular abstract shapes, panel B shows that such a pattern was not present when the task involve packaging shapes instead.

Table 3.1. Pairwise comparisons of the Friedman tests performed on each taste word as a function of the abstract shape in Experiment 6. The table presents all of the shapes numbered (left), and those tastes that were associated with specific shapes more than others at a level that was significantly higher than chance. So, for example, shape 1, was rated as significantly sweeter than shapes 6 to 9 and 15 to 20.

Shape		Bitter	Salty	Sour	Sweet
1		-	-	-	6-9, 15-20
2		-	-	-	6-11, 15-20
3		2	-	2	6-9, 15-20
4		1, 2, 14	-	1-3, 6, 11, 12, 14-17, 19, 20	8, 9, 17, 19
5		2	-	1, 2, 8, 9, 11, 12, 14-16, 19	8, 9, 17
6		2	2, 14	-	-
7		1, 2	2, 14	1, 2, 12	-
8		1-3, 5, 11, 12, 14, 15, 19, 20	1-3, 11, 12, 14	1-3, 6, 7, 11-20	-
9		1-3, 5, 6, 11-16, 19, 20	1-3, 12, 14	1-3, 6, 7, 11-20	-
10		1, 2	1-3, 12, 14	1-3, 6, 11, 12, 14-17, 19, 20	-
11		2	-	-	-
12		-	-	-	8, 9, 17, 19
13		2	-	1, 2, 12	8, 9, 17, 19
14		-	-	-	6-11, 15-20
15		2	2, 14	-	-
16		2	-	-	-
17		1, 2	-	-	-
18		1, 2	1-3, 11, 12, 14, 20	1, 2, 12, 15	-
19		2	-	-	-
20		2	-	-	-

Packaging shapes drag-and-drop task. A 4 (taste words) × 20 (packaging shapes) ATS revealed a significant effect of taste word, F_{ATS} (2.77, ∞) = 9.84, p < .001, packaging

shape, F_{ATS} (8.61, ∞) = 17.09, p <. 001, and an interaction between taste words and shape, F_{ATS} (25.55, ∞) = 9.42, p <. 001. Figure 3.4B presents the mean ratings for the main effect of shape. Once again, the interaction between taste words and shapes, pairwise comparisons are presented in Table 3.4, Section 3.2.3. Pairwise comparisons performed on the main effect of taste word revealed a significant difference between bitter and sweet ($\hat{\psi}_{PB}$ = -4.36, p < .001), salty and sweet ($\hat{\psi}_{PB}$ = -2.90, p=.002), and sour and sweet ($\hat{\psi}_{PB}$ =-4.13, p = .001).

A summary of the results of the interaction are highlighted in Figure 3.4B. Friedman tests revealed significant differences among packages in the cases of sour, χ^2 (19, n=101) = 214.871, p < .001, salty, χ^2 (19, n=101) = 281.487, p < .001, and sweet, χ^2 (19, n=101) = 158, p < .001. As far as the bitter taste was concerned, all of the shapes tended to receive similar ratings. Multiple pairwise comparisons between shapes were carried out using the method described above. Pairwise comparisons are shown in Table 3.2 (Siegel & Castellan, 1988).

***Table 3.2*. Pairwise comparisons of the Friedman tests performed on each taste word as a function of the abstract shape in Experiment 6. The table presents all of the shapes numbered (left), and those tastes that were associated with specific shapes more than others at a level that was significantly higher than chance. For example, packaging form 2, was rated as significantly saltier than packaging forms 1, 5, 11, 12, 14, 15, and 17.**

	Shape	Salty	Sour	Sweet
1		-	2, 4, 6,8, 10, 11, 13, 14, 15, 18	2, 5, 6, 10, 11, 13, 14, 15, 18
2		1, 5, 11, 12, 14, 15, 17	-	-
3		-	4, 6, 10, 13	2, 6, 10, 11, 13
4		12	-	13
5		-	13	13
6		1, 3, 5, 8, 11, 12, 14, 15, 17	-	-
7		1, 5, 11, 12, 14, 15, 17	2, 4, 6, 8, 10, 13, 14, 18	2, 5, 6, 10, 11, 13, 14, 15, 18
8		-	-	2, 5, 6, 10, 11, 13, 14, 15, 18
9		1, 3, 4, 5, 8, 11, 12, 14, 15, 17	2, 4, 6, 8, 10, 13, 14, 18	2, 6, 13
10		12, 15	-	13
11		-	13	13
12		-	13	13
13		1, 3, 4, 5, 8, 10, 11, 12, 14, 15, 17, 18	-	5
14		-	-	13
15		-	13	13
16		1, 3, 4, 5, 8, 10, 11, 12, 14, 15, 17, 18	2, 4, 6, 8, 10, 13, 14, 18	2, 6, 10, 11, 13
17		-	2, 4, 6, 10, 13, 14, 18	2, 5, 6, 10, 11, 13, 18
18		12, 15	-	13
19		12, 15	13	13
20		1, 3, 5, 8, 11, 12, 14, 15, 17	4, 6, 10, 13, 18	2, 6, 13

3.2.3 Discussion

In terms of both the abstract and packaging tasks, the interaction between shape and the taste words is clear in the overlap of lines in Figure 3.4. That is, while a shape can receive a low rating when paired with a specific taste, the very same shape can receive a high rating when paired with another taste; that is, the pattern reverses when other shapes are associated with the same tastes. For example, in the case of the abstract shapes, Shape 2 was rated low when paired with the sour taste, but has a high rating when paired with the sweet taste. The pattern reverses in the case of Shape 8, which received a high rating when paired with the sour taste and a low rating when associated with the sweet taste.

The results of Experiment 6 therefore demonstrate that certain abstract and more concrete packaging shapes are reliably associated with foods/beverages that have specific taste properties. These results are consistent with the literature on shape symbolism which suggests that people consistently match taste (or in this case taste-related, taste words) and non-taste stimuli and that shapes can convey information about the taste/flavour of a product (see O'Mahony, 1983; Spence & Deroy, 2013). Importantly, while associations with concrete packaging forms may rely on previous interactions with specific products (and vary as a function of them), specific features of abstract shapes such as their roundness/angularity (i.e., contour) may guide the way in which people match them to specific tastes or other flavour attributes (e.g., think about the carbonation of a drink, see Ngo et al., 2012).

The results of Experiment 6 demonstrated that certain abstract and more concrete packaging shapes are reliably associated with foods/beverages that have specific taste properties. Overall, round abstract shapes (package numbers 1-5, 12-14) were rated as

more appropriate for sweet tasting foods and drinks, whereas the more spiky and angular shapes (8, 9) were chosen for bitter, salty, and sour foods and drinks instead (see Table 3.1; see also Chapter 2). In addition, the packaging task indicated that while certain image moulds (or packaging forms) have specific associations such as packaging shape 8 (i.e., what looks like a typical soft-drink can) with sweet, and 13 (i.e., a typical can for tuna) with salt, others have less specific associations with tastes (i.e., 1, 3, 7, 9, 16, 20), and others appear to not have a specific association at all (4, 5, 10, 11, 12, 14, 15, 18, 19) (see Table 3.2).

Potentially, those packaging shapes that did not have a specific taste identity, may have resulted from either the shape not being as concrete for the participants (i.e., specific associated to a product or product category), or the same shape potentially being used in a number of product categories (see Groenland, Bloem, & Kuylen, 1996). Indeed, it has been suggested the semantic associations to specific products may guide product categorization (Schoormans & Robben, 1997). Take, for example, packaging form 19, it might be a chocolate or granola bar, or perhaps chewing gum, while packaging form 8 is most definitely a soft drink container (see also Spence, 2012, on shape symbolism). This raises questions as to what is abstract and what is concrete in packaging since, for example, packaging form thirteen was, for most participants, considered more appropriate for a salty product, while packaging form fourteen did not evoke such a clear association with a specific taste.

As suggested by Crilly, Moultrie, and Clarkson (2004), the symbolic value of a product's appearance can be influenced by sociocultural conventions, marketing strategies, and the evolution of, say, product categories over time (see also You & Chen, 2007). Certainly, designers often work on conveying such symbolism in packaging design. It is interesting

to note here that a shape or packaging form that is currently not associated with any taste or flavour, could potentially be taken by a brand in order to create meaning or specific associations to the eyes of the consumer. That is, a company could potentially stand more chance of creating an image mould, and could, for example, use abstract shapes on the label in order to help strengthen the intended taste association.

Although it has been suggested that certain associations may have been picked up intuitively by designers through recent history and thus represented in the available packaging designs (Spence, 2012), the results reported here should be of interest to those considering, or those uncertain, as to which packaging format should be used to deliver their new product to market. Product and packaging designers can engineer the expectations that they wish to inspire in the mind of the consumer by knowing which abstract and concrete shapes best convey a specific taste concept (sweet, sour, salty, bitter, or umami, e.g., Deliza & Macfie, 1996). Of particular interest here is the fact that if one wants to launch a product in a new market, abstract rather than concrete shapes may be used on the labelling/packaging to convey information about the likely taste, as few, if any, concrete associations may exist currently. As I demonstrate in Chapter 2, round is strongly associated with sweet, while sourness, for instance, tend to be associated with angular. Even though these associations should not be assumed to be universal (Bremner at al., 2013), they may, though, be more consistent across cultures (than, say, colour-flavour correspondence, see Chapter 5).

While it is unlikely that a basic tastant truly exemplifies any product on a supermarket shelf (excepting perhaps sugar and 'sweet' and/or salt and salt taste), people can normally categorize food and beverage products as being sweet, bitter, salty, sour, or umami overall. Taste words can certainly provide useful when assessing crossmodal

correspondences to shapes, however, it would be certainly interesting to assess the matching of both abstract shapes and packaging forms to actual tastes. This could be done by using perceptual rather than linguistic stimuli (see also Tomasik-Krókti & Strojny, 2008). It is possible by means of taste words to approximate people's crossmodal associations, since language captures multisensory object representations; Marks, 1978, 2013). This allows one to approximate the way in which information is mapped across the senses. Here, the results of Experiment 6 further the investigation of how to visualize tastes and flavours by providing evidence in support of the idea that both abstract shapes and packaging forms can be reliably matched to specific taste words.

As Experiment 6 provides just some initial evidence on how people associate packaging shapes and abstract shapes to tastes, further ideas may be explored through future studies. An interesting future direction for the Experiment 6 would be to take a number of packaging shapes with round and angular features and see whether on average participants expect those with rounder features to contain sweet products. Alternatively, it would be interesting to not only assess participants taste expectations but also to ask them to rate how round/angular they consider the different packages, and see whether such ratings correlate with the taste ratings.

After assessing the role of both abstract shapes and packaging shapes in shape-taste associations, the experiment reported in the next chapter will focus on correspondences between taste words and typeface. As mentioned before, typefaces are interesting design elements that, not only involved some critical features of shapes (e.g., roundness/angularity) but have been linked to emotion in the literature. In addition, as will be made clear, research has already demonstrated that typefaces can convey meaning over-and-above the actual semantic content of the words written on a specific typeface.

3.2.4 Additional materials

Table 3.3. Pairwise comparisons ($p < .05$), using the percentile bootstrap method (Wilcox, 2005), of the main effect of shape in the abstract shape drag-and-drop task in Experiment 6. The table presents all of the shapes numbered (left), and those that higher ratings as compared to the other shapes at a level that was significantly higher than chance. For example, while shape 1 was not rated as significantly higher than any of the other shapes, shape 3, obtained higher ratings than shapes 1, 2, 11, 12, and 20.

	Shape	>
1		-
2		-
3		1, 2, 11, 12, 20
4		1-3, 6, 11, 12, 14-17, 19, 20
5		1, 2, 11, 12, 15, 16, 19, 20
6		2, 19, 20
7		1, 2, 10-12, 15-17, 19, 20
8		1, 2, 3, 5-7, 11-20
9		1, 2, 5, 6, 7, 10-20
10		1, 2, 6, 7, 11, 12, 14-17, 19, 20
11		-
12		-
13		1, 2, 11, 12, 16, 17, 19, 20
14		2
15		2
16		-
17		-
18		1, 2, 6, 11, 12, 15-17, 19, 20
19		-
20		-

Table 3.4. Pairwise comparisons ($p < .05$), using the percentile bootstrap method (Wilcox, 2005), of the main effect of shape in the packaging drag-and-drop task in Experiment 6. The table presents all of the packages numbered (left), and those with higher ratings as compared to the other packaging shapes at a level that was significantly higher than chance. For example, packaging 1, obtained higher ratings as compared to shapes 2, 4-6, 8, 10-15, and 18.

	Shape	Higher ratings than
1		2, 4-6, 8, 10-15, 18
2		-
3		4, 5
4		-
5		-
6		-
7		4, 5
8		-
9		2, 5, 17
10		-
11		-
12		-
13		-
14		-
15		-
16		2, 3, 5, 6, 8, 12, 17
17		5
18		-
19		4, 5, 10, 14
20		2, 4, 5, 8, 12, 15, 18

CHAPTER 4

Crossmodal correspondences between taste and shape: Typeface

4.1 Introduction

Typefaces constitute a particularly intriguing stimulus set when thinking about crossmodal correspondences since they can take on a number of forms and can convey meaning over-and-above the actual semantic message of the text itself (e.g., Doyle & Bottomley, 2009; Morrison, 1986; Ngo et al., 2012; Salgado-Montejo et al., 2014; Tannenbaum, Jacobson, & Norris, 1964, see also Poffenberger & Barrows, 1924, for an early example of simple lines conveying meaning). Indeed, it has been suggested that visual features of written words can be processed before their actual meaning and that this, in turn, can influence later information processing (Childers & Jass, 2002, see also Celhay, Boyselle, & Cohen, 2015). In the context of consumer behaviour, this is of particular importance given that consumers perceive a font as being more appropriate to a product when both the product and the font have the same connotative meaning (e.g., as measured using the semantic differential technique; see Osgood et al., 1957). In addition, product semantic appropriateness or congruency has also been shown to influence consumer choice (Doyle & Bottomley, 2004). This, in turn, points to the importance of font-product semantic consistency in design.

Experiment 7 presents a study that involves four distinct tasks. Two of these tasks were designed at replicating previous findings concerning the associations between shapes and

taste words by hand drawn marks (round and angular). In the other two tasks, the associations between taste words and typefaces was assessed.

It has been long since it was proposed that both simple angular-like simple lines and typefaces are more associated with negatively-valenced emotion words, while round-like simple lines and typefaces with more positively-valenced emotion words (Poffenberger & Barrows, 1924; Tannenbaum et al., 1964). With this in mind, and the results reported in Chapter 2, it is hypothesized that the first would be match to the bitter, salty, and sour categories, while the later will be match to sweet. Note there that, as abstract shapes (see Chapter 3), typefaces do not need necessarily to have any specific taste-related convention in the market place, or at least, there is no evidence of that, as far as I am aware.

4.2 Experiment 7: The taste of typeface design

4.2.1 Methods and materials

4.2.1.1 Participants

One hundred and one participants (42 females, M age = 35.4 years, SD age = 11.15, range age = 20-69 years) from the United States took part in this study online through the Adobe Flash based Xperiment software (http://www.xperiment.mobi). All of the participants were recruited using Amazon's Mechanical Turk in exchange for a payment of 1.00 USD and all were based in the USA. All of the participants agreed to take part in the study after reading a standard consent form.

4.2.1.2 Apparatus and materials

The images of four marks (Figure 4.1A) and twelve variants of the same text ‘eat me’ were written in different typefaces. Some of those typefaces were created specifically for the purpose of this experiment (see Figure 4.1B). Each image was presented in black and white either alone (71 x 71 pixels) or on a receptacle (85 x 116 pixels), giving rise to a total of 34 stimuli. The marks were designed based on previous research suggesting that people associate sweet tastes with round shapes, while other tastes may not have a distinct association (see Chapter 2 and 3). Likewise, the different typefaces were designed to be distinctively round or angular (see also Tannenbaum, Jacobson, & Norris, 1964). The typefaces included in the present study are shown in Figure 4.1B. The first two typefaces are Arial (typeface 1) and Arial bold (typeface 2), while the remaining ten correspond to designs made by Sarah Hyndman (http://www.sarahhyndman.com/), for the purpose of the present experiment and included: curvaceous – light (typeface 3, a modified light version of Candice typeface), curvaceous, bold (typeface 4, based on Candice typeface), tnr (typeface 5), tnr bold (typeface 6), extremely angular – light (typeface 7, a modified light version of Klute typeface), extremely angular bold (typeface 8, a modified version of regular Klute typeface), angular and contrasting - sloping forwards (typeface 9), angular - sloping forwards (typeface 10, bold version of typeface 9), angular – sloping backwards (typeface 11, bold version of typeface 12), and angular and contrasting – sloping backwards. Note that the first six typefaces are round, while the remaining 6 are angular in form.

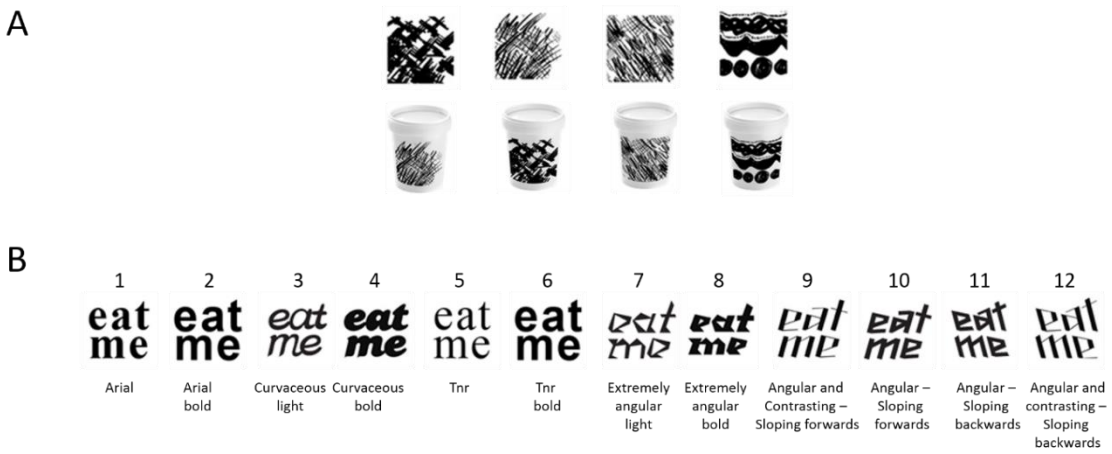


Figure 4.1. Stimuli used in Experiment 7. Panel A shows the marks and the marks on the receptacles, and Pane B shows each typeface used in the experiment.

4.2.1.3 Procedure

The experiment comprised four different tasks. In the *marks drag-and-drop task*, the participants were presented with the four different marks on the screen and had to arrange them in terms of the extent to which they thought they matched bitter, salty, sour, and sweet tastes. Note that each of the participants responded to each taste separately, and the order of presentation of the various taste conditions was randomized across participants. In the *marks-and-mugs drag-and-drop task*, the participants performed the same task but this time arranged the images of the marks on the mugs. The *typeface drag-and-drop task* was similar but here participants had to arrange the different images of the typeface variants of the text "eat me". Finally, the *typeface-and-mug drag-and-drop task* included the different typeface variants presented on mugs (see Figure 4.2, for an example of the task). The different tasks were randomized across participants.

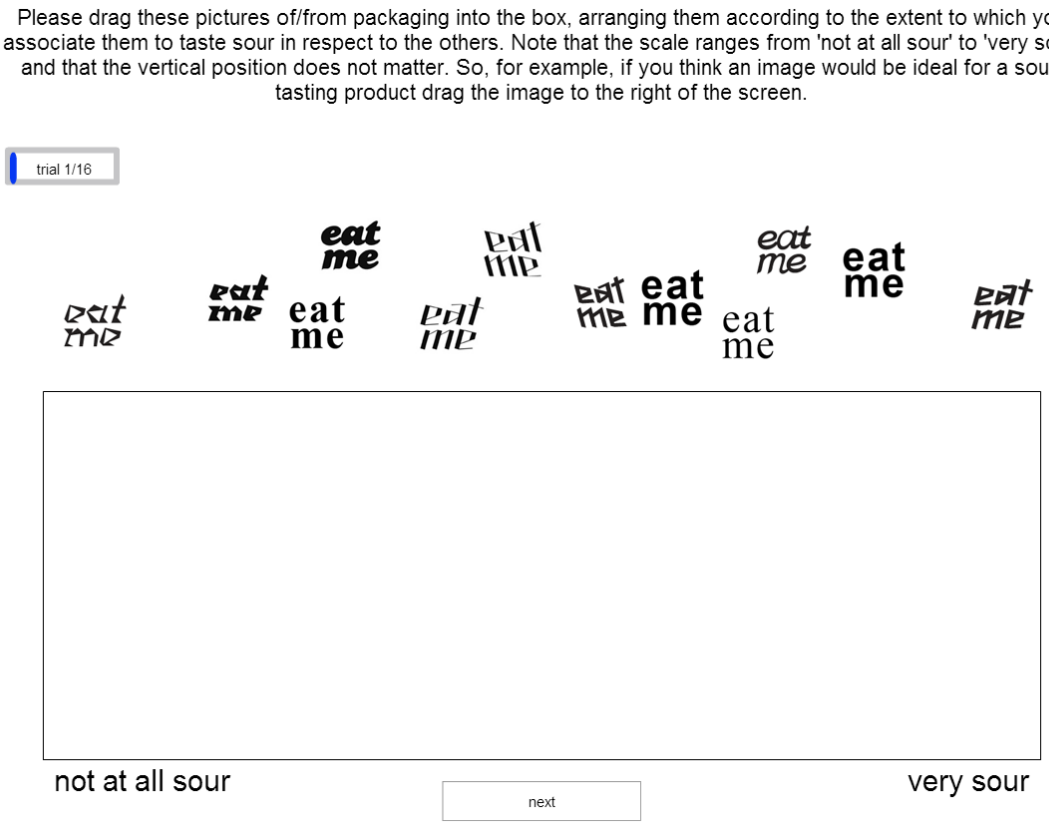


Figure 4.2. Example of the typeface drag-and-drop task in Experiment 7.

Before starting the experiment, the participants were informed about the general aims of the study and they agreed to take part on an electronic consent form. Afterwards, the participants reported their gender and age, and then moved to the actual experiment.

Due to a number of RM-ANOVA assumptions being violated (e.g., the data was not normally distributed), the rank-based ATS was used to analyse the results (see Erceg-Hurn & Mirosevich, 2008), as implemented in the {nparLD} package in R statistical software (see Noguchi et al., 2012). The significant main effects were further analysed by means of the Wilcoxon signed rank test with Bonferroni correction. Moreover, since the main interest in this task was to assess whether the ratings of each stimulus differed

as a function of taste, the significant interactions of taste and shape were analysed with Friedman's test. After this, multiple comparisons were performed following Siegel and Castellan (1988) Formula 7.5a (pp. 180-181), as implemented in {pgirmess} package in R statistical software.

4.2.2 Results

Task with marks. A 4 (taste words) × 4 (marks) ATS revealed a significant effect of mark, F_{ATS} (2.03, ∞) = 6.81, p = 001, a significant interaction between taste words and shape, F_{ATS} (4.85, ∞) = 22.46, p < .001, while no significant effect of taste word was observed (see Figure 4.3A, for a summary of the results). A Wilcoxon signed rank test with Bonferroni correction revealed that participants gave, overall, lower ratings to Mark 4 as compared to Mark 1 (p < .001). Friedman tests were performed to further explore the interaction between taste words and marks. Significant differences among the marks were found for bitter, χ^2 (3, n=101) = 41.93, p < .001, salty, χ^2 (3, n=101) = 26.83, p < .001, sour, χ^2 (3, n=101) = 18.12, p < .001, and sweet, χ^2 (3, n=101) = 76.23, p < .001. Pairwise comparisons revealed that the mark with the round forms (Mark 4) was rated as significantly less bitter, salty, and sour as compared to any of the other marks (p < .05, for all comparisons), and as significantly sweeter than the other marks (p < .05, for all comparisons). In addition, the participants rated mark one as significantly sweeter than mark three (p < .05).

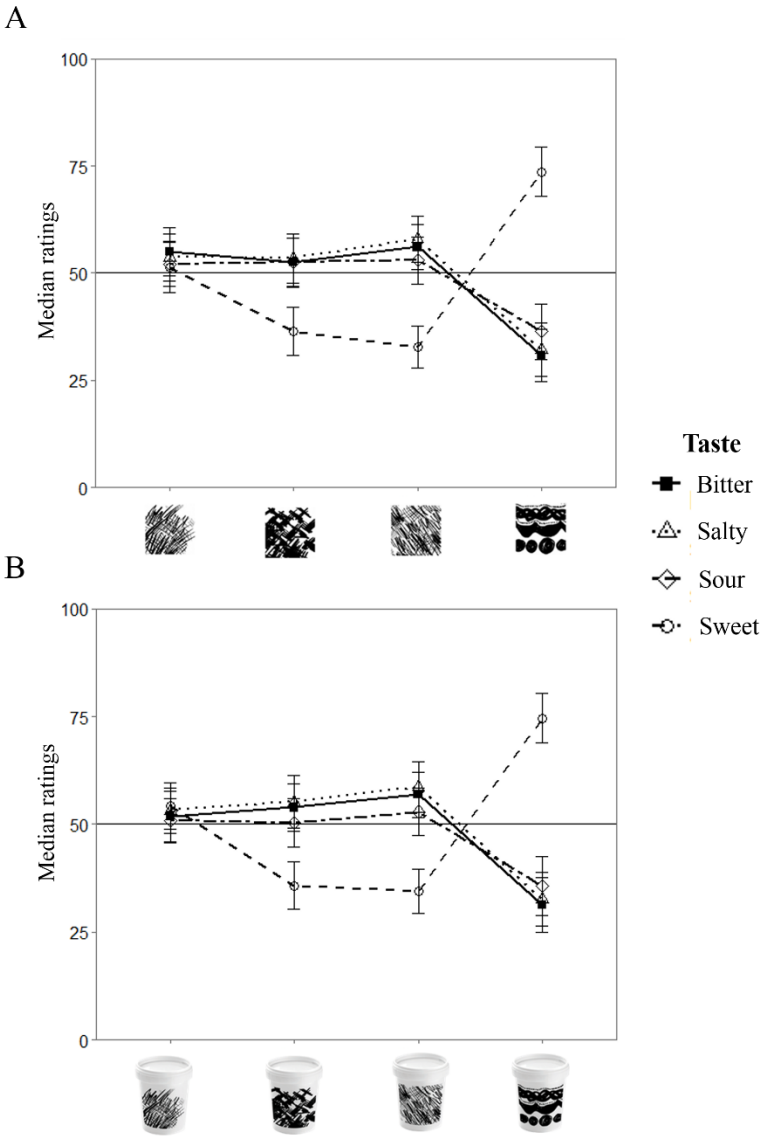


Figure 4.3. Median ratings of the task with marks and the task with marks and mug in Experiment 7. Note that, while the mark with round elements was consistently associated with sweet, there was no apparent distinction between the other tastes/marks associations.

Task with marks and mugs. The same analysis was performed in the task in which the marks were placed on the mugs (see Figure 4.3B for a summary of the results). Similarly, the analysis revealed a significant main effect of mark, F_{ATS} (2.08, ∞) = 5.86, p = .002, and a significant interaction between taste and mark, F_{ATS} (4.614, ∞) = 22.88, p < .001.

Here, again, participants gave lower ratings to mark 4 than mark 1 ($p < .001$). Friedman tests revealed significant differences between the mugs for bitter, $\chi^2(3, n=101) = 29.78$, $p < .001$, salty, $\chi^2(3, n=101) = 25.69$, $p < .001$, sour, $\chi^2(3, n=101) = 14.57$, $p = .002$, and sweet, $\chi^2(3, n=101) = 91.58$, $p < .001$. The mug with the mark with round forms (Mark 4) was rated as significantly less bitter ($p \leq .005$, for all comparisons) and salty ($p \leq .001$, for all comparisons), as compared to any of the other marks/mugs. The participants also rated Mark 4 as significantly less sour as compared to marks one and three ($p < .05$, for both comparisons). In addition, the participants rated Mark 4 as significantly sweeter than all of the other marks, and mark one as significantly sweeter than Marks 2 and 3 ($p < .05$, for both comparisons).

Task with typeface. Similarly, significant main effects of taste, $F_{ATS}(2.54, \infty) = 7.86$, $p < .001$, and typeface, $F_{ATS}(4.36, \infty) = 50.03$, $p < .001$, were obtained, and a significant interaction term was documented for taste and typeface, $F_{ATS}(8.15, \infty) = 54.00$, $p < .001$. After correcting for multiple comparisons, pairwise comparisons of the main effect of taste failed to reveal any difference between taste words. However, participants gave higher ratings to the angular (7-12) as compared to the round (1-6) typefaces ($p < .001$ for all comparisons). Furthermore, typeface 7, extremely angular light, received higher ratings than typeface 12, angular and contrasting – sloping backwards ($p = .03$). As for the interaction term, a significant difference between the different typefaces was found for bitter, $\chi^2(11, n=101) = 455.85$, $p < .001$, salty, $\chi^2(11, n=101) = 216.14$, $p < .001$, sour, $\chi^2(11, n=101) = 428.48$, $p < .001$, and sweet, $\chi^2(11, n=101) = 340.68$, $p < .001$. Pairwise comparisons revealed that the participants rated typefaces 7-12 as more bitter, salty, and sour than typefaces 1-6. In addition, the participants rated typefaces 1 and 2 as significantly sweeter than 7-12, typeface 3 as significantly sweeter than 5, 7-12, typeface

4 as sweeter than 1, 2, 5-12, typeface 5 as sweeter than 7-9, 11, 12, and typeface 6 as sweeter than 7-12 (see Figure 4.4A for a summary of the results). In other words, it is possible to see that the participants rated the angular typefaces as similarly bitter, salty, and sour, as compared to the round typefaces, while the latter were associated to sweet, as compared to the angular typefaces.

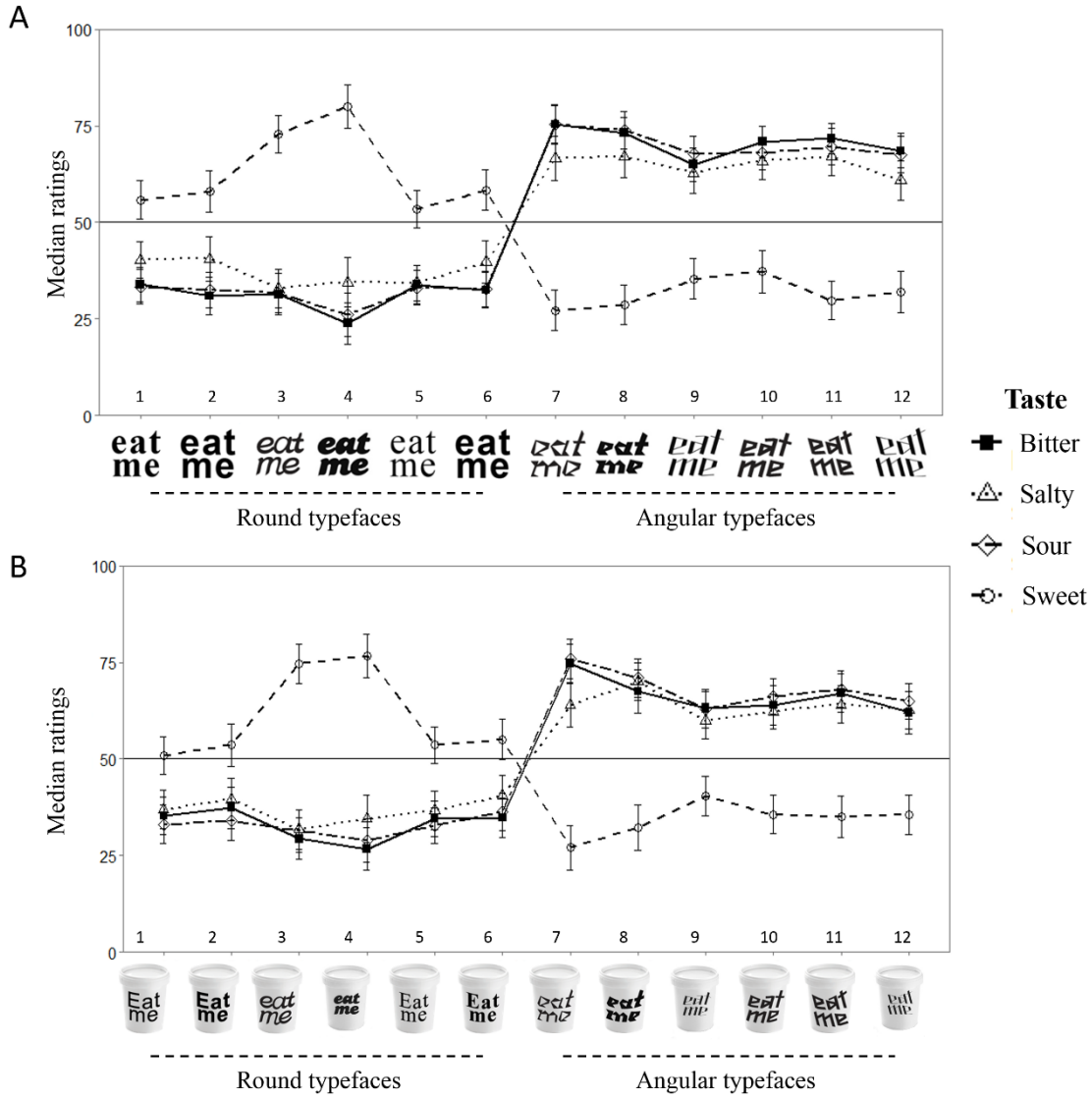


Figure 4.4. Median ratings of the task with typefaces and the task with typefaces and mugs in Experiment 7. Note once again that while the mark with round elements was consistently associated with sweet, there was no apparent distinction between the other taste/typeface associations.

Task with typeface and mugs. A 4 (taste words) × 12 (typefaces) ATS was performed. The analysis revealed significant main effects of taste word, F_{ATS} (2.80, ∞) = 5.17, p = .002, typeface, F_{ATS} (4.09, ∞) = 41.33, p < .001, and the interaction between taste and typeface, F_{ATS} (8.72, ∞) = 40.31, p < .001. Here, again, after correcting for multiple comparisons, no differences were found between taste words. Pairwise comparisons performed on the main effect of typeface also revealed that participants gave higher ratings to the angular (7-12) as compared to the round (1-6) typefaces (p < .001, for all comparisons). Moreover, typeface 7, extremely angular light, received higher ratings than typeface 9, angular and contrasting – sloping forwards, and typeface 12, angular and contrasting – sloping backwards (p < .05, for both comparisons). As for the interaction term, a significant difference between the different typefaces was found for bitter, χ^2 (11, n=101) = 314.64, p < .001, salty, χ^2 (11, n=101) = 249.79, p < .001, sour, χ^2 (11, n=101) = 374.14, p < .001, and sweet, χ^2 (11, n=101) = 254.31, p < .001. Pairwise comparisons of this task replicated those of the task with typeface (see Figure 4.4B, for a summary of the results).

The results of Experiments 4 and 5 reported in Chapter 2 demonstrated that taste liking can influence the way in which people match tastes and shapes. In other words, the more people like a taste, the more they will match it to round shapes, and the less they like it, the more they will associate it with angular shapes. Once again, this evidence is presumably related to the idea that people prefer round, as compared to angular, objects (e.g., Bar & Neta, 2006; Westerman et al., 2012), which in turn may influence the way in which taste liking influences taste-shape associations. That said, and based on the

research review outline in the introduction of this chapter, it appears as if this principle extends to typeface/taste associations.

4.2.3 Discussion

Experiment 7 was designed to replicate the way in which people match taste words and shapes, and extend these results to taste words and typefaces. As expected, the results add evidence to the notion that 'sweet' tends to be associated to rounder shapes, while the other tastes tend to be associated with angular shapes instead. Furthermore, the results reported here also suggest a clear distinction between round and angular typefaces, with the former being associated with a sweet taste, and the latter to the other tastes similarly. Overall, the results reported in this chapter are consistent with the experiments reported in Chapter 2 and 3.

Why would people match tastes and typefaces in a consistent manner? As shown in Chapter 2, taste liking and intensity can influence the way in which people match tastes and shapes. In other words, the more people like a taste, the more they will tend to match it to a round shape, and the less they like it, the more they will associate it with an angular shape instead. Crucially, previous research has suggested that features of the typeface can also convey emotional meaning, with curved typefaces being associated with positively valenced emotions, and angular typefaces with negatively valenced emotions (Kastl & Child, 1968). It is possible to think that the association between curved typefaces with more positive valenced emotions leads to the association of these typefaces with sweetness, a taste that is known by its positive hedonic effects on humans (e.g., Steiner et al., 2001). An additional explanation that is not necessarily incompatible with the latter

may be related to how easily different typefaces are read/processed. Previous research has shown that different typefaces may be differentially processed (e.g., Song & Schwartz, 2008). Moreover, processing facilitation can result in positive affect (cf. Winkielman & Cacioppo, 2001). That, in turn, may well explain the way in which people match rounder typefaces to sweetness, as both share positive affect.

Chapters 2-4 presented evidence suggesting that the associations between abstract shapes and tastes can be related to the hedonic value, intensity, and quality of both tastes and shapes. In addition, it was suggested that, certainly, people do not always match tastes and packaging shapes in the same way that they match them to abstract shapes. The symbolic value of packaging shapes (e.g., specific product categories may tend to uses specific moulds) may be involved in such matchings, thus, making, for example, the sweet-round association disappear (as with a typical shape of a tuna can being associated with salt). In the next chapter, I will move on to assess the context of colour/odour and colour/flavour associations.

CHAPTER 5

The role of culture and context in the crossmodal correspondence between odours/flavours and colours

5.1 Introduction

In Chapter 1, a number of studies were reviewed that had documented the existence of crossmodal correspondences between both colour and smell and colour and flavour. It seems to be an agreement in that many of these associations may have been acquired on the basis of learnt associations (Levitan et al., 2014; Spence, 2011). The idea that these crossmodal associations might result from the pick-up of the statistical regularities of the environment (and hence be based on prior experience) is supported, for instance, by the fact that the particular flavour that people match to a coloured drink has been shown to vary from culture to culture (Shankar et al., 2010a; see also Levitan et al., 2014, for a crosscultural study on odour/colour correspondences). This, however, does not rule out an affective mechanism, as associative learning has a key affective component for those correspondences across dimensions of objects (e.g., Shenhav, Barrett, & Bar, 2013). In this chapter, three experiments are presented in order to assess the role of cultural and packaging context on those associations.

Cross-cultural experiments in the context of crossmodal correspondences are useful in that they can shed light on the extent to which specific correspondences are shared and possible to the way in which they emerge. As suggested by Levitan et al. (2014), while structural correspondences may be mostly universal, not all statistical are universal, and most likely all semantic or linguistic correspondences may differ as a function of culture

due to the number of language differences that may emerge from one culture to another (e.g., Majid & Burenhult, 2014). The aim of this chapter is to evaluate whether colour/odour and colour/flavour correspondences change as a function of culture by bringing in both Western and Eastern participants (as most research in the topic has been performed on Western cultures, see Garber, Hyatt, & Nafees, 2015, for a comment on this idea). Given the variations that can be found in people's food preferences and practices (Kittler & Sucher, 2007), as well as the flexibility of colour to take on new meanings (Taylor, Clifford, & Franklin, 2013), it is reasonable to expect differences in the aforesaid correspondences. On the other hand, there are reasons to expect that certain correspondences may not vary from one culture to another. The literature on object recognition has previously suggested that the extent to which a colour is associated with an object is a critical factor in object recognition (Bramão, Reis, Petterson, & Faísca, 2011). Such a variable, namely colour diagnosticity (or association strength), may arise from the co-exposure of both colours and objects, and those objects with a high colour-diagnosticity (e.g., natural categories such as fruits or vegetables) may have a stronger influence on object identification (Lewis, Pearson, & Khuu, 2013). These ideas suggest that stored knowledge can be a critical factor on crossmodal correspondences, or at least those arising from the statistical regularities of the environment and/or language. Further, since several experiments of this thesis use product packaging (a concrete object which may have specific functions, identity, and/or meanings) as a means to study crossmodal correspondences, it is clear that stored knowledge is a critical element. Experiment 8 was conducted in collaboration with the University of Lorraine and was designed to investigate the extent to which odours and colours are commonly associated in two European countries with geographic proximity and a shared history: England and France.

Note that research on the influence of context and cultural background on such correspondences is still scarce. While it has been documented that there is consistency within cultures but not across cultures (Levitan et al., 2014, for a large sample study comparing Dutch, Chinese people in the Netherlands, German, Malay, Malaysian-Chinese, and US residents), it is worth extending these results to more similar cultural contexts since it will help clarifying the role of culture on colour/odour associations. Again, odours related to edible and non-edible sources are used here based on the fact that odours are some of the first cues to which people are exposed to before eating.

Besides, previous cross-cultural research on the associations people make with colour in the context of marketing communications has not focused on the specific role that products and packaging may play (Garber et al., 2000). Therefore, Experiment 9 was designed to assess the existence of any differences in the colour-flavour words associations that exist between those people living in Colombia, mainland China, and the UK. In particular, this study was conducted using a specific product context, namely, crisps. This study brings various novel elements to the understanding of the ways in which people match colours to flavours in the case of food product packaging: 1. Flavours and colours that are commonly utilised by major brands in Colombia, China, and the UK are used to examine the role of brand colour schemes in colour/flavour associations (which may provide an idea of the effect of brand schemes as a function of people's associations); 2. The participants in each country responded to all of the flavours/colours regardless of whether or not they were available in just one of the countries/markets; 3. Experiment 9 was conducted online taking into account that both commerce and online testing have become increasingly relevant (Dennis, Jayawardhena, & Papamatthaiou, 2010; Sands, Ferraro, & Luxton, 2010), and 4. Two tasks were used, one in which a colour had to be

selected for a packaging with a specific flavour words, and the other in which the packaging of a certain labelled product had to be matched to a colour.

Finally, in order to further our understanding of the role of context in colour/flavour associations, Experiment 10 was designed, together with Tsinghua University, to investigate whether the shape of a receptacle, specifically different glasses containing a transparent coloured liquid, would influence people's colour-flavour words associations. Once again, given that cultural differences have already been reported in terms of the differing meaning of the same colours in participants from the UK and Taiwan (Shankar et al., 2010a), it seemed sensible to extend Experiment 10 to investigate any cross-cultural differences that might exist with respect to those participants from the USA as well as those from mainland China. Furthermore, many international drinks manufacturers are currently thinking about how to enter the market in mainland China; this is a huge area of growth for many businesses. Note also that a substantially larger sample size was used, as compared to Shankar et al.'s (2010a) previous study (35 participants in Shankar et al.'s study vs. 200 participants in Experiment 10).

5.2 Experiment 8: On the colours of odours: Are the French really so different from the British? A cross-country comparison

5.2.1 Methods and materials

5.2.1.1 Participants

59 British participants (42 females, 17 males) and 60 French participants (47 females, 13 males), ranging in age from 18 to 55 years, were recruited from the University populations

of the University of Oxford (United Kingdom) and the Université de Lorraine (France). The participants were instructed not to wear any fragrance on the day of the study and not to have a meal, coffee, or to smoke in the 30 minutes preceding testing. Only those participants who reported having a normal sense of smell with no olfactory dysfunction were tested. The participants were also screened for colour vision anomalies using the Ishihara colour vision test.

5.2.1.2 Apparatus and materials

The olfactory stimuli were the same as those used by Maric and Jacquot (2012, 2013). The materials consisted of 16 odour samples including 9 of the odorants previously tested in research on odour-colour correspondences (namely caramel, cucumber, lavender, lemon, lime, peppermint, pineapple, violet, and strawberry). The odour samples were chosen to be representative of the 4 basic groups into which populations have been reported to classify odours (Chrea et al. 2005): flower (floral odours), sweet (fruits and candy odours), bad (some smoked odours), and nature (plant odours). The samples were prepared by injecting 1mL of each odorant into a small piece of carded cotton that had been placed inside a small opaque glass bottle, and identified by a 3-digit code. Consequently, there were no salient visual cues available to the participants. The odours were refrigerated between uses and were allowed to warm up to room temperature 15 min prior to testing.

The colour stimuli were the same as those used by Maric and Jacquot (2012, 2013). The colour chart consisted of a white A3 size page containing 21 colour patches arranged in a circle from red to purple, and three achromatic colour patches (white, grey, black) presented separately in the lower left corner. Each colour patch (4 cm in diameter) was

identified by a code (one capital letter and one figure). Colour charts were printed on coated paper. L*a*b coordinates were measured for each colour chip by means of a Datacolour system (Pantone® ColourVision™ Spyder Master Suite Spectro), and converted in L*C*H (Lightness, Chroma, Hue) coordinates, to get the exact position in the CIELAB colour space.

5.2.1.3 Procedure

Each participant was presented with the 16 olfactory stimuli in a random order, while viewing the colour chart. For each olfactory stimulus, the participants had to open the glass bottle and sniff its contents orthonasally. Afterwards, the participants were instructed to select from among the 24 colour patches the one that they felt most closely matched the odour.

5.2.2 Results and discussion

Since previous research has demonstrated gender differences in olfactory perception (e.g., Brand & Milloit, 2001), it was first evaluated whether the results from female and male would differ. No significant differences were found between the male and female participants on the odour-colour associations. Therefore, the data were collapsed across gender. Chi-square tests were used to assess whether there were any differences between the colour choices made by the French and British participants for each odorant. In order to evaluate correlations between the mean ratings of odour descriptors and/or the mean coordinates of the matched colours, Pearson correlation coefficients were used.

Chi-square tests for independence were conducted in order to determine whether different colours were chosen for the different odours in each population. Unsurprisingly, the results indicated that colour choice was influenced by the odours presented ($p < .0001$ in both countries). The participants thus matched the olfactory stimuli with the colours in a non-random manner in both countries. Chi-square tests for goodness of fit were performed in order to determine which odours induced a distribution of colour choices that were different from what would have been expected by chance. The results confirmed that the participants did not choose colours uniformly but rather tended to choose certain colours over others when matching the odours. Indeed, all 16 olfactory stimuli led to significant preferences in the choice of colour ($p < .05$ in all cases).

Chi-square tests for independence were conducted in order to investigate whether different colours were associated by the 2 populations with each olfactory stimulus. No significant differences were reported between the French and British participants in terms of the odour-colour associations that were realized for 13 of the odours. These results agree with previous findings. Demattè, Sanabria, and Spence (2006) and Maric and Jacquot (2013) investigated odour-colour associations in British and French populations, respectively, using 5 common odours: caramel, cucumber, lemon, peppermint, and strawberry (see Table 5.1). The similarity in terms of the reported odour-colour associations in these studies may confirm the existence of cross-modal odour-colour correspondences that are stable over time, and indicate common odour-colour associations among Northern Europeans.

Table 5.1. Colour-odour associations reported in the studies of Demattè et al. (2006) and Maric and Jacquot (2013).

Odorant	Demattè et al. (2006)	Maric and Jacquot (2013)
Caramel	Brown, yellow	Light brown, pale orange, dark brown, orange
Cucumber	Green	Green, pale yellow, pale orange
Lemon	Yellow, orange	Yellow, orange
Mint	Turquoise	Green, green–blue, pale blue, blue
Strawberry	Pink, red	Red, pink, purple, salmon-pink

Note: 6 odorants, provided by Quest International, UK, were presented to 21 British participants by Demattè et al. (2006), whereas 16 odorants, provided by Laboratoires Mathé, France, were presented to 155 French participants by Maric and Jacquot (2013). Note also that spearmint was presented in UK *vs.* peppermint in France, strawberry was presented in UK *vs*. wild strawberry in France.

Interestingly, however, significant differences were observed for 3 of the stimuli (from the sweet and natural odour groups): caramel ($\chi^2(18) = 38.9$, $p = .003$), mint chlorophyll ($\chi^2(13) = 29.1$, $p = .006$), and peppermint ($\chi^2(19) = 42.8$, $p = .001$) odorants (see Figure 5.1). The strengths of the effects, measured by Cramer's V, were large (with V= 0.6, 0.5, and 0.6, respectively).

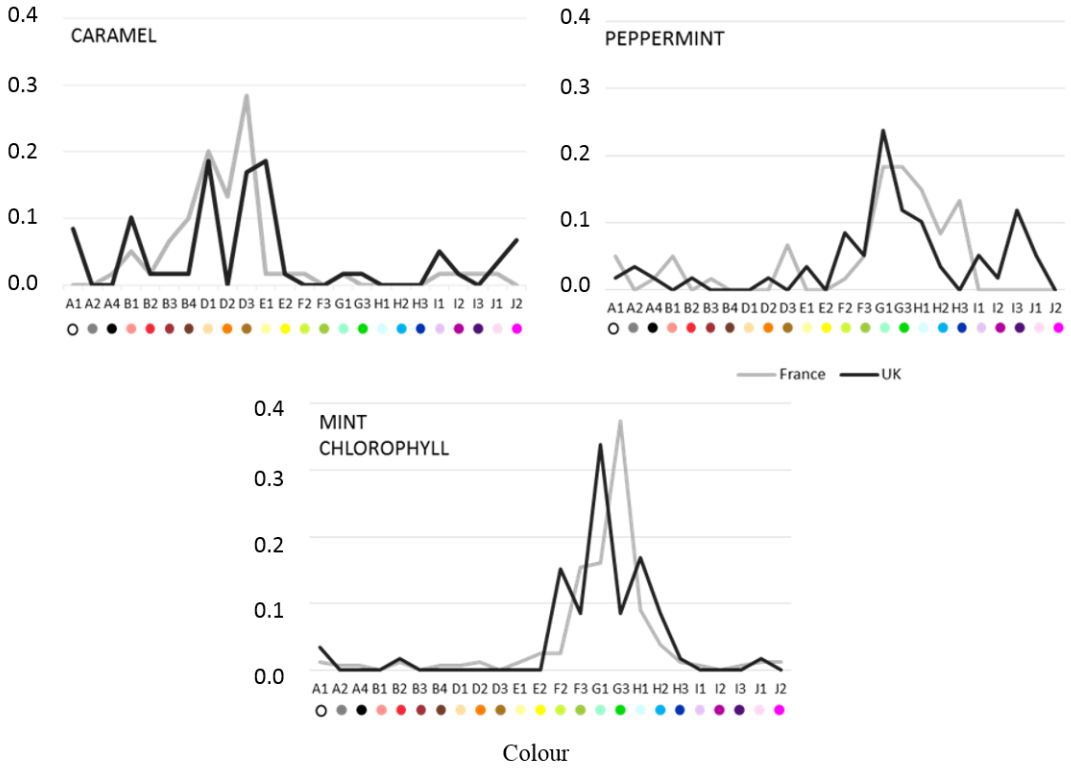


Figure 5.1: Caramel, mint chlorophyll and peppermint odorants: Frequency of colour choice as a function of populations in Experiment 8. Note: A1 to A4: achromatic hues; B1 to B4: red hues; D1 to D3: orange hues; E1 to E2: yellow hues; F2 to G3: green hues; H1 to H3: blue hues; I1 to I3: purple hues; J1 to J2: pink hues.

For the mint chlorophyll odorant, a difference was found between the two populations in terms of the main associated colour: blue-green (33.9% of choices) for the British *vs*. green (40.0% of choices) for the French participants. For the peppermint odour, no differences were found in terms of the main colour that was associated, but rather in the secondarily associated colours. Indeed, peppermint was mainly associated with blue-green (23.7% of choices in UK – 18.3% in France) in both countries. These crossmodal associations of mint to shades of blue-green in the UK are consistent with those reported previously by Demattè et al. (2006) for spearmint (see Table 5.1). The fact that the British participants mainly associated blue-green whatever the kind of mint tested (note that mint

chlorophyll is less aromatic/fresh than peppermint and spearmint, which contains menthol) could perhaps be explained by people's prior exposure to specific combinations of stimuli. The results of a complementary study on the olfactory evocation and pleasantness of colour patches, carried out in France, Lebanon, and the UK indicated that the blue-green colour was semantically associated with mint in UK for 26.7% of participants *vs*. 11.1% of the French participants, whereas the green colour was primarily associated with plant odours in both countries (grass: 43.3% in UK - 55.5% in France). With regard to the peppermint odour's less strongly associated colours, quite surprisingly, 11.8% of the British participants chose dark purple whereas none of the French participants chose this colour.

Finally, the caramel odour was mainly associated with light brown and pale orange colours in both countries (see Figure 5.1). Differences also occurred in the secondarily associated shades: pale yellow in UK, *vs*. orange in France. These results might suggest that learnt associations play a role in driving odour-colour correspondences and, perhaps, that people associate more than one colour to each smell. This, in turn, may suggest that, using more than one colour in tasks like that used in Experiment 8 could provide a better match to smells. Whilst different types of crossmodal correspondences (see Chapter 1) have been suggested to explain the way in which people associate information across the senses (see Parise & Spence, 2012; Spence, 2011), it is possible to think that those that differ as a function of culture may be related to differences in the statistical regularities of the specific contexts in which a culture develops.

Pearson correlation coefficients were used to assess the common relationships between the mean ratings of the odours for each of the evaluated descriptors (familiarity, pleasantness, intensity, and edibility) and the mean lightness, saturation, and hue of the

matching colours that were chosen. In both countries, significant positive relationships ($p < .05$) were found between pleasantness and lightness, and also between pleasantness and saturation. The odours that were rated as more pleasant were generally matched to colours exhibiting a higher lightness and saturation. These results also indicated that colour saturation is positively correlated to perceived odour edibility, and that colour hue varies inversely with perceived odour edibility ($p < .05$ in both cases). The more an odour was judged as edible, the more the hue tended toward yellow and toward more saturated colours. On the other hand, less edible odours were preferentially matched with less saturated colours and with blue hues, which are less often encountered in food and beverage products.

Interestingly, the results of Experiment 8 also confirmed the existence of correlations between perceptual dimensions in olfaction and vision. Specifically, colour lightness varies inversely with perceived odour intensity in both populations ($p < .05$), as demonstrated previously by Kemp and Gilbert (1997).

The results of the present experiment not only demonstrate a categorical-based matching, in which people associate the smell of cucumber with green, or the smell of lemon with yellow. They also show that, over-and-above those matchings that may refer to the same object (e.g., a lemon), there is an association between colour lightness and saturation on the one hand and odour pleasantness on the other, and a negative relationship between colour lightness and odour intensity. It appears as if the crossmodal matching between odour and colour builds both from semantic knowledge about the object, but also more abstract associations between specific features. In other words, they build from features that, for example, can be found across objects, such as their saturation, pleasantness, intensity, or brightness.

After extending previous research on colour/odour associations, and showing that similar correspondences can be found in the UK and France, Experiment 9 presents a study that was designed to assess colour-flavour label (on crisps packaging) associations in three different cultures. If the statistical regularities of the environment shape the way in which people match information across the senses, one may expect that those associations that can be found consistently in different environments, may also show up across cultures.

5.3 Experiment 9: The effect of context on colour-flavour associations in crisps packaging: A cross-cultural study comparing Chinese, Colombian, and British participants

5.3.1 Methods and materials

5.3.1.1 Participants

One hundred and seventy four participants took part in Experiment 9, 50 from each country: Colombia (32 female, mean age = 21.0 years, SD = 2.9, ranging from 18 to 31 years); China (28 female, mean age = 24.4 years, SD = 5.9, ranging from 18 to 50 years); UK (34 female, mean age = 34.7 years, SD = 11.9, ranging from 19 to 59 years). The participants were part of the databases of the three universities; in Colombia (Universidad de la Sabana, Bogotá, Colombia), China (Tsinghua University, Beijing, China), and the UK (University of Oxford, Oxford, UK).

5.3.1.2 Apparatus and materials

The images of eleven packages of potato chips were modified from existing packages for the purposes of the study. Each example of packaging (340 x 700 pixels) was presented in black and white and included a fake logo and brand (Crispies), as well as the name of the flavour (see Figure 5.2 for an example of the packaging used in each country), and was presented against a white background. Each example of packaging displayed on the screen had a different flavour descriptor written across the front of the packaging. The flavours that were assessed in Experiment 9 were: BBQ, cheddar cheese and bacon (from now on, cheese and bacon), cheese and onion, chicken, cucumber, lemon, meat, natural, original, salt and vinegar, and tomato. These flavours were chosen because they are used by different brands in at least one of the three countries where the study was conducted.



Figure 5.2. Examples of the tomato-labelled product packaging used in Experiment 9 (A. Spanish; B. Chinese; and C. English).

In addition, seven colours were used throughout the experiment including the predefined web-safe colours: yellow (FFFF00), blue (0000FF), orange (FFA500), fuchsia (FF0080), red (FF0000), green (00FF00), and burgundy (8C001A). The colours were chosen because of their correspondence with the selected flavours in at least one of the countries

under study. That is, the colours matched at least one of the flavours included in Experiment 9. The experiment was conducted on the internet through the Adobe Flash based Xperiment software (http://www.xperiment.mobi).

5.3.1.3 Apparatus and materials

A 3 (Colombia, China, and UK) x 11 (BBQ, cheese and bacon, cheese and onion, chicken, cucumber, lemon, meat, natural, original, salt and vinegar, and tomato) x 7 (yellow, blue, orange, fuchsia, red, green, and burgundy) experimental design was used. After having completed this, the participants reported their gender, age, country of residence, time living in the country of residence, and whether they had good colour vision or not.

The task was divided into two randomly presented parts. The first part (packaging selection) included 7 randomized trials in which the participants were presented with colours and had to select the flavour-named black-and-white package providing the best match (see Figure 5.3A). Participants from China and the UK were presented with all the flavour-named packages except “natural” and “original”, which were only presented to the participants from Colombia. The second part of the study (colour selection) included 11 randomized trials. In each trial, one of thepackages (the same as in the first task plus “tomato” flavour) was presented and the participants could respond by clicking on one of the several colours used. That is, the participants had to select the colour that best matched the flavour-named black and white package (see Figure 5.3B). The colour was presented in a rectangular box in which the name was also written. The experiment comprised two tasks designed to investigate whether any difference would emerge from having the participants match flavours to colours or colours to flavours. In other words, the aim was

to assess whether participants' associations would be consistent across the two tasks. Slightly different flavours words (i.e., original, natural, tomato) were used in each country across the tasks. It should, however, be noted that this was not methodologically or theoretically driven difference but instead resulted from the involvement of various researchers from several countries and thus a subtle variation in the study design.



Figure 5.3. Sample trial of the packaging selection task (in panel A) and the colour selection task (Panel B) of Experiment 9. In the packaging selection task, participants were asked to match one of

the examples of crisps packaging to the colour, and in the colour selection task they were asked to select one of the colours to the flavour-labelled crisps packaging.

In both parts of the study (i.e., packaging selection and colour selection), the presentation of the possible responses was randomized. Once the participant had clicked on any one of the packaging exemplars, the next trial started. At the end of the experiment, the participants were asked to report how often they usually ate crisps, and their favourite brand. In addition, the participants were also presented with further information about the study.

5.3.2 Results and discussion

Information concerning the frequency with which the participants consumed crisps is presented in Table 5.2. Colombian participants reported their favourite brands as follows: Margarita (58.62%), Super Rica (17.24%), Pringles (8.62%), Frito-Lay (5.17%), and other brands (10.34%). The Chinese participants' favourite brands were as follows: Lay's (60.34%), Copico (12.06%), and other brands (18.96%). A small percentage of Chinese participants reported that they did not consume crisps (8.62%). The British participants' favourite brands were more diverse: Walkers (22.41%), Kettle (18.96%), McCoys (10.34%), Tyrrells (6.89%), Doritos (6.89%), and other brands (24.13%). A small percentage of the British participants did not have a favourite brand (10.34%). Here, other brands refer to the sum of those brands that were mentioned by two or less people.

Table 5.2. How often do you eat potato chips (crisps)? Answers for Experiment 9.

How often do you eat potato chips?	Colombia	China	UK
Daily	6	0	4
Weekly	28	6	13
Maybe once per month	19	29	33
Maybe once per year	5	19	6
Never	0	3	2
Did not respond	0	1	0

The Colombian and Chinese participants tended to report Margarita and Lay's as their favourite brands, respectively, while for participants from the UK, there was no such clear trend. In addition, note that in the UK, more brands were reported by the participants but some were mentioned by just 1 or 2 individuals.

Packaging selection. The responses to each packaging in the task in which the participants had to match one of the packages to the presented colours were analysed using the chi-squared test for one variable. Figures 5.4A-C present an association plot for each country (Cohen, 1980; Friendly, 1991).

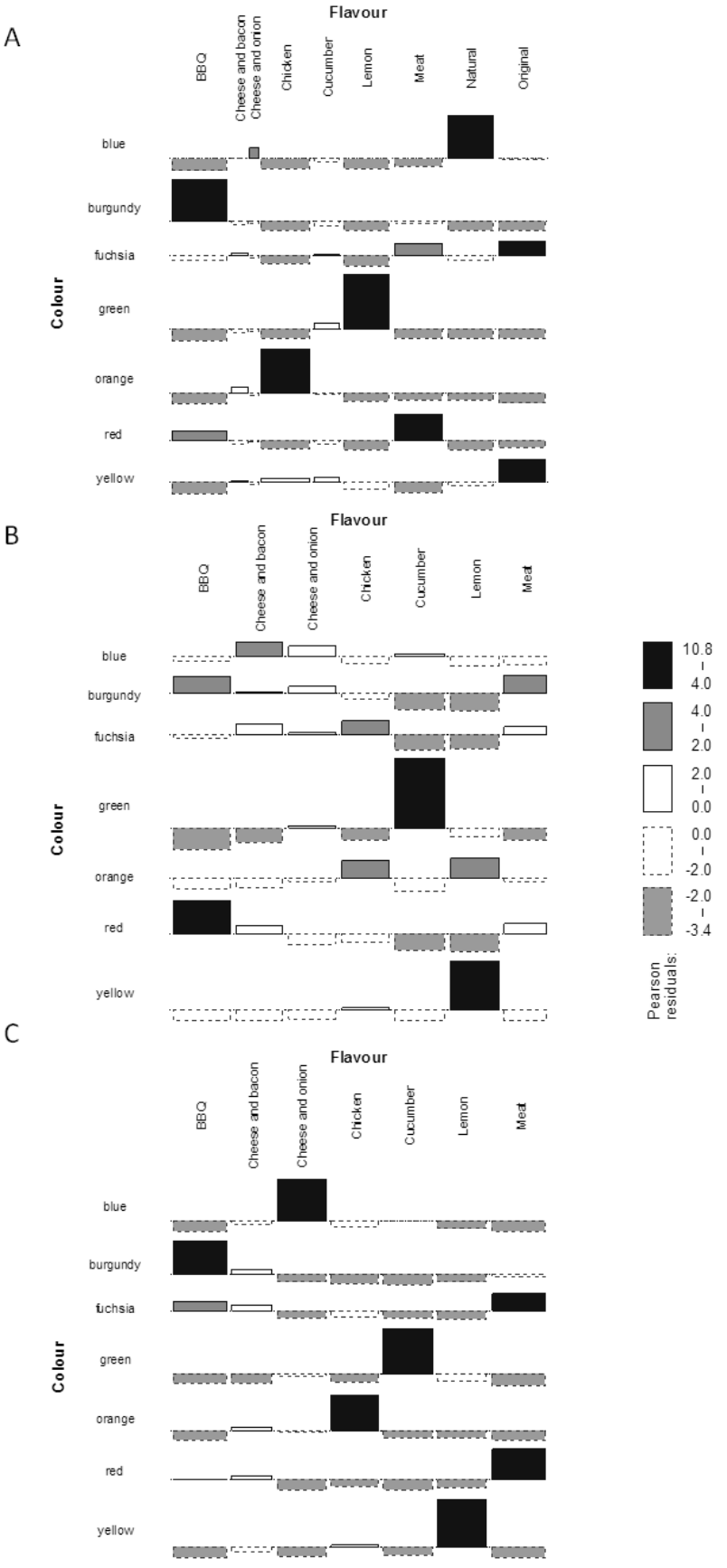

A
Flavour
BBQ
Cheese and bacon
Cheese and onion
Chicken
Cucumber
Lemon
Meat
Natural
Original
Colour
blue
burgundy
fuchsia
green
orange
red
yellow
B
Flavour
BBQ
Cheese and bacon
Cheese and onion
Chicken
Cucumber
Lemon
Meat
Colour
blue
burgundy
fuchsia
green
orange
red
yellow
10.8 – 4.0
4.0 – 2.0
2.0 – 0.0
0.0 – -2.0
-2.0 – -3.4
Pearson residuals:
C
Flavour
BBQ
Cheese and bacon
Cheese and onion
Chicken
Cucumber
Lemon
Meat
Colour
blue
burgundy
fuchsia
green
orange
red
yellow

Figure 5.4. Association plot (Cohen, 1980; Friendly, 1991; Zeileis, Meyer, & Hornik, 2007) between crisps packages and colours in the packaging selection task of Experiment 9. The area covered by each box corresponds to observed – expected values from the contingency table. The legend represents the Pearson's' residuals.

Table 5.3 presents a summary of the chi-square values and the most frequently selected packages for a given country. Overall, it is possible to see that in some cases different associations can be found as a function of the participant's country, while, in others, certain similarities can be found. For example, most of the Colombian participants associated "natural" with the colour blue, while the Brits tended to associate that colour with the flavour of "cheese and onion". What is more, most participants matched "chicken" to orange in both Colombia and the UK. More than half of both the Colombian (52.2%) and British (62.1%) participants associated "meat" with red and "BBQ" labelled crisps with the colour burgundy, while half of Chinese participants (50%) matched "BBQ" to red and about one third (34.5%) associated "BBQ" to burgundy. More than half of both Chinese (51.7%) and British (77.6%) participants matched "lemon" to the yellow colour patch, whereas almost all of the Colombians (91.4%) associated "lemon" with green. Finally, most of the Chinese (70.7%) and British (75.9%) participants paired "cucumber" with the green colour.

Table 5.3. Chi-square test for one variable (packaging selection) and most selected packaging after each colour presentation in Experiment 9. The flavours that were selected significantly more as compared to the others for each colour are highlighted in bold.

Country	Colour	Flavours	χ^2	p
	Blue	**Natural (75.9%)**	149.93	<.001
	Orange	**Chicken (81%)**	173.31	<.001
	Fuchsia	Original (36.2%)	48.69	<.001
Colombia	Red	**Meat (55.2%), BBQ (36.2%)**	69.07	<.001
	Burgundy	**BBQ (89.7%)**	36.48	<.001
	Yellow	Original (48.3%)	66.07	<.001
	Green	**Lemon (91.4%)**	39.72	<.001
	Blue	Cheese and bacon (24.1%)	13.93	.030
	Orange	Lemon (29.3%)	24.07	.001
	Fuchsia	Chicken (24.1%)	15.62	.016
China	Red	BBQ (50%)	54.55	<.001
	Burgundy	BBQ (34.5%)	22.69	<.001
	Yellow	**Lemon (51.7%)**	70.17	<.001
	Green	**Cucumber (70.7%)**	126.55	<.001
	Blue	**Cheese and onion (72.4%)**	101.48	<.001
	Orange	**Chicken (60.3%)**	105.41	<.001
	Fuchsia	**Meat (41.4%), BBQ (29.3%)**	58.35	<.001
UK	Red	**Meat (62.1%)**	68.55	<.001
	Burgundy	**BBQ (65.5%)**	78.38	<.001
	Yellow	**Lemon (77.6%)**	87.79	<.001
	Green	**Cucumber (75.9%)**	114.57	<.001

Colour selection. The chi-squared test for one variable was also used in the task in which the participants had to select a colour for each labelled packaging in order to analyse the responses to each colour. The results are shown in Figures 5.5A-C, which present an association plot for each country.

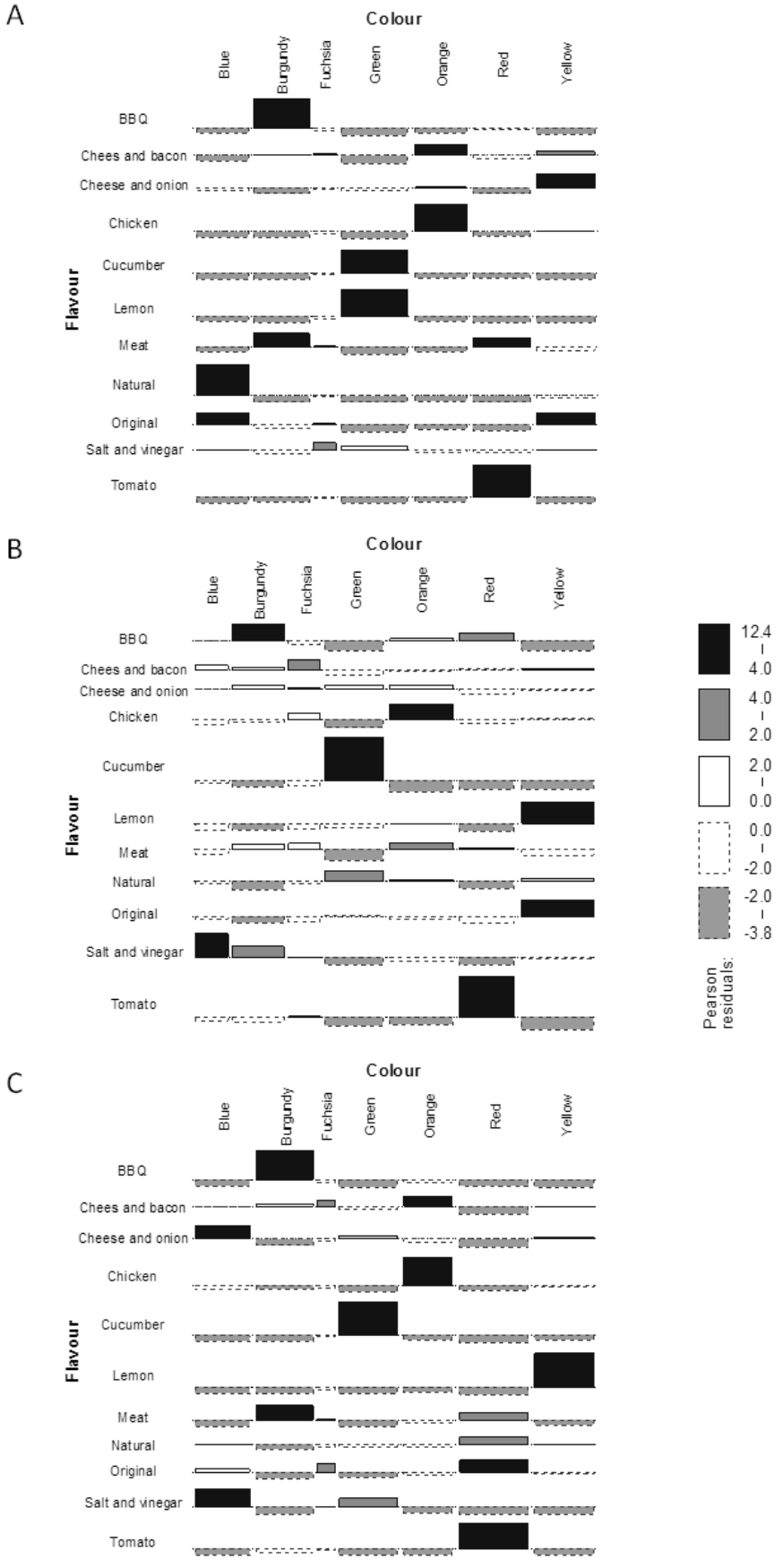

A
Colour
Blue
Burgundy
Fuchsia
Green
Orange
Red
Yellow
Flavour
BBQ
Chees and bacon
Cheese and onion
Chicken
Cucumber
Lemon
Meat
Natural
Original
Salt and vinegar
Tomato
B
Colour
Flavour
12.4 – 4.0
4.0 – 2.0
2.0 – 0.0
0.0 – -2.0
-2.0 – -3.8
Pearson residuals:
C
Colour
Flavour

Figure 5.5. Association plot between colours and crisps' flavours in the colour selection task in Experiment 9. The area of each box corresponds to observed – expected values from the contingency table.

Table 5.4 presents a summary of the chi-square values and the pairwise comparisons. It can be seen that most of the Colombian (86.2%) and British (87.9%) participants matched the burgundy colour with the "BBQ" flavour. Almost all of the participants in all three countries matched red to "tomato", and green to "cucumber". All of the participants from Colombia associated green with "lemon", whereas all of the British participants and 65.5% of the Chinese participants associated it with yellow. Over two thirds of both the Colombian (77.6%) and British (69%) participants, and half of those from China (44.8%), associated the "chicken" flavour with orange. The colour green was associated with the "cucumber" labelled crisps by most of the participants across all three countries.

Table 5.4. Chi-square test for one variable (colour selection) and most selected colours after each packaging presentation in Experiment 9. The most frequently selected colours are presented and those that after the post-hoc comparisons, Bonferroni corrected with p = .05 before comparison, were selected significantly more as compared to the other flavours are highlighted in bold.

Country	Flavour	Colours	χ^2	p
Colombia	BBQ	**Burgundy (86.2%)**	30.41	<.001
	Salt and vinegar	Green (34.5%)	22.86	.001
	Natural	**Blue (84.5%)**	152.4	<.001
	Meat	**Burgundy (48.3%). red (39.7%)**	57	<.001
	Tomato	**Red (96.6%)**	104.3	<.001
	Cheddar cheese and bacon	Orange (37.9%)	34.69	<.001
	Lemon	**Green (100.0%)**	-	-
	Chicken	**Orange (77.6%)**	52.38	<.001
	Cheese and onion	**Yellow (53.4%)**	81.28	<.001
	Original	Yellow (46.6%)	74	<.001

	Cucumber	**Green (91.4%)**	184.8	<.001
	BBQ	Burgundy (36.2%)	46.03	<.001
	Salt and vinegar	Burgundy (27.6%)	28.41	<.001
	Natural	Yellow (32.8%)	51.1	<.001
	Meat	Orange (32.8%)	18.97	.001
	Tomato	**Red (75.9%)**	147	<.001
China	Cheddar cheese and bacon	Yellow (27.6%)	11.03	0.09
	Lemon	**Yellow (65.5%)**	80.45	<.001
	Chicken	**Orange (44.8%)**	41.52	<.001
	Cheese and onion	Orange (24.1%)	16.59	0.01
	Original	**Yellow (56.9%)**	73.17	<.001
	Cucumber	**Green (82.8%)**	143.6	<.001
	BBQ	**Burgundy (87.9%)**	77.83	<.001
	Salt and vinegar	Blue (56.9%)	50.83	<.001
	Natural	Red (46.6%)	42.55	<.001
	Meat	**Burgundy (50.0%). red (41.4%)**	65.1	<.001
	Tomato	**Red (93.1%)**	43.1	<.001
UK	Cheddar cheese and bacon	Orange (31.0%)	14.62	0.01
	Lemon	**Yellow (100.0%)**	-	-
	Chicken	**Orange (69.0%)**	88.38	<.001
	Cheese and onion	Blue (46.6%)	20.07	<.001
	Original	**Red (55.2%)**	69.03	<.001
	Cucumber	**Green (96.6%)**	104.3	<.001

A key difference between experiments 8 and 9 is that the flavour labels used in Experiment 9 not only included natural categories such as lemon or tomato (which refer to specific objects), but also more abstract categories such as “salt and vinegar” or “natural”. Importantly, those smells or words that referred to specific objects, such as lemon and cucumber, were systematically matched to yellow and green in Experiments 8 and 9 (except for lemon in Colombia, where lemon is the name given to limes, Piqueras-Fiszman et al., 2012). One possible explanation here is that the level of concreteness of the information (a smell or a flavour concept) could influence the associations by

activating categorical knowledge or relying on abstract information (e.g., Schoormans & Robben, 1997). The presence of such concrete objects across countries may explain the existence of certain odour/colour or odour/flavour correspondences. In order words, if the object that people refer to as "lemon" is yellow in China and the UK, it is likely that such a correspondence will be shared. If a composed category ("salt and vinegar") or a more abstract category ("natural") are presented in the matching task it may not evoke specific colour associations unless there is a high exposure (e.g., in the market place) to the object and associated colour.

In Experiments 8 and 9 the role of culture was assessed in both odour-colour and flavour label-colour associations. It is important to mention that a number of other contextual variables such as the type of packaging, receptacle, and even cutlery in which flavours are presented or eaten have been pointed to as potential factors influencing the way in which people associate information across the senses (e.g., Spence, Harrar, & Piqueras-Fiszman, 2012). For example, whereas red may be associated with tomato in crisps products, it may not necessarily be associated with the same flavour in the context of yogurt products. With that in mind, in Experiment 10 the hypothesis was that both culture and receptacle type would influence colour/flavour associations.

5.4 Experiment 10: Does the shape of the glass influence the crossmodal association between colour and flavour?

5.4.1 Methods and materials

5.4.1.1 Participants

One hundred participants (50 women, mean age = 27.3 years, SD = 1.8, ranging from 20 to 32 years) from mainland China took part in this study via the website www.unipark. One hundred participants (44 women, mean age = 32.9 years, SD = 11.2, ranging from 19 to 61 years) from the USA took part in this study via the website www.opensourcesci.com.

5.4.1.2 Apparatus and materials

Photos of coloured drinks (180 pixels wide x 240 pixels high) were shown to the participants. The water was coloured with different commercial food colourings to achieve six colours: red, green, yellow, blue, brown, and orange. Clear water was also presented as the seventh condition. As shown in Figure 5.6, the drinks were presented in four different containers, including a water glass, a wine glass, a cocktail glass, and a plastic cup.



Figure 5.6. The drinks in 7 different colours and 4 different types of cups used in Experiment 10.

5.4.1.3 Procedure

A 2 (Culture: USA vs. China) x 4 (Receptacle Type: water glass, wine glass, cocktail glass, or plastic cup) design was used, with Culture as a between-groups factor and Receptacle Type as a within-group factor. Each participant completed a total of 28 trials (7 colours x 4 types of glass) which were presented in a random order. Before starting the experiment, the participants were informed about the general aim of the study, and only those who accepted to take part in it began with some demographic questions, followed by the first trial. During each trial, the participants were shown one picture and asked to perform the task. They had to choose the first flavour or drink that came to their mind

based on its colour from a list of 24 pre-selected flavours, including apple, banana, blackcurrant, blueberry, cherry, cola, cranberry, grape, kiwi, lemon, lime, lychee, mandarin, melon, mint, orange, peach, pear, pineapple, raspberry, strawberry, watermelon, flavourless, and other. The list was constructed by combining those flavour options from the papers of Shankar et al. (2010a), Zampini et al. (2007), the wine aroma wheel (winearomawheel.com), and several flavours that are commonly found in the Chinese marketplace. The options were presented in a random order in each trial in order to avoid any order or position effects. The participants were instructed to specify which flavour they had in mind if they chose the option "other".

5.4.2 Results and discussion

The colour-flavour responses for each group are highlighted in Table 5.5. One-sample Kolmogorov-Smirnov tests revealed that the pattern of flavours associated with each coloured drink in each type of glass was significantly different from a uniform distribution in both groups of participants, all *p*s < .001, suggesting the existence of robust colour-flavour crossmodal associations in each group. Fisher's Exact Tests with p values estimated with 100,000 Monte Carlo simulations and Bonferroni's corrections for multiple testing revealed that the two groups had different colour-flavour associations for (1) red or blue drinks in all type of cups, (2) green drinks in the water and wine glasses, and (3) yellow, orange, or brown drinks in the plastic cup, all *p*s < .01. In contrast, there was no cross-cultural difference in the flavour associations for (1) the green drink when presented in a cocktail glass or plastic cup; (2) the yellow, orange, or brown drinks in the

water, wine, or cocktail glass, or (3) the clear water sample in any of the cups, all *p*s > .01.

Table 5.5. Top 3 flavour responses for each coloured drink in each type of cup in the participants from the USA and China in Experiment 10 (with exact count in brackets).

Colour	Cup	Participants from the USA (N = 100)	Participants from China (N = 100)	Difference
Red	Water	Cherry (27), Cranberry (25), Strawberry (19)	Strawberry (27), Watermelon (25), Cherry (12)	**
	Wine	Strawberry (28), Cherry (25), Cranberry (16)	Watermelon (24), Cherry (20), Strawberry (18)	**
	Cocktail	Cherry (31), Strawberry (25), Cranberry (17)	Watermelon (27), Cherry (18), Strawberry (17)	**
	Plastic	Cherry (31), Strawberry (25), Watermelon (14)	Watermelon (35), Strawberry (20), Cherry (19)	**
Green	Water	Kiwi (34), Lime (27), Apple (13)	Kiwi (54), Apple (14), Lime (12)	**
	Wine	Kiwi (31), Lime (30), Melon (12)	Kiwi (40), Apple (20), Lime (16)	**
	Cocktail	Lime (32), Kiwi (27), Apple (19)	Kiwi (33), Lime (23), Apple (17)	
	Plastic	Kiwi (40), Lime (23), Apple (13)	Kiwi (58), Lime (16), Apple (7)	
Yellow	Water	Lemon (32), Lime (24), Pineapple (14)	Lemon (26), Lime (14), Pineapple (13)	
	Wine	Lemon (49), Lime (15), Pineapple (13)	Lemon (36), Pineapple (14), Lime (10)	
	Cocktail	Lemon (45), Pineapple (22), Banana (9)	Lemon (25), Pineapple (19), Pear (10)	
	Plastic	Lemon (49), Pineapple (18), Banana (13)	Lemon (28), Pineapple (26), Pear (11)	**
Blue	Water	Blueberry (63), Raspberry (16), Mint (8), Other (8)	Blueberry (43), Mint (30), Other (12)	**
	Wine	Blueberry (61), Raspberry (14), Mint (9)	Blueberry (35), Mint (31), Other (12)	**
	Cocktail	Blueberry (59), Raspberry (18), Mint (8), Other (8)	Blueberry (32), Mint (30), Other (12)	**
	Plastic	Blueberry (61), Raspberry (18), Other (9)	Blueberry (38), Mint (27), Other (12)	**
Orange	Water	Orange (43), Peach (18), Mandarin (17)	Orange (24), Mandarin (21), Peach (11)	
	Wine	Orange (46), Peach (21), Mandarin (17)	Orange (38), Mandarin (34), Peach (7)	
	Cocktail	Orange (44), Peach (23), Mandarin (23)	Orange (32), Mandarin (31), Melon (10)	
	Plastic	Orange (48), Peach (15), Mandarin (14)	Orange (38), Mandarin (21), Watermelon (13)	**
Brown	Water	Cola (66), Blackcurrant (12), Grape (9)	Cola (46), Blackcurrant (16), Other (14)	
	Wine	Cola (68), Grape (13), Blackcurrant (10)	Cola (43), Blackcurrant (21), Other (10)	

	Cocktail	Cola (63), Blackcurrant (23), Cranberry (4)	Cola (48), Blackcurrant (20), Other (10)	
	Plastic	Cola (71), Grape (14), Blackcurrant (6)	Cola (32), Blackcurrant (27), Other (13)	**
Clear	Water	Flavourless (91)	Flavourless (81), Other (6)	
	Wine	Flavourless (88)	Flavourless (73), Other (10)	
	Cocktail	Flavourless (86)	Flavourless (73), Other (12)	
	Plastic	Flavourless (89)	Flavourless (71), Lychee (8), Other (8)	

Note: Flavour counts of less than 5 are not shown in this table, while responses that tied for third place are both shown (where ** $p < .01$).

Taken together, then, the findings of Experiment 10 demonstrate that the type of glass, as a contextual factor, can interact with a participant's cultural background when it comes to influencing the flavour expectations they hold for green, yellow, orange, and brown drinks. The cross-cultural difference in colour-flavour associations is presumably based on different expectations generated from the repeated co-occurrence of certain pairings of colour and flavour in everyday life, exposure to different commercial products, and the difference in agriculture in different countries (Shankar et al., 2010a, 2010b; Spence, 2012). The influence of the shape of the glass on such cross-cultural differences makes one think that participants' expectations might be strengthened, weakened, or otherwise altered by contextual factors, such as the shape of the container. This point demonstrate that the receptacle (or packaging) in which a drink or a food is presented, can create a context for the specific associations between colours and flavours.

5.5. General discussion and conclusions

5.5.1 Colour-odour correspondences

The results of Experiment 8 confirm the existence of common odour-colour associations in both French and British participants. Such a pattern of results is certainly consistent with the idea that there may be a core representation of odours, which might be common across European cultures. Indeed, the perception of odours appears to be categorized according to their function (Chrea et al., 2005), which could vary from country to country, depending on their practices. In those countries where a number of variables such as geographical proximity, experiences with similar environments, cuisine, and commercial products, are shared, only a small difference may be expected in terms of odour-colour correspondences. With these ideas in mind, it is possible to think that, at least in part, odour-colour associations reflect those statistical regularities, and thus, that learnt associations may partly underlie odour-colour associations. Note that an affective mediation here cannot be ruled out. It may be the case that there are common odour/colour "likes" and "dislikes" across the countries, which in turn may explain the way in which people match odours and colours (e.g., Bremner et al., 2013; Schifferstein & Tanudjaja, 2004). Indeed, it may be the case that the way in which people match information across the senses is not only based on a common identity (or semantic congruence, as Spence, 2011) but also based on more abstract features of sensory information, as is suggested by the correlations reported in Experiment 8. Note that, as in Experiments 4-5, the results of Experiment 8 suggest that odour hedonics and intensity are related to colour lightness and saturation.

5.5.2 Colour-flavour label correspondences

Experiment 9 assessed any cross-cultural differences in colour-flavour associations in the packaging of crisps (referred to as potato chips in some countries). It is worth noting that the only two colour-flavour interactions that proved to be consistent across all three countries were those for the cucumber and tomato flavours, which were associated with green and red, respectively. Notably, Colombian and UK participants shared more associations between colours and flavours than did the participants from mainland China: Specifically, the BBQ flavour was associated with burgundy, and the chicken labelled crisps were associated with the orange colour. Thus, the results of Experiment 9 are consistent with previous research in suggesting that colour-flavour associations can vary by country/culture (e.g., Aslam, 2006; Piqueras-Fiszman et al., 2012).

Although the participants responded in a similar way to both of the tasks, the Colombian contingent performed differently in the two tasks when it came to the yellow colour. 48.3% of the participants selected "original" for yellow in the packaging selection task, whereas 53.4% selected yellow for the "cheese and onion" variety in the colour selection task (though 46.6% selected it for original in the later task). Since the "cheese and onion" flavour is not common in the Colombian marketplace, one explanation is that the participants ignored this unusual flavour in the packaging selection task (they could just select other better known flavours to represent a given colour), but were forced to make a colour choice in the colour selection task.

It is likely that colour-flavour associations are statistically mediated, at least in the context of the packaging of crisps. In fact, to some extent, participants' responses are consistent with the colour schemes that have been adopted by some of the major brands of crisps

(though significant associations were not found in every country) in each of the cultures included in Experiment 9. However, although certain associations may be learnt by brand, others may rather be learnt by more general co-occurrence of foods and colours. This becomes potentially interesting since both brand-driven and any other associations may interact in determining the consumer's perception of a given product.

It is also pertinent here to look at those associations that the participants came up with for crisp flavours that did not exist (to the best of my knowledge) in their respective culture/country. For instance, "cucumber" labelled crisps are currently only available in China, while natural (though original could be the equivalent in the UK) and lemon in Colombia, and other flavours such as cheddar cheese and bacon or cheese and onion are more common in the UK. Having the participants respond to the different flavours, independently of whether they were available in their countries or not, provides some evidence that certain flavours elicit colour associations independently of their availability. Importantly, people may use the associations that they have learnt from other contexts (i.e., product categories) when responding to newly presented flavours in a given product category. That said, some of the colour-flavour associations were consistent across the cultures tested in Experiment 9, namely, those for tomato and cucumber. It would therefore seem as though certain associations are based on the distinctive colours of the foods putatively giving rise to the named flavours, tomatoes and cucumbers commonly being red and green, respectively, across the world (notwithstanding the existence of green tomatoes in a few places). It is, though, an open question as to how the colour schemes that are used by brands and the colour of the product itself interact in guiding consumers' flavour expectations. Take, for instance, the case of cucumber and tomato: Tomato labelled crisps are presented in fuchsia coloured packaging by a major brand in

the Chinese marketplace while cucumber labelled crisps are currently only available in China. In China, though, tomato is mostly associated with red, and cucumber is associated with green in those countries where this flavour of crisp is not currently available.

Flavour names such as lemon, though, can refer to different foodstuffs across-countries. This, presumably, is the explanation behind why the Colombian participants match lemons with green. Other colour-flavour correspondences may be based on rather arbitrary parameters. This is most likely to be the case for those flavours such as "natural" and "original" that have no naturally-associated colour. It is though worth mentioning that the range of colours used in Experiment 9 was limited and that, potentially, even those flavours that were initially not consistent might have common associations in all countries. In addition, one might also want to know how strongly the participant feels that a given colour matches a certain flavour, since the responses in the present task were limited to just a few colours.

There are a number of caveats that should be taken into account when it comes to the interpretation of the results outlined in Experiment 9. First, colour is complex, composed as it is of several different features (e.g., hue, value, and Chroma); these different features may be expected to exert different effects on people/consumers (see Elliot & Maier, 2014, for a review of colour and psychological functioning in humans). Furthermore, due to the fact that Experiment 9 was conducted online, there was no control over the specific monitors that were used by the participants. Obviously, this may have introduced some unwanted noise in the way in which the various colours were perceived. Note, though, that the influence of any such differences, if present, should have been attenuated by the inclusion of the name of the colour in each colour chart presented in each trial. Moreover, the colours that participants had to choose from were very distant from each other; in

other words, even if the exact colour was not presented it was still a good approximation relative to the other options[8].

5.5.3 Colour-flavour label correspondences and receptacle type

Both the statistics and counts of chosen flavours consistently demonstrated the interaction between the shape of the glass and the cultural background of the participants on the flavour associations elicited by the green, yellow, orange, and brown drinks. The cross-cultural difference for yellow, orange, and brown drinks emerged only when the drinks were presented in a plastic cup. This allowed for a direct comparison (though with a much larger sample size) of these results with those reported by Shankar et al. (2010a). In their study, all of the drinks were presented in a plastic cup. When the yellow drink was presented in a plastic drink in Experiment 10, the two most common flavour choices were lemon and pineapple for both groups of participants, whereas far more of those participants from the USA chose lemon than in the Chinese group. The third most common choice was banana flavour for the participants from the USA but pear flavour for the participants from China. When the orange drink was presented in a plastic cup, the most frequent choice was orange for both groups, but the second and third most common choices were peach and mandarin for the participants from the USA, but

[8] It is also worth highlighting the fact that e-commerce and online testing has grown significantly over the last few years, and the prospects for the future look increasingly optimistic (Dennis et al., 2010; Sands et al., 2010). This has led to a growing number of companies using the Internet as a marketing tool in order to present, promote, sell their products and services, and even to interact with their consumers (Peterson, Balasumbramanian, & Bronnenberg, 1997; Sharma & Sheth, 2004). Online research can help researchers and marketing practitioners understand how colour, in the different digital interfaces, is currently being used to convey information about the likely attributes of a product, such as that in crisps packaging.

mandarin and watermelon for those participants from China. As for the brown drink presented in a plastic cup, the most frequent choice was cola for both groups, but the second most frequent choice was grape flavour for the participants from the USA but blackcurrant for the participants from China. Note that in Shankar et al.'s (2010a) study, the most common choices for yellow, orange, and brown drinks for the participants from the UK were the flavours of lemon, orange, and cola, respectively. By contrast, for Taiwanese participants, yellow soda, cranberry, and grape, were chosen, respectively. Therefore, these results confirmed the cross-cultural difference in the associations between flavour and colour yellow, orange, and brown, and highlight the possibility that such cross-cultural differences are more likely to occur when the drinks happen to be presented in a plastic cup.

As for green drink presented in a water or wine glass, the most common flavour choice was kiwi for both groups of participants, but the second most common choice was lime for the participants from the USA, and apple for the Chinese participants. These results therefore provide important new information relative to that collected by Shankar et al. (2010a). In their paper, the participants from both the UK and Taiwan consistently chose the flavour of mint for green drink when it was presented in the context of a plastic cup. Yet, it should be noted that the participants (no matter whether they were from the USA or from China) most often chose the flavour of kiwi even for the green drink when seen in a plastic cup, thus suggesting a cross-cultural difference here.

CHAPTER 6

Exploring colour-flavour (label) congruence and visual search

6.1 Introduction

Although a number of studies have assessed the role of colour-flavour congruence (and incongruence) in flavour perception (e.g., Spence et al., 2010), far less research has assessed the role of colour-flavour label congruence on classification of, and visual search for, food products (e.g., Garber et al., 2000). As a consequence, the aim of the experiments reported in this chapter was to assess any effect of colour/flavour (names) congruence on (product) flavour classification and search.

The literature on the Stroop effect suggests that when a colour name does not match the colour in which the text is presented, people take longer and make more errors when trying to name the colour of the word. A reverse Stroop effect, in which naming the colour word when its colour does not match the word, people are slower and make more errors has also been demonstrated (see Durgin, 2000; MacLeod, 1991). This effect has even been observed in the context of food names and colour (e.g., Nijboer et al., 2006), thus suggesting that associations between colours and objects can influence information processing in humans. The strength of the association between a particular concept (e.g., a flavour word) with a colour, may be important in the way in which either interference or facilitation occurs (e.g., Berthet et al., 2011).

Most food products come in coloured packages (or coloured symbols), together with flavour names. Therefore, understanding the associations that exist between colours and flavour names, and their influence on visual search for flavour information, can provide important information concerning the way in which people relate specific flavour concepts and colours, as well as insights for the marketplace within and between countries. In the context of product packaging and, in particular, in the context of the packaging of crisps (potato chips), the name of the flavour written on the pack can be important when it comes to deciding which product to buy, since colour schemes can vary as a function of brand and product category (e.g., Madden et al., 2000; Piqueras-Fiszman et al., 2012). With that in mind, it is possible to expect that when the flavour name on the packaging of a packet of crisps happens to be congruent with the colour of that packaging (i.e., tomato and red), people would find it more rapidly than when the colour is incongruent (i.e., tomato in blue blue).

In this chapter, I build on the results reported in Chapter 5. In particular, the flavour names were demonstrated to be consistently matched to particular colours in mainland China, namely tomato, cucumber, lemon, chicken, and BBQ, were used to create both congruent and incongruent stimulus combinations. These flavours were selected because they presented the most robust colour associations across countries but some variation from one country to another was observed for the case of lemon, chicken, and BBQ. Moreover, these flavours were used in a go/no go task and a visual search task in order to assess the role of colour/flavour (name) congruency (Experiments 11 and 12). While it may be reasonable to expect a Stroop effect in pairings such as tomato and red, it is less clear whether this would also be the case for previously found associations such as between chicken flavour and the colour orange, or between BBQ flavour and a burgundy colour.

With that in mind, it is not clear how these associations would influence search efficiency. That said, Experiment 13 was conducted and included a set-size manipulation in order to assess the influence of congruence and association strength (weaker vs. stronger) on search efficiency. Here, flavours with a strong colour identity are defined as those which were associated consistently by Chinese participants and similarly to a specific colour across countries in Experiment 9.

6.2 Experiment 11: Colour/flavour (names) congruence in go/no go and visual search tasks

6.2.1 Methods and materials

6.2.1.1 Participants

Thirty-two participants (17 female) aged 18-25 years (M = 20.25 years, SD = 1.88) from mainland China took part in this experiment. In the present and following experiments, all of the participants were Chinese who reported normal or corrected-to-normal vision and had no colour blindness by self-report. They were all recruited from the subject pool of the Applied Cognitive Psychology Laboratory of the Psychology Department at Tsinghua University, Beijing, China. Each participant only took part in one of the experiments, and were either paid (20/30/25 Chinese Yuan in Experiments 11, 12, and 13, respectively, according to the duration of different experiments), or else given partial credit to fulfil the requirements of an introductory psychology course in return for taking part in the experiments.

6.2.1.2 Apparatus and materials

E-Prime 2.0 software (Psychology Software Tools, Inc.) was used to present the stimuli and to collect the data. The participants were seated in front of a 17 inch monitor (at a distance of approximately 50 cm from the screen). The screen had a resolution of 1024 × 768 pixels, and a screen refresh rate of 60 Hz.

An image of the packaging of a fictitious brand of crisps ("Crispies") was modified using Adobe Photoshop CS4 in order to create a set of congruent and incongruent (colour/flavour) packaging designs, and additional packaging designs for use in the target-absent trials (see Figure 6.1 for an example of the packaging stimuli used in Experiments 11-13). The packages had a mean luminance of M = 103.73 Lumas (SD = ±39), and all of the packages were presented against a full-screen white background.



Figure 6.1. Example of the packaging used in Experiments 11-13. Panel A shows the flavour written on the package corresponding to BBQ in Chinese. Panel B shows the English version.

The colours used were selected from RGB colour codes in Adobe Photoshop CS4 as follows: burgundy 8a1d36 (red (R) = 138, green (G) = 29, blue (B) = 54), green 6fae54 (R = 111, G = 174, B = 84), orange e67f48 (R = 230, G = 127, B = 72), red d44141 (R = 212, G = 65, B = 65), and yellow fdd808 (R = 253, G = 216, B = 8).

The experiment comprised two tasks, a go/no go task and a visual search task. The order in which the two tasks were presented was counterbalanced across participants. The targets in both tasks included congruent and incongruent stimuli. The congruent stimulus combinations included a total of 5 packages: BBQ flavour in burgundy, chicken flavour in orange, cucumber flavour in green, lemon flavour in yellow, and tomato flavour in red (based on the results presented in Chapter 5). The incongruent stimulus combinations included packages with the same flavour labels but now presented in one of the other four (incongruent) colours (i.e., BBQ crisps presented in an orange, green, yellow, or red colour) giving rise to a total of 20 different incongruent packages. The participants were not told about the congruent or incongruent associations prior to taking part in the study. In addition to the targets, a pool of 20 stimuli was created and used for the no-go and target-absent trials in the go/no-go and the visual search tasks, respectively. This pool included four task-irrelevant flavour labels, namely, meat, natural, original, and spice, each of them against the five colours of the targets, namely, burgundy, orange, green, yellow, and tomato.

6.2.1.3 Procedure

Go/no go task. At the beginning of the task, written instructions were provided on the computer screen, followed by the practice trials (6 congruent, 6 incongruent, and 6 catch trials). In each flavour block, the participants were shown a flavour label (e.g., tomato,

chicken, cucumber, BBQ, or lemon, for 1000 ms), followed by a central fixation cross (for 1000 ms), and then the first packaging image (for a maximum of 1500 ms). Each packaging image was designed to fit within an area of 15.2° (height) × 24.5° (width) of visual angle and the written flavour names subtended approximately 1.5° × 4.3° of visual angle.

The participants' task (see Figure 6.2A) consisted of pressing the space bar as quickly as possible when the target was presented (either a congruent or incongruent 'go' trial) and to withhold any response if a package with a flavor label different from that of the target was presented ('no-go' trials). The experiment started with practice trials, including two congruent, two incongruent, and two target-absent trials. In these trials, accuracy feedback was given for 500 ms during the practice trials (the word "correct" following a correct response, "incorrect" following an incorrect response, and "no response was detected" for those trials in which the participants did not make any response). For each incongruent trial, one of the four incongruent packages designed for the targeted flavor was selected at random. No-go trials were also randomly selected from the aforementioned pool of 20 possible target-absent stimuli. After the practice blocks had been finished, the main experiment began. The main experiment comprised two blocks of 6 congruent, 6 incongruent, and 6 target-absent trials for each of the 5 flavor labels (BBQ, chicken, cucumber, lemon, and tomato), giving rise to a total of 90 trials per block and 180 for the whole experiment.

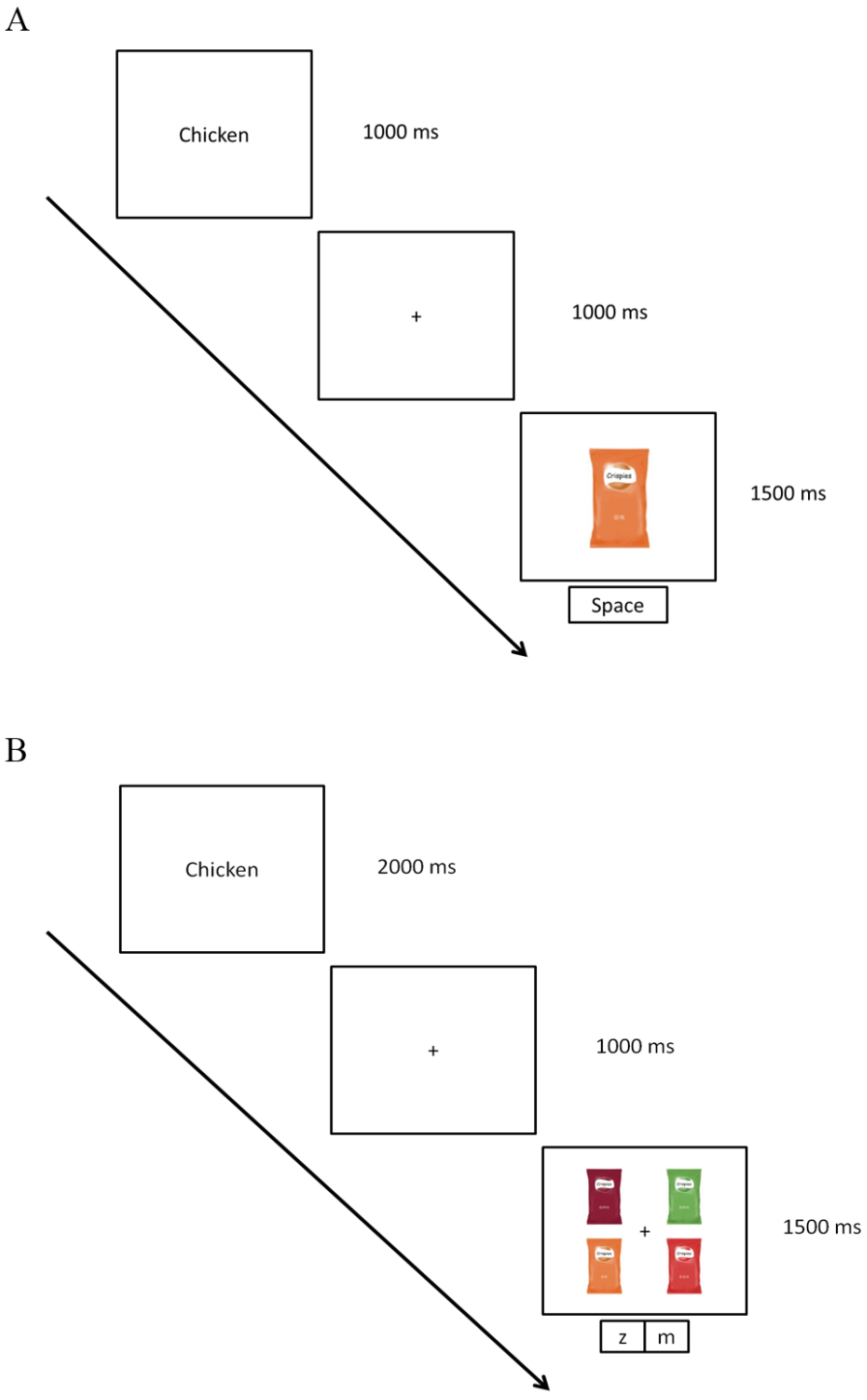


Figure 6.2. Scheme of a congruent trial in the (A) go/no go task and (B) visual search task used in Experiments 11-12.

Visual search task. The participants were presented with written instructions on the computer monitor stating that in every trial, they would first read a target flavour word, followed by a display containing four products, and that their task was to press one key when the target was present and another key when the target was absent. Half of the participants responded by pressing the 'z' key for target-present trials, while the other half responded by pressing the 'm' key instead (and vice versa for target-absent trials; see Figure 6.2B). All of the participants started the experiment with 15 practice trials, including five congruent, five incongruent, and five target-absent trials, all presented in a random order.

Four packaging designs were presented in every trial in a 2 × 2 array. Three were randomly assigned as distractors and the fourth product was the target (congruent or incongruent in terms of color), or else a non-target product (in target-absent trials). Five packages, selected randomly from the pool of distractors, were used as a list from which one was picked randomly on each target-absent trial. The incongruent packages were randomly selected from a list in which the target flavour was presented in incongruently coloured packaging. The position of all of the packages was randomized on every trial. Each packaging image was designed to fit within an area of 8.4° × 12.3° of visual angle, and the written flavour names subtended approximately 0.6° × 0.8° of visual angle. The horizontal and vertical distances between the packages consisted of 7.8° and 5.5° of visual angle, respectively. After the practice trials had been completed, the main experiment started. In the main experiment, 75 congruent, 75 incongruent, and 75 target-absent trials were presented randomly, giving rise to a total of 225 trials.

6.2.2 Results and discussion

Go/no go task. The data from three participants were excluded from the analysis due to poor performance on the task (less than 60% correct)[9]. From the total of 3480 congruent and incongruent trials including the data from all remaining participants, 76 (2.1%) incorrect responses were excluded from the analysis. The incorrect responses comprised 59 (1.7%) incongruent trials, and 17 (0.4%) congruent trials. A paired-sample t-test did not reveal a significant difference between the incongruent and congruent error rates, $t(28) = 1.077$, $p = .29$, Cohen's d = .237. In addition, those RTs that fell two standard deviations above or below the mean were also excluded from the analysis (4.1% of the 3404 remaining, for a total of 3263 trials used in the analyses). Mean RTs were computed for correct, target-present trials across conditions (congruent and incongruent). The difference in RTs between the congruent (M = 417 ms, SE = 10) and incongruent (M = 426 ms, SE = 11) trials was significant according to the results of a paired samples t-test, $t(28) = 3.845$, $p = .001$, Cohen's d = .782, 95% CI = -13 <= μ1 - μ2 <= -4 (see Figure 6.3A for mean RTs). As for the target-absent trials, participants made on average 18.84% (SE = 2.3%) errors, however, no significant difference was found on the error rates between flavor labels in these trials, $F(4, 116) = .801$, $p = .527$, $\eta_p^2 = .027$. On average, the participants responded more slowly to the target-absent trials than the target-present trials (M = 1172ms, SE = 4ms). No significant difference was found in the target-absent RTs as a function of flavor cue, $F(4, 116) = 2.179$, $p = .076$, $\eta_p^2 = .070$.

[9] The data analyses reported in Experiments 11-13 were also performed with the excluded data included. Note that the pattern of results was statistically similar to the results reported in the main text.

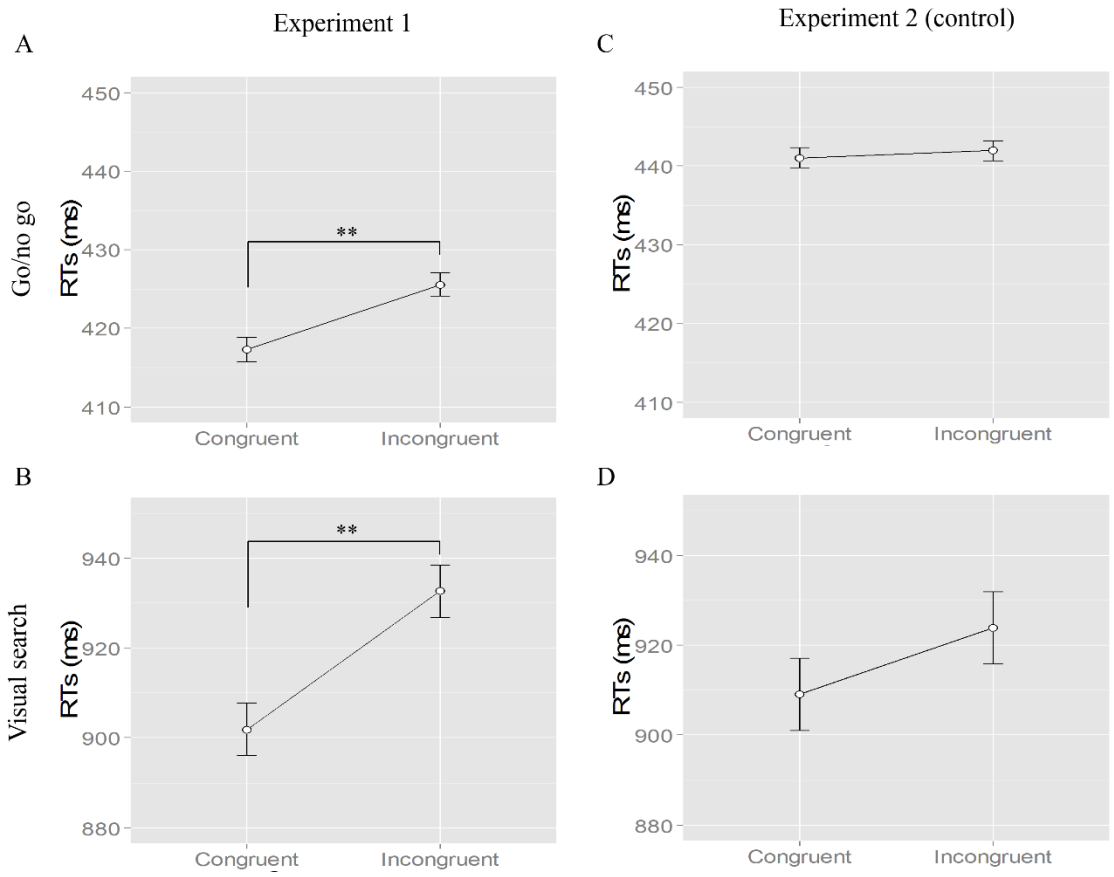


Figure 6.3. Mean RTs (in ms) in each congruence condition in Experiments 11 (A and B) and 12 (C and D). While a significant difference between congruent and incongruent pairings can be observed in the two tasks of Experiment 11, such difference disappears in Experiment 12 The asterisks (*p* = .001) highlight the significance of the difference and the error bars represent 95% confidence intervals.**

Visual search task. The data from two of the participants were excluded from the analysis due to poor performance (less than 60% correct). A paired sample t-test on the error rate revealed that participants made less errors in the congruent (*M* = 12.8% ms, *SE* = 1.23%) than in the incongruent (*M* = 22.8% ms, *SE* = 3.0%) condition, *t*(29) = 3.890, *p* = .001, Cohen's d = 0.710, 95% CI = -15.2% <= µ1 - µ2 <= -4.7%. From the total of 4500 congruent and incongruent trials including the data from all of the participants, 802

(17.8%) incorrect responses were excluded from the data analysis. In addition, those RTs that fell two standard deviations above or below the mean were excluded from the analysis (resulting in the removal of 2.21% of the remaining trials, meaning that a total of 3616 trials were used in the analyses).

Mean RTs were computed for correct, target-present trials across conditions (congruent and incongruent). A paired sample t-test was used to assess any difference between the congruent (M = 908 ms, SE = 15) and incongruent (M = 939 ms, SE = 15) trials. This revealed a significant difference of 31 ms, $t(29) = 3.554$, $p = .001$, Cohen's d = .648, 95% CI = -49 <= μ1 - μ2 <= -13 (see Figure 6.3B for mean RTs). As for the target-absent trials, participants made on average 18.84% (SE = 2.3%) errors, however, no significant difference was found on the error rates between flavor labels in these trials, $F(4, 116) = .801$, $p = .527$, $\eta_p^2 = .027$. On average, the participants responded more slowly to the target-absent trials than the target-present trials (M = 1172ms, SE = 4ms). No significant difference was found in the target-absent RTs as a function of flavor cue, $F(4, 116) = 2.179$, $p = .076$, $\eta_p^2 = .070$.

The results of both tasks provide consistent initial evidence for the idea that color/flavor label congruence facilitates visual search and that, as expected, there is a Stroop-like effect. Participant RTs are slower when responding to flavor words against an incongruent than congruent packaging colors. However, one potential limitation with the interpretation of the results of Experiment 11 relates to the fact that the congruent stimuli always consisted of the same five color/flavor combinations, while the incongruent stimuli were randomly selected from a pool of various incongruent stimuli. One may therefore wonder whether the obtained congruency effects would at least partially be attributable to the differing variety of targets in the congruent versus incongruent trials,

and thus the frequency of the same congruent targets (cf. Godwin et al., 2014; Wolfe et al., 2007). Perhaps, less variety in the congruent trials, in turn, might have led to higher familiarity of the congruent stimuli and therefore faster RTs. . As a consequence, a control go/no go task and a control visual search task (Experiment 12) were also conducted in order to assess whether presenting an incongruent stimulus combination with the same frequency as the congruent combinations in Experiment 11 would still lead to a similar pattern of results.

6.3 Experiment 12: Colour/flavour (names) congruence in go/no go and visual search tasks (control)

6.3.1 Methods and materials

Twenty three participants (11 female) aged 19-28 years (M = 22.00 years, SD = 2.73) took part in this experiment. All of the aspects of the methods in this experiment were the same as those in Experiment 11 except for those specified as follows.

As for the go/no go task, the congruent and incongruent combinations were modified in order to assess whether the frequency of presentation of the congruent trials in Experiment 11 gave rise to the faster RTs for the congruent condition. For experimental purposes, the analogous (to Experiment 11) congruent combinations in these experiments were as follows: chicken presented in burgundy, lemon in red, BBQ in green, tomato in orange, and cucumber in yellow. The analogous incongruent combinations included each flavour name presented against any of the other colours. So, for example, the incongruent stimuli for chicken included the colours red, green, orange, and yellow. Note that for practical

purposes, the name of the corresponding congruent condition will be "congruent control" and the name of the analogous incongruent condition will be "incongruent control". These stimulus combinations were created in order to assess whether presenting the congruent combinations as frequently as presented in Experiment 11 (that is, more frequently), independently of the colour/flavour congruence, would lead to faster RTs, as compared to the other combinations.

As for the visual search task, the new stimulus combinations introduced in the go/no go task were utilized: chicken presented in burgundy, lemon in red, BBQ in green, tomato in orange, and cucumber in yellow.

6.3.2 Results and discussion

Go/no go task. The data from four of the participants was excluded from the analysis of the go/no go task due to poor performance (less than 60% correct). From the total of 2280 congruent control and incongruent control trials including the data from all of the remaining participants, 22 (0.9%) incorrect responses were excluded from the analysis. From the incorrect responses, 10 (0.4%) corresponded to incongruent control trials, and 12 (0.5%) to congruent control trials. From the 2258 remaining trials, those RTs that fell two standard deviations above or below the mean were excluded from the subsequent data analysis (4.0%, for a total of 2167 trials used in the analyses). Mean RTs were computed for correct, target-present trials across conditions (congruent and incongruent control). A paired samples t-test failed to reveal any significant difference between the RTs in the congruent control (M = 441 ms, SE = 9) and incongruent control (M = 442 ms,

SE = 9) conditions, *t*(18) = .498, *p* = .624, Cohen's d = .125, 95% CI = -5 <= μ1 - μ2 <= 3 (see Figure 6.3C for mean RTs).

The results of the go/no go task of Experiment 12 therefore help to rule out the possibility that it was only the frequency of the presentation of the congruent trials in the first experiment what caused a congruency effect. In other words, the higher frequency of presentation of the congruent combinations in Experiment 11, as compared to the incongruent combinations, which were randomly selected from a pool of incongruent stimuli, did not necessarily speed participants' responses on the congruent trials.

Visual search task. Data from two participants were excluded from the analysis of the data from the go/no go task due to their poor performance (less than 60% correct). A paired-samples t-test failed to reveal any significant difference between the congruent (*M* = 19.17%, *SE* = 2.95%) and incongruent (*M* = 18.67%, *SE* = 2.46%) error rates, *t*(20) = .341, p = .737, Cohen's d = 0.07, 95% CI = -2.60% <= μ1 - μ2 <= 3.61%. From the total of 3150 congruent control and incongruent control trials including the data from all of the remaining participants, 596 (18.9%) incorrect responses were excluded from the analysis. From the incorrect responses, 294 (9.3%) corresponded to incongruent control trials, and 302 (9.6%) to congruent control trials.

From the 2554 remaining trials, those RTs falling two standard deviations above or below the mean were excluded from the analysis (2.6%, for a total of 2486 trials used in the analyses). Mean RTs were computed for correct, target-present trials across conditions (congruent and incongruent control). A paired samples t-test did not reveal a significant difference between the RTs in the congruent (*M* = 909 ms, *SE* = 17) and incongruent

control (*M* = 923 ms, *SE* = 17) conditions, t(20) = 1.300, p = .208, Cohen's d = 0.269, 95% CI = -38 <= μ1 - μ2 <= 9 (see Figure 6.3D for mean RTs).

These results support the idea that the congruency effect obtained in Experiment 11 may have resulted from the congruency manipulation rather than from any difference in the relative frequency of occurrence of congruent as compared to incongruent trials. It is important to note, though, that although accuracy for incongruent and congruent trials was almost identical in Experiment 12 (which differs from what was reported in Experiment 11), the RTs were numerically, though not significantly, faster. In other words, colour/flavour label congruence influence search times, but it is not possible to rule out a relative effect of target prevalence on the RTs. In Experiment 13, the results of the visual search task reported in Experiments 11 and 12 are extended by using the same number of congruent and incongruent stimulus combinations (e.g., frequency is controlled). In addition, Experiment 13 moved toward a more complex visual search scenario, and directly addressed two questions: (1) Does color/flavor congruence influence search efficiency? (2) Does the strength of the association between a flavor word and a color affect participants' search times to flavor words as a function of congruency? To this end, the strength of the association between a flavor word and a color, and the number of packages on the screen (set size), were manipulated. The strength of the association (or association strength) includes two levels. One of the levels (stronger) corresponded to those flavor labels (tomato and cucumber) to which the participants in Chapter 5 consistently selected the same color across three countries (Colombia, China, and UK) and which were highly associated with a color in China, and the other (weak) to those flavor labels (BBQ and Chicken) to which participants' associations varied as a function of country and which were only associated by some of

the participants to a color. Presumably, those flavor labels have a clear color identity due to their frequent co-occurrence in the environment (e.g., cucumbers are green) as compared to those which have a less straightforward association. Here, it was hypothesized that not only should an effect of congruency be expected, but also an effect of association strength. In MacLeod's (1991, p. 173) words: *"…as the word's semantic association to the concept of color increases, so does its potential to interfere".*

6.4 Experiment 13: The role of colour/flavour (names) congruence and association strength in search efficiency

6.4.1 Methods and materials

6.4.1.1 Participants

20 participants (10 female) aged 18-24 years (M = 21.25 years, SD = 1.74) took part in this experiment.

6.4.1.2 Apparatus and materials

The experimental setting of Experiment 13 followed that of Experiments 11 and 12. In Experiment 13, however, only four pairs of congruent stimuli and four pairs of incongruent stimuli were utilized. In particular, the congruent combinations included chicken in orange, BBQ in burgundy, tomato in red, and cucumber in green. The incongruent combinations included chicken in burgundy, BBQ in green, tomato in orange, and cucumber in red. Thus, an equal number of color-flavor label pairs were used in the congruent and incongruent conditions in order to control for the differing variety

of these pairings in Experiment 11. All of the packaging colours were set to equal luminance (122 Lumas) in Experiment 13. The colours RGB codes in Adobe Photoshop CS4 were as follows: burgundy 732532 (red (R) = 115, green (G) = 37, blue (B) = 50), green 2d4511 (R = 45, G = 69, B = 17), orange 8b2800 (R = 139, G = 40, B = 0), and red 9e1616 (R = 158, G = 22, B = 22). The distractors were the same as those used in Experiments 11 and 12. In addition, the experimental procedure here manipulated the set size of the packaging display, by including 3, 6, and 9 packages.

6.4.1.3 Procedure

As in Experiments 11 and 12, the participants first completed the practice trials (24 trials). The timing of each trial in Experiment 13 is illustrated in Figure 6.4. The participants were first presented with a fixation cross for 500ms, then a flavour tag (e.g., chicken) for 500ms, then a new fixation cross for 500ms, and then the display with the different packages (3, 6, or 9) for a maximum allowable RT (after which the trial was terminated) of 3000 ms (due to the inclusion of larger set sizes).

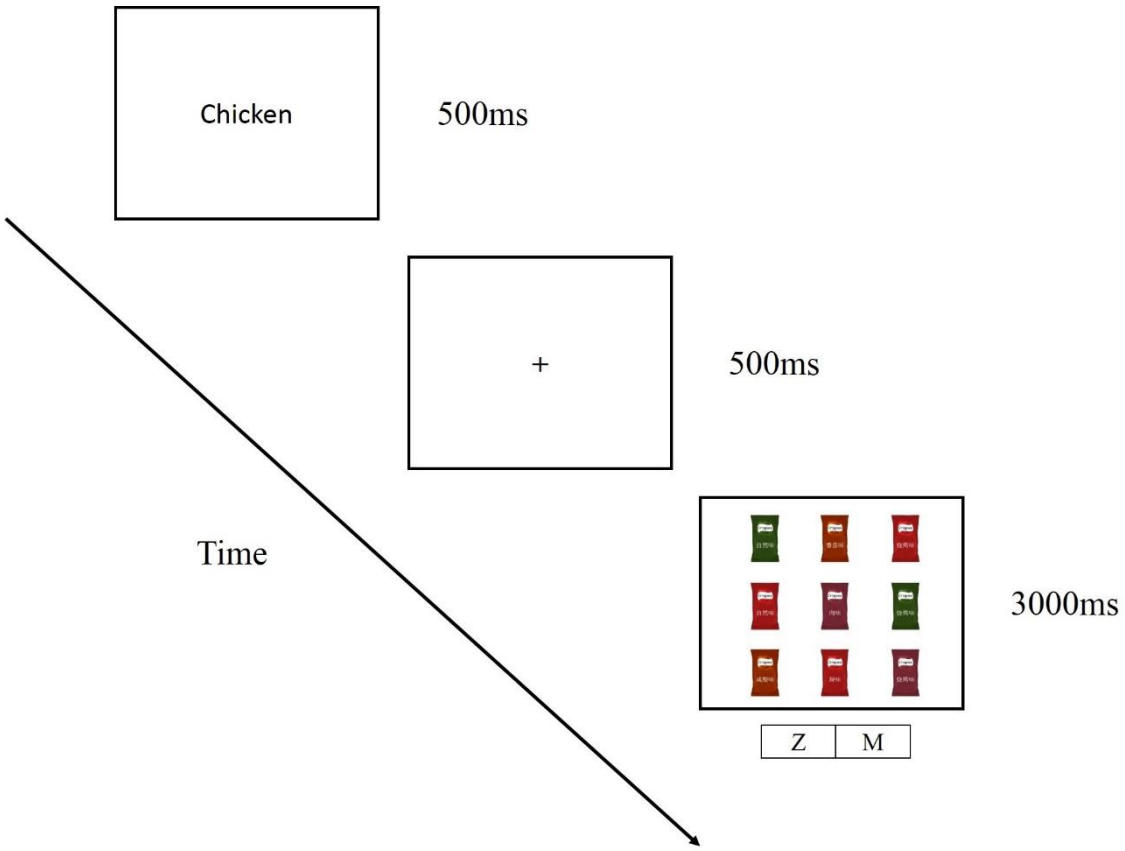


Figure 6.4. Schematic representation of a trial in the visual search task (set size = 9) in Experiment 13. Z and M in this Figure are the response keys.

After the practice trials, the main experiment was presented. The design consisted of two blocks of trials. In each block, 20 congruent, 20 incongruent, and 40 target-absent trials for each set size were included, giving rise to 240 trials per block, and 480 for the whole experiment. Note that 50% of the trials were target-absent trials. When the target was absent, it was replaced by a package that was randomly selected from a list of four packages that were all labeled with the label "salt and vinegar" but were either orange, burgundy, green, or red. When the target was absent, the flavour label "salt and vinegar" was used against any of the packaging colours used in the experiment. Half of the participants responded by pressing the 'z' key for target-present trials, while the other

half responded by pressing the ‘m’ key instead. The participants were given a break between the blocks of trials. Here, each packaging image was designed to fit within an area of 6.8 ° × 11.8° of visual angle. The horizontal and vertical distance between the packages was 7.8° and 1.6° of visual angle for the set size with 9 packages. The distances of between the packages in the other set sizes (3 and 6) varied as a function of the position of both target and distractors, as it was randomly assigned to any of the 9 positions used in the bigger set size. The flavour names written on each package subtended approximately 1.16° × 2.98° of visual angle.

6.4.1.4 Analyses

We performed two separate 3 (set size: three, six, and nine items) x 2 (association strength: weaker, stronger) × 2 (congruence: congruent, incongruent) RM-ANOVAs on both the RTs and error rates, and a 2 (association strength) x 2 (congruence) RM-ANOVA on the slopes that resulted from each condition. In addition, the error rate and RTs of the target-absent trials were analyzed by means of a 3 (set size: 3, 6, and 9) x 2 (association strength: weaker and stronger) RM-ANOVA.

6.4.2 Results and discussion

Error rates. A summary of the error rates is presented in Table 6.1. Significant main effects of set size, $F(2, 38) = 6.326$, $p = .004$, $\eta_p^2 = .250$, association type, $F(1, 19) = 6.774$, $p = .017$, $\eta_p^2 = .263$, and congruence, $F(1, 19) = 8.552$, $p = .009$, $\eta_p^2 = .210$, were found. Furthermore, the analyses revealed a significant 2-way interaction between association type and congruence, $F(2, 38) = 13.327$, $p = .002$, $\eta_p^2 = .412$. Bonferroni-

corrected pairwise comparisons revealed that the participants made more errors in the larger set size (M = 13.13, SE = 1.45) than in the 3- (M = 8.19, SE = 1.06) and 6-packaging (M = 10.31, SE = 1.30) set sizes (p = .019 and p = .034, respectively). In addition, the participants made more errors when the target was a flavour label with a strong colour association (M = 11.75, SE = 1.11) than when it was one of those with a weaker association (M = 9.33, SE = 1.10, p = .017). Similarly, the participants made more mistakes in the incongruent (M = 12.17, SE =1.06) than in the congruent (M = 8.92, SE = 1.23) condition (p = .009). As for the interaction term, it was found that, in the incongruent condition, the participants made more errors when responding to the flavour labels with a strong colour association (M = 14.58, SE = 1.49), than those with a weaker association (M = 9.75, SE = 1.31) (p = .004).

Table 6.1. Error rates for both target-present, congruent and incongruent, trials, as well as target-absent trials, as a function of both association strength and set size.

Congruence	Association strength	Set size (ER %)		
		3	6	9
Congruent	Weaker	6.75	7.00	13.00
	Stronger	6.00	9.75	11.00
Incongruent	Weaker	8.00	9.50	11.75
	Stronger	12.00	15.00	16.75
Target-absent	Weaker	6.38	7.88	11.00
	Stronger	6.75	9.25	10.63

The analysis of the error data (using the Greenhouse-Geisser correction) of the target-absent trials only revealed a significant main effect of set size, F(1.529, 29.045) = 6.605, p = .008, η_p^2 = .258 (see Table 6.1). The participants made fewer errors in the smallest packaging set size (M = 6.6%, SE = 2.4%) than in the 9-packaging set size (M = 10.8%,

SE = 3.1%) (p = .012). A marginally significant difference between the 3- and the 6-packaging (*M* = 8.6%, *SE* = 2.9%) set sizes was also observed (p = .058).

RTs. From the total of 4800 congruent and incongruent trials including the data from all of the participants, 506 (10.5%) incorrect responses were excluded from the RTs analysis. In addition, those RTs falling two standard deviations either above or below the mean of each set size condition's RTs were excluded from the data analysis (3.98% of the 4294 remaining trials, leaving a total of 4123 trials in the final analyses). The results revealed a significant main effect of set size, $F(2, 38) = 338.946$, $p < .001$, $\eta_p^2 = .947$, and congruence, $F(1, 19) = 37.073$, $p < .001$, $\eta_p^2 = .661$, and a significant two-way interaction between association type and congruence, $F(1, 19) = 5.978$, $p = .024$, $\eta_p^2 = .239$. In addition, the results also revealed a borderline significant trend for the interaction between set size and congruence, $F(2, 38) = 3.195$, $p = .052$, $\eta_p^2 = .144$ (see Figure 6.5 for a visualization of the results). No significant effect was found for association type, the interaction between set size and association type, or the interaction between set size, association type, and congruence.

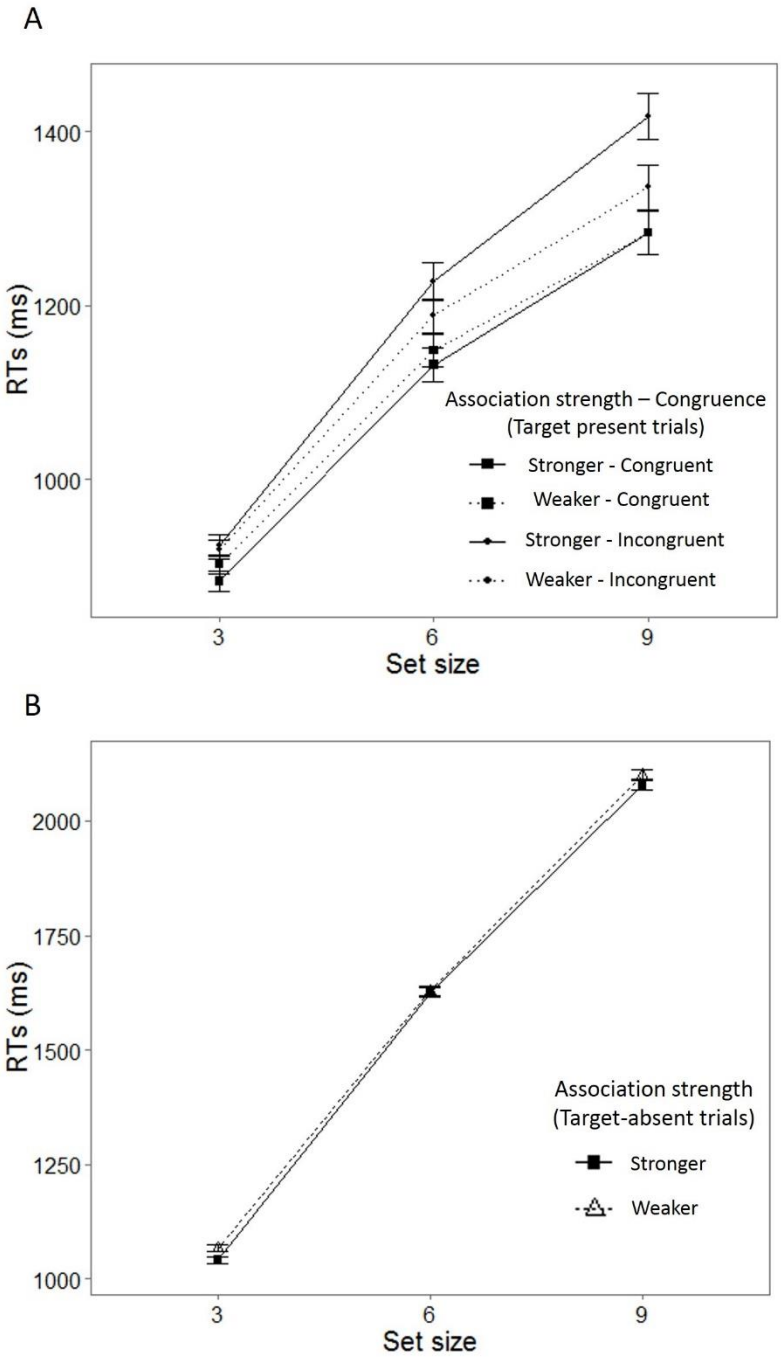


Figure 6.5. Summary of the results of the visual search task in Experiment 13. Panel A presents the mean RTs to target-present trials as a function of set size, association strength, and congruence, and panel B presents the mean RTs to target absent trials, as a function of set size and association strength. The error bars represent the standard error of the means.

Bonferroni-corrected pairwise comparisons revealed that the participants responded more rapidly to the targets in the set size with 3 packages (*M* = 910 ms, *SE* = 21) than the other two set sizes, and more rapidly to the targets in the set size with six packages (*M* = 1179 ms, *SE* = 30) than in the set size with nine packages (*M* = 1339 ms, *SE* = 30) set size ($p < .001$, for all comparisons). Moreover, the participants responded more rapidly to the congruent (*M* = 1112 ms, *SE* = 24) than the incongruent trials (*M* = 1174 ms, *SE* = 28) ($p < .001$). As for the interaction between association type and congruence, the analyses revealed that, in the incongruent condition, the participants responded faster to the flavour labels with a weaker colour association (*M* = 1149 ms, *SE* = 29) than to those with a stronger colour association (*M* = 1191 ms, *SE* = 29) ($p = .028$).

The analysis of the RT data only revealed a significant effect of set size (note that the Greenhouse-Geisser correction is used), $F(1.226, 23.301) = 725.604$, $p < .001$, $\eta_p^2 = .974$. The participants identified faster that a target was absent in the 3-packaging set size, followed by the 6-, and 9-packaging set size ($p < .001$, for all comparisons).

Details of the mean RTs, slopes, and intercepts for each condition are shown in Table 6.2 (see also Figure 6.5 for a visualization). A 2 (association strength: weaker and stronger) x 2 (congruence: congruent and incongruent) was performed on the slope values. The analysis revealed significant main effects of association strength, $F(1, 19) = 5.925$, $p = .025$, $\eta_p^2 = .238$, and congruence, $F(1, 19) = 5.052$, $p = .037$, $\eta_p^2 = .210$. The interaction was not significant. The slopes were steeper when the participants responded to flavor words with a stronger (*M* = 76, *SE* = 3) than a weaker (*M* = 67, *SE* = 4) association strength ($p = .025$). Likewise, the slopes were steeper in the incongruent (*M* = 77, *SE* = 4) than the congruent (*M* = 66, *SE* = 3) combination ($p = .037$).

Table 6.2. Mean RTs (in ms) as a function of set size, association strength, and congruence in Experiment 13. The last two columns provide the mean slopes and intercepts (all significant, $p < .001$).

Congruence	Association strength	Set size (mean RTs)			Slope	Intercept
		3	6	9		
Congruent	Weaker	919	1148	1284	64	729
	Stronger	923	1132	1284	67	697
Incongruent	Weaker	901	1188	1333	70	730
	Stronger	883	1228	1418	83	694
Target-absent	Weaker	1067	1629	2099	172	566
	Stronger	1041	1625	2078	172	544

The results of Experiment 13 therefore replicate those of Experiment 11 while providing further evidence to suggest that the effect is still present across different set sizes. In addition, they support the idea that when the packaging color is incongruent those flavor words to which a color is more strongly associated will be harder to find than those which are less strongly associated to a color. Importantly, search efficiency is affected by both congruence and association strength, with congruent combinations producing more efficient searches on the one hand, and flavor words with a weaker association strength on the other. There are several points to be mentioned here: First, color is a preattentively processed feature that can guide attention more efficiently towards a target, producing near-flat search slopes (Wolfe & Horowitz, 2004). In the context of the present study though, when a packaging's color is congruent but the word is not the target (mismatch), participants then have to move to another target, thus, producing slower, more effortful, searches (see also Grossberg, Mingolla, & Ross, 1994). Moreover, the strength of the association may also be key as participant's previous associations between a flavor and a word may then determine which color would guide attention. Finally, while the aforementioned points may help to explain why color does not seem to produce efficient

searches, it is also worth mentioning that the packages used as distractors could also have had a color that was semantically congruent with the target (though with a distractor flavor label). Such an element may have increased noise (cf. Wolfe, 2005), and thus made search less efficient as if each search trial had had categorically different colors.

6.5. General discussion

In Chapter 6, evidence is provided in support of the view that participants classified and searched for the target flavour labels more rapidly when they were presented in a colour that was congruent (vs. incongruent) with the cued flavour. In addition, incongruent colours tended to interfere more with flavour words that have a strong colour association (e.g., cucumbers tend to be green) than with those with a weaker colour identity (e.g., chicken can be orange in the context of crisps).

The results of the experiments reported in this chapter are consistent with the literature on the Stroop and the reverse Stroop effects (see MacLeod, 1991, for a review). According to this literature, not only can the name of a colour influence the way in which people name the colour in which that name is written, but a physical colour can also influence the way a colour word is read (e.g., Richter & Zwaan, 2009). It may be possible to think that a particular word or colour can activate related representations that may then exert some kind of top-down influence on task performance. It is possible that the visual elements that people link to a particular food or food word may influence both the classification of, and the search for, that word in the context of product packaging.

The interaction between association type and congruence of Experiment 13 is comparable to one of the experiments (Experiment 3) reported by Berthet et al. (2011) who found an interaction between relevant information strength (e.g., how strongly a target is associated with a colour) and congruence, both in an affective priming task and in a Stroop task. In particular, Berthet and colleagues found a significant difference between congruent and incongruent trials in the stronger condition but not in the weaker one. While a difference between congruent and incongruent trials was found both in the weaker and stronger condition in Experiment 13, it would appear as if the difference is larger in the stronger condition than in the weaker condition. This, in turn, suggest greater interference, which is reflected in the difference between weaker and stronger conditions in the incongruent trials in this experiment.

Here it is important to mention that the pattern of performance observed in the target-absent trials in Experiment 13 should be interpreted with some degree of caution. When the target was absent, one of four possible packages, labeled with "salt and vinegar" and either orange, burgundy, green, or red color, was randomly selected and used in the trial. As only one flavor label was used, it is possible that our participants may have adopted a strategy whereby they responded 'absent' as soon as they saw 'salt and vinegar' (and hence a target), with the second target being the intended target for that trial. However, one finding that suggests that this strategy was not adopted by the participants is the observation that the mean slope of the target absent trials was more than twice as steep as the slopes of both the congruent and incongruent target present trials. This slope pattern is typically observed for target-absent versus target-present trials (cf. Wolfe, 1998). In addition, the results regarding the main hypothesis of this study would be unaffected by

such a response strategy; and the main hypothesis is therefore still supported by the results of both experiments.

The importance of flavour labelling and colour congruence when it comes to classifying and searching for flavour information is highlighted. As suggested in Experiment 9, it is likely that the colour/flavour label associations presented are learnt by the internalization of the statistical regularities in the environment (Spence, 2011). Such regularities also extend to the marketplace (e.g., Labrecque & Milne, 2013) and frequently object/colour co-occurrences can be internalized by the consumer and then influence information processing as a function of the level of congruency (e.g., Clydesdale, 1991; Piqueras-Fiszman et al., 2012; see also Chapter 5). The experimental approach outlined here may thus potentially be useful for marketing practitioners interested in launching a new product. By assessing the effects of specific colour-related words such as flavour words, one may be able to understand which colours may or may not interfere with such words.

It is worth mentioning that the Stroop-like effect observed in the experiments reported in Chapter 7 are also compatible with the literature on visual search. Eimer (2014) recently put forward a model of selective attention that was designed to account for the existence of four key stages in visual search, which include preparation, guidance, selection, and finally identification. Preparation refers to the activation of representations, or 'target templates' in working memory, related to the target information, before the actual search; working memory is in charge of holding the object's sensory features relevant to the search task, that are not accessible directly via the senses. Guidance, on the other hand, refers to the process of gathering target-related information in parallel, while selection refers to the assignment of resources to the potential targets, and identification, to the process of binding the object's features for the subsequent recognition of the target's

identity. The colour associated with a flavour may therefore be represented in working memory while searching for a specific flavour label, and potentially, those flavour labels that are presented in a manner that is consistent with the statistical regularities of the environment (see Parise & Spence, 2013, and Spence, 2011), such as cucumber in green, may be easier to classify and hence to search for (cf. Vickery, King, & Jiang, 2005). Importantly, search efficiency is affected by both congruence and the strength of the association. This result is particularly intriguing given the existing evidence suggesting that search is guided by preattentive features such as color, as suggested by Eimer (2014; see also Wolfe et al., 2007). There is, however, research suggesting that when a mismatch is found (e.g., an incongruent color after a flavor cue) a deeper search is performed, which could influence RTs (Grossberg et al., 1994). Furthermore, as the color of the distractors could also match participants' color representation of a flavor, search may have been less efficient.

The task used here could be interesting for both researchers and marketers. For the former, this type of task may help to assess the influence of crossmodal correspondences captured in language (e.g., flavour words) on information processing. For the latter, it may provide useful when assessing which colour to use when, for example, a new product is launched.

CHAPTER 7

Exploring taste-shape congruence, packaging classification, and taste perception

7.1 Introduction

As mentioned in Chapter 1, and as demonstrated in Chapters 2-4, people can match tastes and flavours with shapes (see Spence & Deroy, 2013, for a recent review). Importantly, it appears as though the roundness/angularity of the shapes is critical for such matchings (e.g., Spence, 2012; Spence & Ngo, 2012, for reviews, see Chapters 2-4). Recent evidence suggests that the crossmodal correspondence between taste and shape can also influence human information processing. Evidence from Liang et al. (2013) has demonstrated that presenting a round shape before participants taste a sweet solution, can serve to enhance sweetness sensitivity, as compared to when an angular shape was presented instead (see also Becker et al., 2011; Gal et al., 2007; Stewart & Goss, 2013). However, to date, there have not been so many studies that have attempted to investigate the implications of these crossmodal associations between shapes and tastes/flavours for human information processing.

Experiment 14 was therefore designed to assess the way in which different product packaging features' such as its shape, name, sounds, and typeface influence participants' classification in terms of taste attributes and expectations about how sweet and or sour a product may be. New packaging designs were created in order to avoid as much as possible any relationship between the moulds and a specific product category. Based on the results of Chapter 3, it would be expected that, by using existing product shapes,

people's associations would vary as a function of product schemes (e.g., Schoormans & Robben, 1997).

In Experiment 15, I move on to evaluate whether shapes on mugs influence participants' perception of sweet and sour taste solutions. Specifically, whether shapes influence taste quality, hedonics, or intensity perception. The idea here is to assess whether results such as those from Liang and colleagues (2013) can also be extended to the other basic tastes, and across a range of suprathreshold stimulus intensities. In particular, the aim was to evaluate whether having angular versus round shapes on a receptacle (in this case a mug) would influence participants' perception of sweet and sour solutions with different concentrations (and water, as control).

7.2 Experiment 14: Predictive packaging design: Tasting shapes, typographies, names, and sounds

7.2.1 Methods and materials

7.2.1.1 Participants

Thirty four participants (8 males, M_{age} = 26.1 years, SD_{age} = 6.0, $range_{age}$ = 19~43 years) took part in this experiment. The experiment lasted for approximately 20 minutes.

7.2.1.2 Apparatus and materials

E-Prime 2.0 software (Psychology Software Tools, Inc.) was used to present the stimuli and collect the data. The participants were seated approximately 60 cm in front of a 23''

LED monitor, with a screen resolution of 1920x1080 pixels, and a screen refresh rate of 60 Hz.

The auditory stimuli were created using Audacity, a free software package for audio editing and recording (http://www.audacity.sourceforge.net/). The higher pitched sound had a frequency of 1100 Hz, whereas the lower pitched sound had a frequency of 70 Hz. The sounds had a duration of 1000ms, and were presented right before the visual stimuli, at a level of 70dB, through a pair of Sony MDR-ZX100 stereo headphones. The auditory stimuli were chosen on the basis of previous research demonstrating that sour tastes tend to be matched to relatively high-pitched sounds, while sweet tastes tend to be matched to both high and low pitched sounds (see Knöferle & Spence, 2012, for a review). Based on these findings, high and low pitched sounds were included in order to investigate any effect that they might have on participants' sourness and sweetness ratings.

The Photoshop CS4 software was used to create the visual stimuli. The visual stimuli consisted of various images of product packaging. The designs were created with the idea of conveying information about the taste of a product by means of their shape (angular vs. rounded), typeface (Holywood Hills – Regular, 53 pt, for the angular typeface, and Swis721 B1kRnd BT – Black, 44pt for the more rounded typeface), and name (angular vs. rounded, namely Clax and Blum, respectively, see Figure 7.1). Crossing these factors gave rise to a total of 8 combinations (2×2×2) of visual stimuli. In addition, plain (i.e., unlabelled) rounded and angular packages were also included in the design but were not included in the data analyses. All of the images (620x780 pixels) were set to an equal mean luminance, and presented against a white full-screen background. The images were 18cm high on the screen.

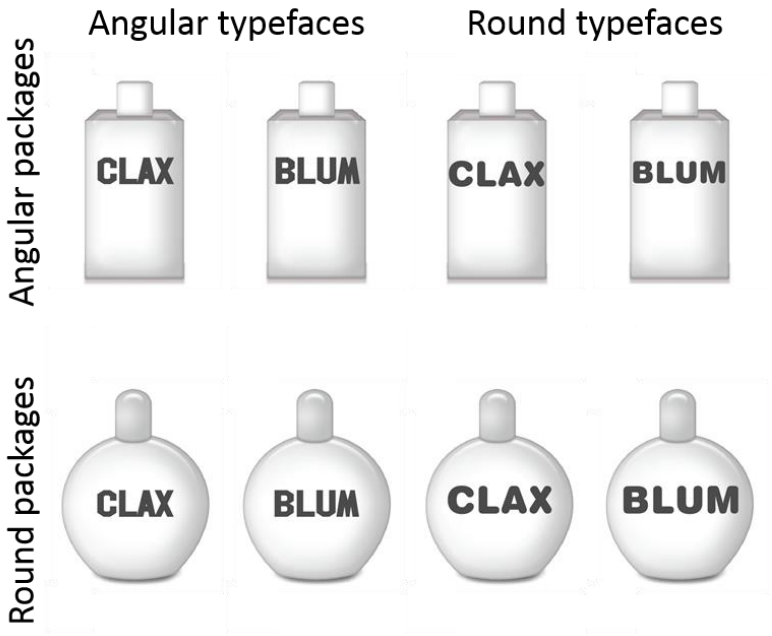


Figure 7.1. The 8 examples of product packaging used in Experiment 14.

The various packaging images were created on the basis of previous research presented in this thesis (Chapters 2-4) suggesting that sour tastes are matched crossmodally with angular shapes and sharp-sounding words (see also Ngo et al., 2013). By contrast, sweet tastes are generally matched to rounder shapes, and soft, rounded speech sounds (see Knöferle & Spence, 2012; Ngo et al., 2013; Spence, 2012; Spence & Gallace, 2011).

7.2.1.3 Procedure

Ten images were presented, each one of them after either a high- or low-pitched sound, thus giving rise to a total of 16 randomly presented trials that were repeated 3 times (3 blocks of trials) giving rise to a total of 48 trials.

At the beginning of the experiment, written instructions were presented on the screen. Once the participants had read the instructions, a fixation cross was presented on the

screen for 1000 ms together with one of the sounds (either high or low in pitch). After that, the package was presented until the participants made a response. The participants were instructed to maintain their fixation on the centre of the screen (on the fixation cross) that was presented at the beginning of each trial, and to indicate, as rapidly as possible, whether they thought that the packaging (presented after the cross) that was shown on the screen would be more appropriate for a sweet- or for a sour-tasting product. The participants responded by pressing the 2 and 8 keys on the computer keyboard, with their left and right index fingers, respectively. In addition, the participants were instructed to rate how sweet and sour they thought that the product in the packaging might be, using two 10-point Likert scales, ranging from 1 (not at all) to 10 (very). These two scales were presented, one after the other, in a random order. The participants were only allowed to move on to the response scales once they had made a response as to whether sweet or sour was most appropriate. At the end of the trial, and after the participants had responded to the scales, a new trial was signalled by the reappearance of the fixation cross (see Figure 7.2).

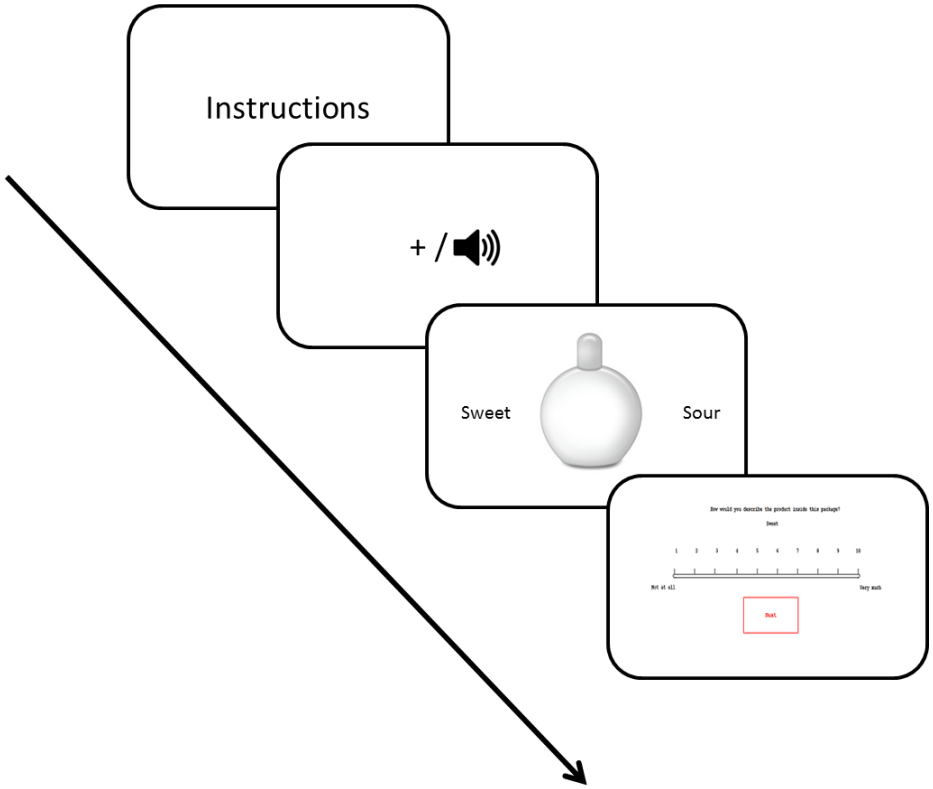


Figure 7.2. The experimental procedure used in Experiment 14.

Three response measures were obtained from the experimental design: A speeded taste categorisation response (sour or sweet), the RTs, and mean ratings of sweetness and sourness. The latter two continuous variables were analysed via an ANOVA for repeated measures and the former was analysed using a test for repeated categorical response data. Specifically, the log-likelihood test (G^2) of independence with Williams' correction (Agresti, 2002) was used and the results of this test were represented via mosaic plots (Friendly, 1994). The G^2 is based on a specific multinomial distribution (distribution that the χ^2 only approximates) and computes observed and expected values based on the deviance from a log-linear model. More importantly, the G^2 test can be used whenever there are repeated categorical data (Agresti, 2002). The mosaic plot is a graphical method that represents the counts in a contingency table by drawing tiles whose area is

proportional to the cell frequency. Colouring and shading can be used to represent the sign and magnitude of standardized residuals from a specified log-linear model (for further details, see Hartigan & Kleiner, 1984). The measures of effect sizes used for the ANOVA and the categorical analyses were the partial eta square (ηp^2) and the Cramér's V (V), respectively (more details as to these and other measures of effect size can be found in Ferguson, 2009).

7.2.2 Results and discussion

RT data: A 2 (shape: angular, rounded) × 2 (typeface: angular, rounded) × 2 (name: angular, rounded) × 2 (sound: high pitch, low pitch) × 2 (taste: sour, sweet) RM-ANOVA was carried out on the median RT[10] data. This analysis revealed a significant main effect of name and 2-way and 3-way interactions between all these factors (see Table 7.1).

Table 7.1. Results of the ANOVA performed on the RT data with the factors of shape, sound, taste, name, and typeface in Experiment 14.

Main effect	Interaction	F [a]	p-value	ηp^2
name		4.12	.046	.059

[10] The RT and rating data sets had some values missing at random (33.9% of trials, overall). To minimise any loss of power due to the presence of these missing values, a 'linear trend at point' missing value replacement procedure was used (Martin & Bridgmon, 2012). Every participant had the task of categorising a combination of the levels of the variables "shape", "typeface", "name", and "sound" as either "sweet" or "sour". Remember that each combination was presented three times during the course of the experiment. Thus, the same experimental combination could have been categorised as either "sour" or "sweet" every time that it was presented or else could have been categorised as "sour" or "sweet" one or two out of the three times. Whereas the latter situation led to averaged RTs and ratings for the same experimental combination for the two types of tastes, the former situation led to missing averaged RTs and ratings for either "sweet" or "sour" categorisations for the same experimental combination. The 'linear trend at point' (LiTaP) method replaces missing values with the linear trend for that point. The existing series is regressed on an index variable scaled 1 to n and missing values are replaced with their predicted values. An estimation of the central tendencies of the different experimental conditions on the data set with missing values showed that the trends in the data remained similar before and after the LiTaP method was applied.

typeface × sound	6.38	.014	.088
typeface × taste	7.26	.009	.099
typeface × name × taste	8.65	.005	.116
shape × name	8.79	.004	.118
shape × typeface × name	14.99	<.001	.185
shape × typeface × sound	16.26	<.001	.198
shape × name × taste	24.42	<.001	.27
shape × taste	33.73	<.001	.338

[a] $df_n = 1$, $df_d = 66$.

Note. Partial eta squared effect sizes (ηp^2) can be interpreted as follows: 0.01 ≅ small, 0.06 ≅ medium, and 0.14 ≅ large (Kittler, Menard, & Phillips, 2007). Results are sorted in increasing order as determined by their effect size; large effect sizes are shaded.

The participants responded to the rounded names ($M_{rounded}$ = 1652 ms, SE = 79) more rapidly than to the angular names ($M_{angular}$ = 1798 ms, SE = 81) leading to a significant main effect of name. Rounded typographies were categorized more rapidly than angular typographies when associated with a high-pitched sound; By contrast, angular typographies were responded to more rapidly than were the rounded typographies when they were presented together with a sound having a lower-pitch (see Figure 7.3A).

Angular typographies were categorised as sour more rapidly than the rounded typographies; whereas rounded typographies were categorised as sweet more rapidly than the angular typographies (see Figure 7.3B). Angular shapes paired with angular names were responded to more rapidly than rounded shapes paired with angular names. Rounded shapes paired with rounded names were responded to more rapidly than angular shapes that had been paired with rounded names (see Figure 7.3C). Finally, angular shapes were categorised as sour more rapidly than rounded shapes; whereas rounded shapes were categorised as sweet more rapidly than angular shapes (see Figure 7.3D).

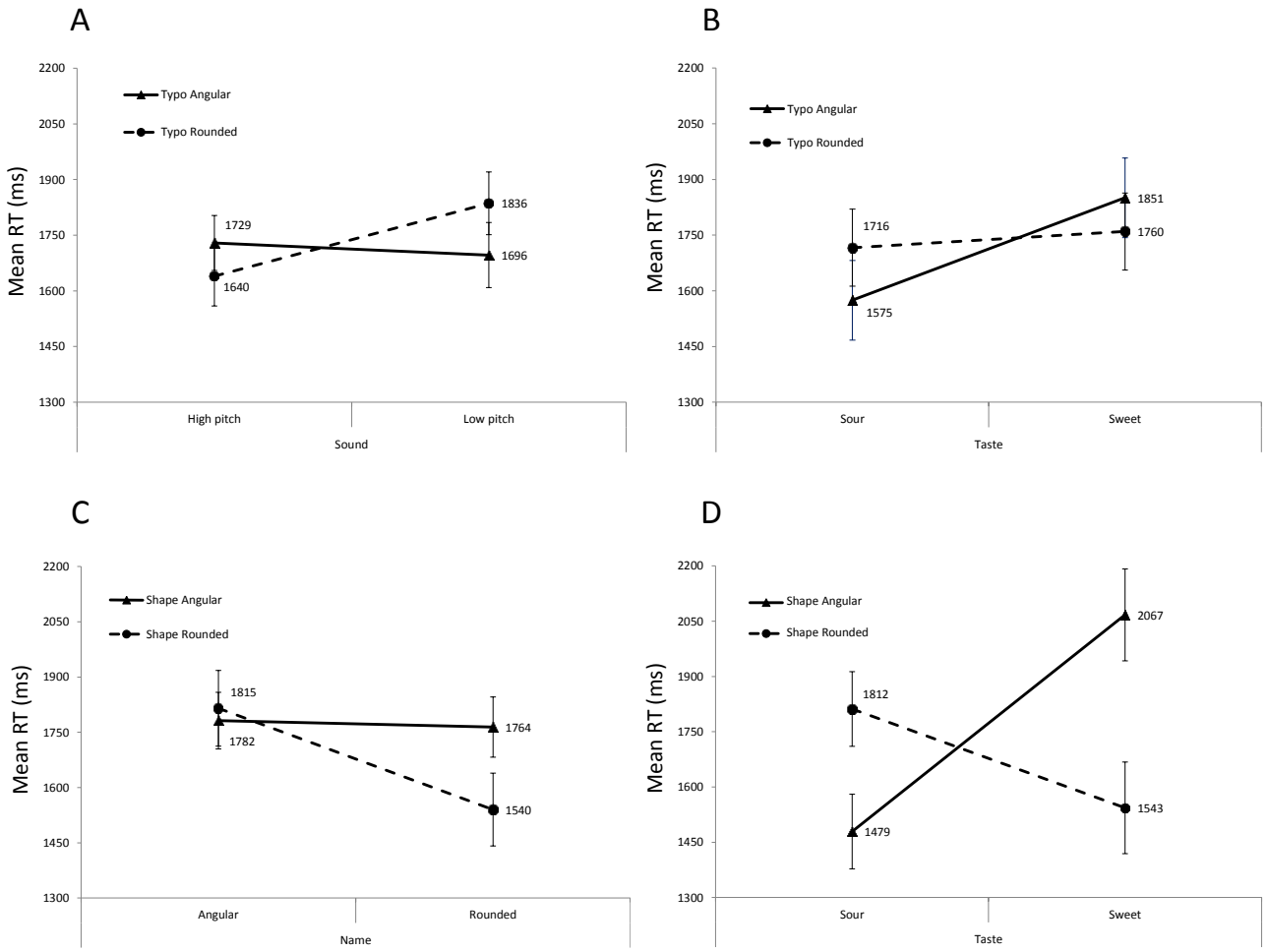


Figure 7.3. Line plot representing the results of the 2-way interactions documented in the RT data in Experiment 14. A)

Typeface × sound; B) Typeface × taste; C) Shape × name; and D) = Shape × taste. Error bars represent ± 1 *SE*.

Sweet and sour ratings: Similar separate 2 (shape: angular, rounded) × 2 (typeface: angular, rounded) × 2 (name: angular, rounded) × 2 (sound: high pitch, low pitch) × 2 (taste: sour, sweet) RM-ANOVAs were carried out on the median "sour" and "sweet" ratings. These analyses revealed significant main effects of sound, name, typeface, and shape, and 2-, 3-, and 4-way interactions between all these factors (see Table 7.2 for a summary of these statistical terms).

Table 7.2. Results of the ANOVA performed on the "sour" and "sweet" rating data with the factors of shape, sound, taste, name, and typeface in Experiment 14.

Rating type	Main effect	Interaction	*F* [a]	*p*-value	ηp^2
Sour		shape × sound × taste	4.23	.044	.06
		shape × typeface × name × taste	4.45	.039	.063
		name × taste	4.98	.029	.07
		shape × typeface × name × sound × taste	6.18	.105	.086
		typeface × taste	7.66	.007	.104
		shape × typeface × name × sound	7.76	.007	.105
		shape × typeface × sound	8.02	.006	.108
		sound × taste	9.50	.003	.126
		typeface × name × taste	16.64	<.001	.201
		shape × typeface × taste	18.94	<.001	.223
	sound		33.78	<.001	.339
	name		44.33	<.001	.402

	shape		47.91	<.001	.421
	typeface		54.28	<.001	.451
Sweet		shape × typeface × name × taste	4.17	.045	.059
	sound		4.48	.038	.064
		typeface × taste	5.40	.023	.076
		shape × name × sound	7.77	.007	.105
		shape × typeface	10.43	.002	.137
		typeface × name × taste	12.42	.001	.158
	typeface		13.57	<.001	.171
	name		49.94	<.001	.431
	shape		75.96	<.001	.535

[a] $df_n = 1$, $df_d = 66$.

Note. Partial eta squared effect sizes (ηp^2) can be interpreted as follows: 0.01 ≅ small, 0.06 ≅ medium, and 0.14 ≅ large (Kittler et al., 2007). Results are sorted in increasing order as determined by their effect size; large effect sizes are shaded.

In the "sour" ratings, the main effect of sound indicated that the higher-pitched sounds ($M_{high\ pitch}$ = 5.03, *SE* = .10) were rated as being more sour than the lower-pitched sounds with a ($M_{low\ pitch}$ = 4.56, *SE* = .09). In the "sweet" ratings, this main effect indicated that the lower pitched sounds ($M_{low\ pitch}$ = 5.23, *SE* = .10) were rated as being sweeter than sounds with a higher pitch ($M_{high\ pitch}$ = 5.05, *SE* = .10). For the "sour" ratings, the main effect of typeface indicated that angular typographies ($M_{angular}$ = 5.05, *SE* = .10) were rated as being more sour than were the rounded typographies ($M_{rounded}$ = 4.54, *SE* = .09). For the "sweet" ratings, this main effect indicated that rounded typographies ($M_{rounded}$ = 5.26, *SE* = .10) were rated as sweeter than angular typographies ($M_{angular}$ = 5.02, *SE* = .09).

In addition, the main effect of name on the "sour" ratings indicated that angular names ($M_{angular}$ = 5.13, SE = .09) were rated as sourer than the rounded names ($M_{rounded}$ = 4.46, SE = .11). In the case of the "sweet" ratings, this main effect indicated that rounded names ($M_{rounded}$ = 5.51, SE = .10) were rated as sweeter than angular names ($M_{angular}$ = 4.77, SE = .10).

The main effect of shape for the "sour" ratings indicated that the angular shapes ($M_{angular}$ = 5.19, SE = .11) were rated as sourer than the rounded shapes ($M_{rounded}$ = 4.40, SE = .09). For the "sweet" ratings, this main effect indicated that the rounded shapes ($M_{rounded}$ = 5.67, SE = .10) were rated as sweeter than the angular shapes ($M_{angular}$ = 4.62, SE = .11).

A medium effect size 2-way interaction between typeface and taste was present in both ratings (it was also present in the RT data) and reached a large effect size when the variable name was added to the interaction. This large effect size 3-way interaction between typeface, name, and taste, which was common to both ratings, suggests that shapes with rounded names and typographies were rated as sweeter when they were categorised as sweet than when they were categorised as sour (see Figure 7.4A), and that shapes with angular names and typographies were rated as more sour when they were categorised as sour than when they were categorised as sweet (see Figure 7.4B).

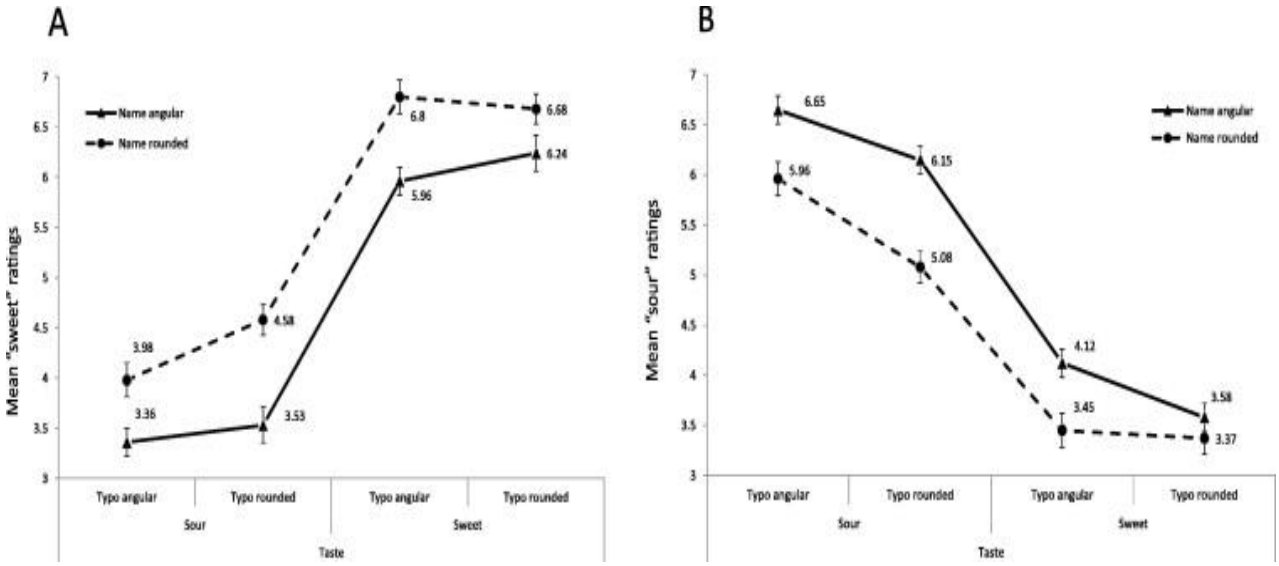


Figure 7.4. Line plot representing the results of the 3-way interactions observed in the rating data in Experiment 14. (A) Typeface × name × taste in the "sweet" ratings; (B) typeface × name × taste in the "sour" ratings. Error bars represent ±1 SE, and the numbers represent the value of the corresponding point.

The results of the analysis of the RT data and ratings indicated that rounded shapes, typographies, names, and lower-pitched sounds were all associated with "sweet" tastes, whereas angular shapes, typographies, names, and higher-pitched sounds were all associated with "sour" tastes. To further corroborate this idea, the Log-likelihood ratio (G^2) test of independence was performed on the categorisation (e.g., sour or sweet) that participants made during the course of the experiment.

Categorization: As shown in Figure 7.5, there was a significant association between all the factors; G^2 (31) = 137.48, p = <.001. The 5-way contingency table was broken down into eight 2 × 2 contingency tables with the factors of "taste" (sweet and sour) and opposite combinations of the factors shape, typeface, name, and sound (e.g., the opposite combination to Angular $_{\text{shape}}$ + Angular $_{\text{typeface}}$ + Angular $_{\text{name}}$ + High Pitch $_{\text{sound}}$ would be

Rounded $_{shape}$ + Rounded $_{typeface}$ + Rounded $_{name}$ + Low Pitch $_{sound}$) in order to determine which combination of stimulus parameters gave rise to the strongest association with sweetness or sourness.

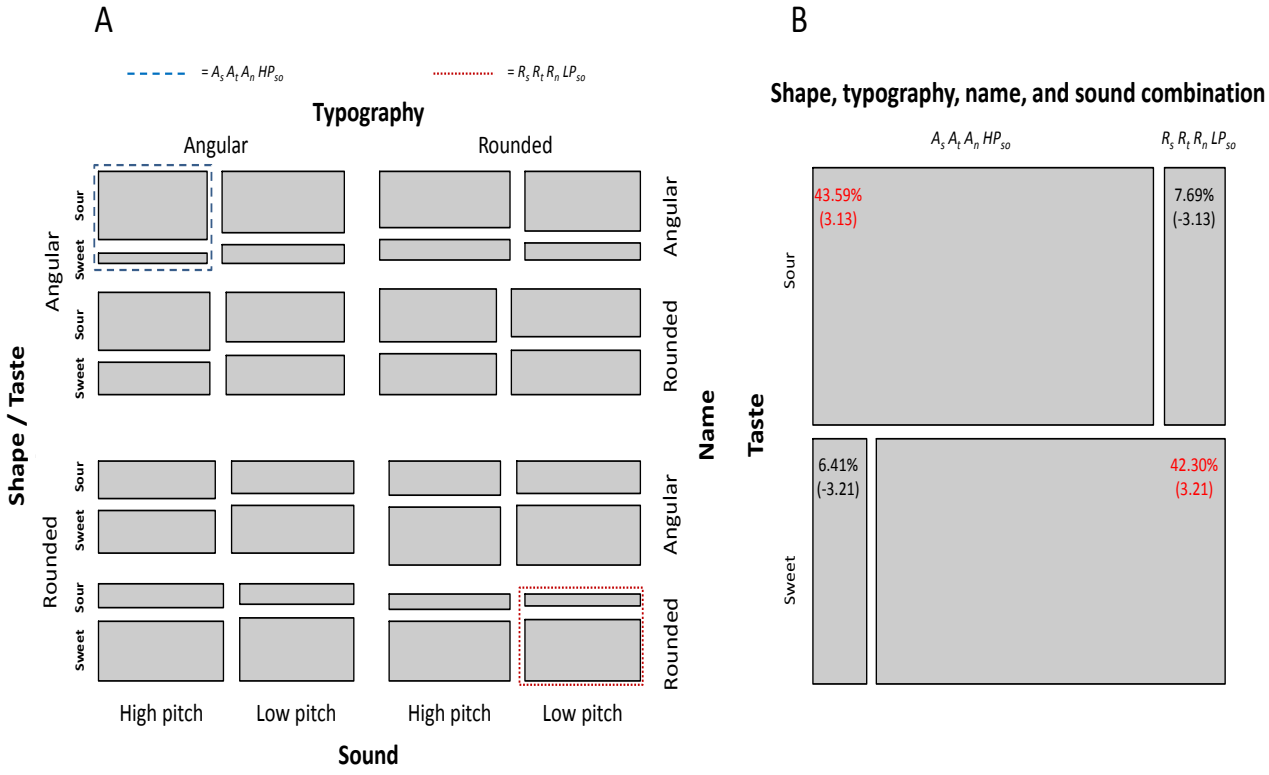


Figure 7.5. Mosaic plot representing a 5-way contingency table with the factors of shape, typeface, name, sound, and taste (A) and the 2 × 2 contingency table with the factors of taste and two opposite combinations of the factors of shape, typeface, name, and sound (B). $A_s A_t A_n HP_{so}$ = angular shapes typographies, and names paired with high pitched sounds, $R_s R_t R_n LP_{so}$ = rounded shapes typographies, and names paired with low pitched sounds, in Experiment 14. In (B), the percentages represent total percentages and their standardised residuals appear between parentheses.

Table 7.3 presents the results of the association test applied to the eight combinations of shape, typeface, name, sound, and taste. The results suggest that the strongest association occurred when the taste factor was associated with the combinations $A_s A_t A_n HP_{so}$ and R_s

$R_t\ R_n\ LP_{so}$ (see Figure 7.5B). Specifically, as suggested by an odds ratio analysis, $A_s\ A_t\ A_n\ HP_{so}$ combinations were approximately 7 times (*OR* = 6.8, *95% CI* = [1.89, 24.45]) more likely to be associated with "sour" than with "sweet" tastes, whereas $R_s\ R_t\ R_n\ LP_{so}$ combinations were approximately 5 times (*OR* = 5.5, *95% CI* = [1.52, 19.77]) more likely to be associated with the "sweet" than with the "sour" tastes.

Table 7.3. Results of the G^2 test on eight 2 × 2 contingency tables associating the factors taste ("sour" and "sweet") and combinations of the factors of shape, typeface, name, and sound in Experiment 14.

Associated combination	G^2 (1)	*p*-value	*V*
$A_s\ R_t\ R_n\ LP_{so} \sim R_s\ A_t\ A_n\ HP_{so}$	.18	.66	.04
$A_s\ R_t\ R_n\ HP_{so} \sim R_s\ A_t\ A_n\ LP_{so}$	2.42	.11	.16
$A_s\ A_t\ R_n\ LP_{so} \sim R_s\ R_t\ A_n\ HP_{so}$	3.47	.06	.19
$A_s\ A_t\ R_n\ HP_{so} \sim R_s\ R_t\ A_n\ LP_{so}$	8.11	.004	.29
$A_s\ R_t\ A_n\ LP_{so} \sim R_s\ A_t\ R_n\ HP_{so}$	20.98	<.001	.48
$A_s\ R_t\ A_n\ HP_{so} \sim R_s\ A_t\ R_n\ LP_{so}$	21.33	<.001	.48
$A_s\ A_t\ A_n\ LP_{so} \sim R_s\ R_t\ R_n\ HP_{so}$	29.66	<.001	.57
$A_s\ A_t\ A_n\ HP_{so} \sim R_s\ R_t\ R_n\ LP_{so}$	43.87	<.001	.71

Note. Cramér's *V* effect sizes can be interpreted on a range between 0 (no association) and 1 (perfect association) such that .2 ≅ small, .5 ≅ medium, and .8 ≅ large (Ferguson, 2009). Results are sorted in increasing order as determined by their effect size; large effect sizes are shaded. *s* = shape, *t* = typeface, *n* = name, and *so* = sound. *A* = angular, *R* = rounded, *HP* = high pitch, *LP* = low pitch (e.g., $A_s\ A_t\ A_n\ HP_{so}$ = items in which angular shapes, typefaces, and names were paired with high pitch sounds).

Experiment 14 was designed to assess how the various different elements in a product's packaging can convey information about, and are associated with, the likely taste of its contents. In particular, shapes, typographies, names, and sounds related to various packages, designed specifically for this experiment, were manipulated so as to investigate

whether there would be any effect on the expected taste of the product within the packaging. The results obtained provide empirical support for the notion that "sweeter" tastes are better expressed by means of rounded shapes, typographies, and names (soft, rounded), while "sour tastes" are better conveyed by means of more angular shapes, typographies, and names (sharp, angular). In addition, it would seem that sounds having a lower-pitch enhance the categorization of a packaging as sweet whereas higher-pitched sounds for sour (see Figure 7.6 for a visual representation of the results).

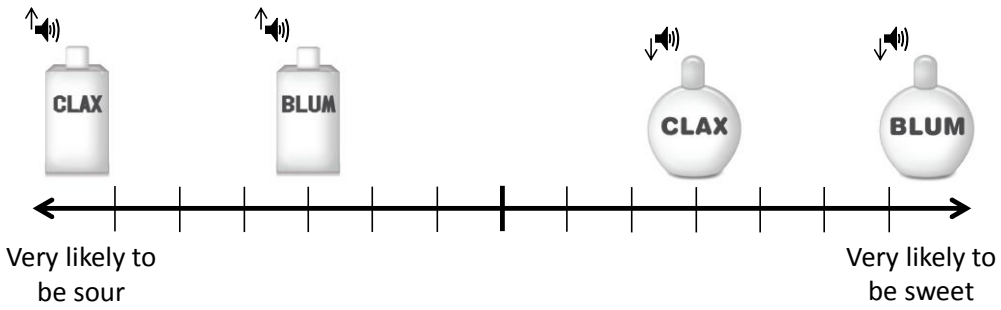


Figure 7.6. Figure showing the likelihood of a product being categorised as "sour" or "sweet" given the combination of the factors shape, typeface, name (angular, rounded) and sound (high pitch: ↑, low pitch: ↓) in Experiment 14. This representation was complete based mainly on the results of the G2 test.

Based on the results of Experiment 14, it is possible to assert that the associations between tastes and shapes influence information processing. In other words, the level of roundness/angularity consistency between the different design elements influences packaging taste ratings and categorization. When indicating which taste may be contained in a specific product's packaging, people may rely on specific abstract features such as the curvature of the different design elements.

It is important to remember that no actual tastants were used in Experiment 14, and thus, the effects may well have been driven by taste expectations as a function of packaging shape, typeface, name, and sound. Experiment 15 was designed to explore whether tastes and shapes actually interact during taste perception, that is, whether taste-shape congruence influences the perception of taste quality, hedonics, and intensity.

7.3 Experiment 15: Exploring taste/shape correspondences: When exactly do shape/taste correspondences influence taste perception?

7.3.1 Methods and materials

7.3.1.1 Participants

Twenty participants (13 female) aged between 19 and 40 years (M = 27 years; SD = 6.70) took part in the experiment. The participants volunteered for the study which lasted for approximately 30 min. They were rewarded with £5 in cash for their participation.

7.3.1.2 Apparatus and materials

Twenty white mugs were used as stimuli. Each mug was presented with one of four different shapes printed in black ink, which were either round or angular (see Figure 7.7). Two round and two angular shapes were selected, based on previous research suggesting that people match sour tastes with angular shapes and sweet tastes with more rounded shapes (see Ngo et al., 2013; Spence, 2012; Spence & Deroy, 2013, 2014; Spence & Gallace, 2011).

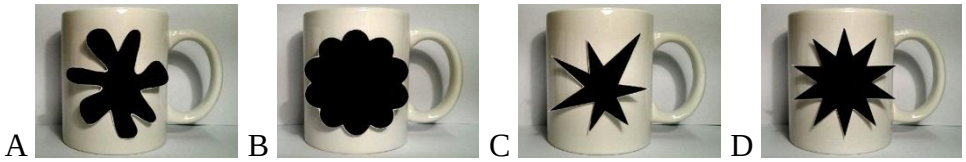


Figure 7.7. Pictures of mugs used as stimuli with round shapes (a and b) and angular shapes (c and d) in Experiment 15.

Two different tastes, each one in two different concentrations (giving rise to a total of four) and distilled water as control, were used as the taste stimuli in this experiment. The taste solutions were prepared with distilled water on the day of testing in accordance with the recommendations found in previous research (Hoehl et al., 2010) and ISO 3972:2011. Sucrose was used for the sweet taste (7.20 g/L and 12.00 g/L) and citric acid for the sour taste (0.48 g/L and 0.60 g/L). Each tastant was presented in four different mugs (varying in terms of the visual shape that was presented on the front of it) giving rise to a total of 20 randomly presented trials per participant.

7.3.1.3 Procedure

At the beginning of the experiment, written instructions were presented on the screen. Next, a picture of a mug (see Figure 7.7) was shown on the screen (at approximately the same size of the actual mug) together with a number indicating the specific mug to the experimenter. The experimenter would then take the respective mug (the mugs were hidden from the participant's view) and hand it to the participant. After receiving the mug, they were instructed to sample the liquid and then to expectorate it into a disposable cup. They then had to rate the taste on four VAS, ranging from 0 (not at all) to 100 (very much) presented on the screen: liking, intensity, sweetness, and sourness. The scales were presented in a random order and the participants had to use the mouse to indicate their

responses. After having made their ratings, the participants rinsed their mouth with water prior to moving on to the next sample. This procedure was repeated for each sample.

7.3.2 Results and discussion

A 2 (shape: angular, rounded) x 5 (taste: low sweet, high sweet, water, low sour, high sour) RM-ANOVA was carried out on the liking, intensity, sweetness, and sourness ratings. The analysis revealed a significant main effect of taste but no main effect of shape nor any interaction between taste and shape for any of the scales (see Table 7.4 for a summary of the results). The main effects of taste indicate that the solutions were perceived as different with regard to the various rating scales. Bonferroni-corrected pairwise comparisons were performed for each of the main effects of taste across liking, intensity, sweetness, and sourness questions. The participants preferred the more concentrated sweet solution to the less concentrated sour solution ($p < .05$). Moreover, they also perceived both sour solutions as more intense than either of the sweet solutions and water, and the more concentrated sweet solution as more intense than the other sweet solution ($p < .005$). The participants perceived the less concentrated sucrose solution as sweeter than both the citric acid solutions and water, and the more concentrated sucrose solution as sweeter than the remaining ($p < .01$). Finally, the participants rated both sour solutions as sourer than the sweet solutions and water, and water as sourer, as compared to the more concentrated sweet solution ($p < .005$).

Table 7.4. Results of the RM-ANOVA performed on liking, intensity, sweetness, and sourness ratings with the factors shape and taste in Experiment 15. The significant values are highlighted in bold.

Rating type	Main effect	Interaction	F	p-Value	ηp2
Liking					
	Taste		5.36	**.008**	.220
	Shape		0.42	.524	.022
		Taste x Shape	0.79	.493	.04
Intensity					
	Taste		31.28	**<.001**	.622
	Shape		0.01	.925	.000
		Taste x Shape	0.44	.774	.023
Sweetness					
	Taste		32.18	**<.001**	.629
	Shape		0.06	.809	.003
		Taste x Shape	1.74	.150	.084
Sourness					
	Taste		77.38	**<.001**	.803
	Shape		1.00	.329	.050
		Taste x Shape	1.67	.166	.081

The shapes that were attached to the mugs did not significantly affect participants' ratings of the different taste solutions. Therefore, although it has been shown that people reliably match different tastes (i.e., sweetness and sourness) to different shapes (round and angular) that vary in terms of their curvilinearity (see Chapters 2-4), these crossmodal matches, or correspondences apparently do not always necessarily bias people's taste evaluations in an automatic manner. It is interesting to evaluate this result in light of the findings reported by Liang et al. (2013). The latter researchers reported that (near threshold) sweetness sensitivity can be enhanced by round, as compared to angular shapes. One explanation for the different results could be related to the fact that the two experiments included different tasks and stimuli. Liang et al. only used abstract shapes presented on a screen and not a receptacle with a shape. Importantly, the timing of

stimulus presentation was also different. What is more, while Liang et al. assessed sweetness detection with a binary response ("1" for detection or "0" for not detected), here VAS scales were used. Whilst the results certainly do not invalidate those of Liang and her colleagues, they do raise important questions concerning the experimental context needed for an effect of shape on taste to appear. On the basis of these results, one may think that the correspondences between basic tastes and shapes may operate at a higher level (i.e., perhaps based on expectations; Piqueras-Fiszman & Spence, 2015) rather than at a perceptual level (i.e. involving actual taste experiences). Another relevant point here concerns the ecological validity of the stimuli used. Perhaps, in the end, the shapes used on the mugs do not necessarily represent a realistic enough situation. Future research may aim to replicate Liang et al. study and to extend the results to other ecologically valid contexts.

7.4 General discussion

7.4.1 Shape classification as a function of taste

Both the results of the categorization task and of the rating task of Experiment 14 suggest that people both categorize and rate those packaging combinations including a congruent rounded shape, name, typeface, and lower-pitched sound as sweeter while categorizing and rating those combinations that are congruent in terms of their angularity as sourer. These results are consistent with previous studies in which associations between sweet and sour tastes, and names, sounds, and shapes have been assessed (e.g., Liang et al., 2013; Ngo at al., 2013; see also Aveyard, 2012). What is more, the results of Experiment 14 extend previous studies in that they demonstrate that each of these design elements in

the product packaging can be used to express the likely overall taste (or at least to enhance the consumer's expectations) concerning a product.

The lower-pitched tone was associated with sweet tastes, whereas the higher pitched sound was matched with the sour taste instead. While this is certainly consistent with the results reported previously by Simner et al. (2010), it is worth noting that they contradict the results reported by Crisinel and Spence (2009; 2010a, b). It is possible that the outcome of this research was somehow different to Crisinel and Spence's since the tasks differed quite significantly. In Experiment 14, the participants were not asked to match sounds and tastes but rather, the influence of the relative pitch of one of two sounds on participants' taste expectations was assessed. What is more, in Experiment 14, only two sounds were included and assessed in relationship to two very different tastes. It may, of course, be that the results obtained depend, in part; on what sweetness and sourness are contrasted with. Future studies may therefore assess whether sweetness is associated to a lower pitched sound when compared with bitterness, but with the relatively high pitched sound when compared to sourness.

The various attributes of a product's packaging (e.g., its typeface and shape) can be used to help communicate specific product attributes and to prepare the consumer for a particular consumption experience (see Spence, 2012, for a review). In this sense, then, incongruent product information derived from the packaging may modulate expectations in the mind of the consumer (no matter whether or not they happen to be consciously aware of that or not) about the taste of a product.

Potentially relevant in this regard, Darke, Ashworth, and Main (2010) have shown that unfulfilled expectations can increase product distrust and can tarnish the relationship

between consumers and brands (see also Anderson, 1973; Piqueras-Fiszman & Spence, 2012). Creating packaging that is congruent with a product's attributes can therefore help to form more appropriate expectations and can thus potentially enhance the consumer's consumption experience.

It is important to note that Experiments 7 and 14 are the first to provide evidence to suggest that the typeface in which the name of a product is written can actively contribute to the expectations about a product's taste. Again, it appears as if the same associations that people make between the shape of forms and tastes may be extended to the angularity of the typographies. That is, the angular typeface used in Experiment 14 was more associated to sourness, while the rounded typeface was more associated to sweetness instead. These results are consistent with previous findings that have led to the suggestion that typeface can convey meaning and actually influence brand perceptions and thereafter consumer memory (Childers & Jass, 2002; Doyle & Bottomley, 2004, 2006, 2011).

As is so often the case, further research will undoubtedly be needed in order to figure out the answers to different questions relevant to the predictive packaging design approach outlined here. For example, it would be interesting to determine whether the different multisensory features of the packaging influence the perceived taste of the actual product, and how these features interact with those tastes (e.g., how do 'sweet' visual features influence the perception of sweetness and sourness of the product itself). In addition, future research should consider more complex shapes and tastes. In Experiment 14, the focus was on rounded and angular shapes; however, packaging actually comes in a number of different shapes that may convey information about the taste of a product. Based on this idea, it is possible to think that taste-related shape moulds may become a potential tool for product marketing.

According to Calder and DuPuis (2010), packaging design has become a part of brand design. In this sense, then, packaging has become part of the strategies that can, if used effectively, communicate the essence of a brand to the consumer. Designers and product managers should therefore try to capitalize on this fact by trying to understand how various sensory cues are involved in building brand perception. As Walker (2012) suggested, crossmodal correspondences move across many dimensions of experience; for example, angular shapes are related to hard surfaces or materials, to high pitch sounds and to bright stimuli. Such knowledge could be used to develop communication via packaging design that is intimately tied to brand values, meaning, and product attributes. Research on the topic of crossmodal correspondences can therefore potentially empower designers by helping them to understand how well particular sensory attributes communicate specific components linked to a brand. What is more, these results highlight the importance of early intervention in packaging design to increase the success of product launches, as well as reducing the costs generated by understanding how to match packaging, with product attributes and brands in later stages of development. In the future, it could certainly be very interesting to roll out this predictive approach to packaging design to the internet, and thus assess the associations of consumers in different markets (Bremner et al., 2013; Woods et al., 2013).

7.4.2 Taste-shape congruence and taste perception

A number of points deserve to be mentioned here with regard to Experiment 15: First, Liang et al. (2013) suggested that the shapes they used in their experiment hedonically primed participants, thus enhancing sweetness recognition. That said, it may be the case that the timing and stimuli used in the present study did not prove to be an efficient prime. Alternatively, it is possible that whilst shape priming works at near-threshold levels, it

may not be as effective with clearly suprathreshold stimuli. Third, and finally, another possibility here that, in more realistic contexts in which, say, receptacles are used, shapes may influence expectations but that this may not necessarily carry over to influence perceptual processing.

Furthermore, one may wonder, for example, whether mugs and packages provide a different context for taste/shape correspondences. While it would be natural to consider a one-to-one relation between them, the foods or drinks that are contained within them can differ. As shown in Chapter 5, context can affect, at least, colour/flavour correspondences. That said, it is not possible to rule out that the differences found between Experiment 14 and 15 (apart from one using tastes and not the other) were also due to using different containers.

In addition to this experiment, two visual search pilot studies were conducted in order to assess the role of taste (sweet, sour, and water for control) on participants' shape search (where targets were round or angular). Each experiment included a different group of 10 participants. Using an experimental set-up that was similar to that used in the experiment presented in Appendix C, participants were given a task-irrelevant taste before each block of visual search trials. However, the results of these two studies failed to reveal an effect of taste congruence on shape search. This, together with the results of Experiment 15, raise questions about the level of information processing at which tastes/shapes may interact. Nevertheless, in the context of the replication crisis and the absence of null reports published in the literature (e.g., Pashler & Wagenmakers, 2012), studies such as those presented in Experiment 15 take on new meaning (see also Frick, 1995).

As a final note here, the experiment included in Appendix C evaluated the influence of flavour on visual search for congruent vs. incongruent objects. The results of that experiment indicated that flavour can facilitate search for congruent visual objects. These finding are preliminary but provide some first evidence for the idea that the association between flavour (a complex multisensory construct) and vision can be robust and can influence performance. This is interesting because people generally see food first and then eat, not the other way round. Further, it is expected that, for example, orthonasal olfaction influences attention as it provide initial cues before we eat (Chen et al., 2013). For the case of flavour, however, it is less clear why it would influence attentional processes (though we almost always see what we eat, which may reinforce those associations). While this is a fascinating area of research that I continue to explore, it will not be included in the present thesis. The study in Appendix C, however, could potentially provide useful for future experiments assessing the influence of taste on categorization and search (see Appendix C for further theoretical and experimental details).

CHAPTER 8

General discussion, limitations, future research, and conclusions

The first aim of the experiments reported in this thesis was to investigate the crossmodal correspondence between taste/flavour (tastants and words) and visual information (specifically, colour and shape), as well as their influence on human taste perception and visual search for flavour information. In addition, the present thesis also evaluated the ways in which these crossmodal correspondences express themselves in the context of multisensory packaging design, an area that has received increasing attention from both psychologists and practitioners in fields as diverse as marketing and design. Over six experimental chapters (Chapters 2-7), fifteen experiments have been reported (a number of pilot and complementary experiments have also been described in footnotes throughout the text). The experiments reported in Chapters 2-5 dealt specifically with crossmodal associations between taste information and visual attributes (specifically colour and shape), whilst the experiments reported in Chapters 6 and 7 dealt with the influence of such crossmodal correspondences on both visual and taste information processing. In particular, the experiments reported in the latter two chapters used go/no go and visual search tasks in order to assess how taste/shape and flavour/colour congruence may facilitate information processing. In Section 8.1, the results of the various streams of experiments are summarized in light of the extant theories of crossmodal associations. In Section 8.2, the limitations of the different experiments and potential future directions are

described. Section 8.3 draws together some of the general conclusions to have emerged from this thesis.

8.1 Summary of findings and framework

8.1.1 A framework for crossmodal correspondences between taste and shape

8.1.1.1. Understanding the correspondence between basic tastes and abstract shapes

In Chapter 2, six experiments designed to assess how and why people match basic tastes and abstract shapes were reported. Experiments 1-3 revealed that participants tended to associate basic tastes with the roundness/angularity of abstract shapes consistently. Specifically, the experiments reported in this chapter documented a tendency for people to match sweetness with roundness, while matching all of the other basic tastes, namely bitter, sour, salty, and umami, to more angular shapes instead. While these results are in agreement with previous research in as far as they suggest a crossmodal association between sweetness and roundness (e.g., Ngo et al., 2013; Spence, 2014), they also demonstrate that there is no apparent distinction in terms of the shape properties that participants associate with the other four basic tastes (bitter, sour, salty, and umami). Why would this be the case? Experiments 4 and 5 were designed to assess the underlying mechanisms that were hypothesized to explain why people associate specific tastants with particular shapes (or at least curvilinearity vs. angularity).

Experiment 4 revealed that taste liking helped to explain, in part, the roundness/angularity ratings of tastes. That is, the more liked the taste, the more round (and less angular) the shape that was chosen as matching. Notably, participants reported liking the sweet taste

more than any of the other tastes, and also liking the round shapes more than the angular shapes. This, in turn, points to a hedonic mechanism underlying taste/shape correspondences. Thus, the results reported in Experiment 4 suggest that the crossmodal correspondence between taste and shape can be thought of, at least partly, in terms of affective correspondences. However, in light of the fact that taste liking only predicted a part of the variance in terms of participants' taste roundness/angularity ratings, Experiment 5 was designed in order to replicate and further assess the role of concentration on the roundness/angularity ratings of tastes. Experiment 5 replicated the findings of Experiment 4 and also revealed that the concentration of the tastant influenced participants' roundness/angularity matches. That is, the more a tastant was liked, the more round, and the less liked, the more angular the shape that was chosen as matching. Further, the more concentrated the tastant, the more angular, while the less concentrated, the rounder the shape that was chosen as matching. Note that the experiment presented in Chapter 4 revealed essentially the same results as in Chapter 2 in that round typefaces were associated with the word sweet, whereas more angular typefaces were associated with the other taste words. With that in mind, these results will be summarized and discussed in this section of the general discussion.

In Chapter 4, the results obtained from the experiments discussed in Chapter 2 were extended to a frequently used design element in both product packaging and taste-related objects, namely typeface. A number of different typeface designs, varying in terms of their roundness/angularity, boldness, orientation, and whether or not they were italicised were used in a task involving basic taste words. The results of Experiment 7 revealed that participants tended to associated rounder typefaces with sweet and angular typefaces with the other tastes. Research has demonstrated that the roundness/angularity of typefaces

tends to convey emotion and potency (as suggested by the literature that has used the semantic differential technique, Osgood et al., 1957) similar to the way in which shapes convey emotion (e.g., Collier, 1996; Poffenberger & Barrows, 1924; Tannenbaum et al., 1964; Morrison, 1986). Therefore, it seems reasonable to extend the framework for abstract taste/shape associations to typeface taste associations.

It is well known that unisensory stimuli can evoke specific affective responses (e.g., Barrett, 2009; Collier, 1996). That is, common affective properties of objects can be perceived through the different senses (see also Royet et al., 2000). Crucially, researchers have acknowledged for a long time the possibility that certain crossmodal associations may reflect the hedonic matching of sensory information (Marks, 1978; Spence, 2011; Werner, 1957). However, not until recently have scientists started to argue that crossmodal correspondences may be mediated by affect (see Collier, 1996; Palmer et al., 2013; Schifferstein & Tanudjaja, 2004). Moreover, other amodal dimensions, such as, for example, stimulus brightness (e.g., Marks, 1989; Martino & Marks, 1999) or intensity, may explain the way in which people match stimuli across the senses (Parise & Spence, 2013). The idea here is that people may match more intense stimuli in one sensory modality with more intense stimuli in another modality (see Stevens, 1957). In chapters 2-4, the influence of taste hedonics and taste intensity on taste/shape correspondences was tested.

While the results presented in Chapters 2-4 certainly point to the fact that the hedonic and sensory-discriminative (in particular, intensity) properties of tastes and abstract shapes (potency in terms of the semantic differential technique) can influence the way in which people match them (e.g., Collier, 1996; Marks, 1978; Spence, 2011), further inspection of such results is undoubtedly required. As mentioned earlier, Bremner et al., (2013)

found that people in a rural community in Namibia, who do not use written language, matched increasing bitterness with round shapes, which contrasts with the results from Westerners who showed the opposite pattern of results (e.g., Ngo et al., 2011). Bremner and his colleagues acknowledged the possibility that food or shape preference can vary as a function of culture, and therefore, influence taste/shape correspondences. That said, one may wonder whether affective correspondences are independent of statistical correspondences. Indeed, the fact that taste identity, hedonics, and stimulus intensity contributed to explaining the roundness/angularity ratings documented in Experiment 5 suggests, as highlighted by Parise and Spence (2013), that the associations between taste and shape cannot be explained by only one of the types of correspondences outlined by Spence (2011).

Note that Osgood et al.'s (1957) suggestion, emerging from their work on the semantic differential technique, was that any object could be rated in terms of three affect-related bipolar dimensions, namely, valence (e.g., good-bad), activity (e.g., fast-slow), and potency (e.g., weak-strong). Such dimensions were extracted from various adjectives/dimensions used in their original studies (see also Hiessl & Skrandies, 2013; Woods et al., 2013, for recent examples). In effect, Osgood et al.'s suggestion was that those dimensions constituted general characteristics that could be used to describe objects. Since the introduction of the semantic differential technique, some researchers have proposed that common dimensions of connotative meaning may explain the way in which people match information across the senses (Walker et al., 2012, for one example).

Similarly, Martino and Marks (2001) developed their semantic coding theory which states that high level mechanisms that connect information across the senses may evolve from developmental experiences with various percepts that are coded into language, which can

affect multiple levels of human information processing. The semantic coding hypothesis makes four specific claims about cross-sensory correspondences: 1. That they can emerge from early sensory mechanisms but mirror semantic mechanisms; 2. That experience with different percepts and the language that is used to describe those percepts can generate an abstract network of meaning; 3. Congruent cross-sensory inputs are recoded into such networks of meaning; and 4. The extent to which stimuli from different senses are perceived as corresponding depends on the context (e.g., whether the relevant sensory dimension in an experiment is manipulated orthogonally or not); that is, judgments of correspondence are relative to the contrast that arises as a result of the manipulation of the stimuli (this may explain, in part, the findings of Experiment 14). One possibility here is that an early sensitivity to different associations between sensory information (e.g., Walker et al., 2014) shapes an amodal network of meaning (see also Walker, 2012; Woods et al., 2013). Perhaps both shapes and tastes are categorized along a hedonic and intensity (or potency, as defined by Osgood et al., 1957, for the case of shapes) dimension, which reflects an early interaction with such sensory stimuli, and may, in turn, explain the way in which people match them.

On the basis of the experiments reported in Chapters 2 and 4, it is clear that both stimulus hedonics and intensity explain, in part, the association between tastes and shapes. Further research, however, is undoubtedly still needed in order to help clarify the way in which the putatively different mechanisms underlying crossmodal correspondences interact. Based on the literature and the experiments reported in this thesis, it is difficult to think of the crossmodal correspondences between tastes and shapes as purely structural, statistical, linguistic, or affective. While people may learn what tastes/shapes to like and dislike (statistical and affective), they may then code that into language. Potentially, such

putatively different mechanisms may form the building blocks of cross-sensory correspondences, which interact while making sense of the multisensory world.

8.1.1.2. Tastes and packaging shapes

The experiment reported in Chapter 3 dealt with taste words, abstract shapes, and packaging shapes. In a task involving abstract shapes and packaging shapes, people consistently matched both of them to specific taste categories (e.g., sweet, sour, bitter, salty). However, the roundness/angularity dimension appeared to be less essential when concrete packaging shapes were used. The results presented in Chapter 3 revealed that when participants were presented with concrete packaging shapes, the roundness/angularity dimension of those packaging shapes did not seem to influence their expected taste ratings.

Previous experience with a specific product class or category may be a key element when deciding which packaging shape is more likely to contain a product with a specific taste quality (e.g., soft drinks tend to be packed in round cans and canned tuna, too, Peracchio & Tybout, 1996; Spence, 2012). In effect, this idea raises questions about the role that concreteness/abstractness of shapes (or sensory objects in general) can play in driving crossmodal correspondences[11]. Here, semantic congruence may well explain the specific associations people make between packaging shapes and tastes. On the other hand, abstract shapes may make people rely on other (more abstract) elements, such as the

[11] The idea that concreteness/abstractness of visual objects can influence crossmodal correspondences can also be considered when it comes to typefaces. For example, one may wonder whether a brand's signature typeface such as Coca Cola's typeface would be differentially matched to tastes.

emotional response it evokes (e.g., Lyman, 1979). With that in mind, one may wonder whether two interrelated semantic systems define the associations between the senses, with one of specific object categories and features tied to such categories, and another, more abstract, which builds from abstract interrelations that may be founded on attributes such as affect and intensity.

Specific product representations can be activated by means of exposure to specific packaging shapes (e.g., a fizzy drink can), and people may respond to them as a function of the elements that belong to that representation (semantic congruence). On the other hand, when an abstract shape (and perhaps a novel packaging) is utilized, people may depend more on its abstract visual features (e.g., aesthetic elements, e.g., Palmer et al., 2013) that are manipulated in an experiment in order to guide their taste ratings (see Chapter 2). Previous research suggest that, when presented with a specific product, people make sense of it by contrasting the available sensory information with semantic knowledge such as that of product categories (Schoormans & Robben, 1997). The categorization process involves the recognition of a product's origin, class affiliation, qualities, and purpose, among others (Crilly, Moultrie, & Clarkson, 2004). The more 'typical' the product, the easier it will be to classify it as part of a category (and respond as a function of it), however, such 'typicality' is related to familiarity with a product, since it leads to narrower and more easily recognizable categories (Felcher, Malaviya, Mcgill, 2001). The suggestion here then is that it is the experience with a specific product class which drives such categorization process (see also Spence, 2012). In Chapters 2 and 4, a number of different abstract shapes and typefaces were used as anchors for the rating scales, and no differences were found across them as a function of the taste. One may want to argue that the concrete shapes of packaging combine both angular and rounded

edges. However, in Experiment 6, packaging image moulds that were clearly round or angular were used and were not associated by the participants in the direction that would have been predicted based on the results reported in Chapter 2. For example, the image mould generally used for tuna (Figure 8.1A) or canned salty products (Figure 8.1B), which is itself round, was rated as significantly saltier. In addition, certain packaging shapes clearly defined by their roundness (Figure 8.1C-D) were not rated as significantly higher in any of the taste attributes that were included in Experiment 6.

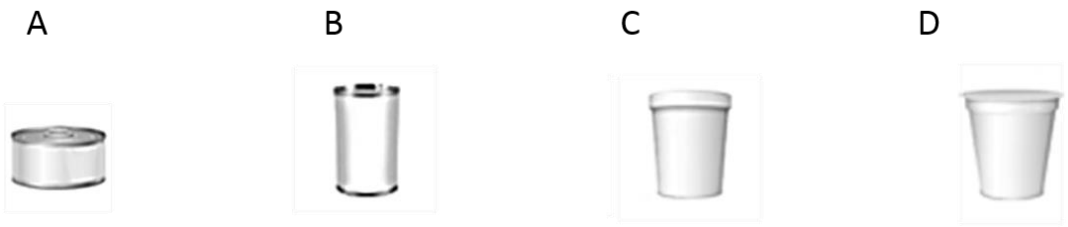


Figure 8.1. Packaging examples used in Chapter 3. The round packaging moulds A and B were rated as containing salty products, while the round packages C and D, did not have any specific taste association.

The results of the experiment reported in Chapter 3 suggest that the way in which people match abstract shapes with tastes and packaging shapes with tastes differs (though they may, of course, interact, as seen in Experiment 14). It is, however, worth mentioning that over-and-above any such associations, there may be a fundamental preference for round shapes that, overall, could lead people to associate a round packaging shape with sweetness. Following on from Bar and Neta's (2006) study, Westerman et al. (2012) used several different packaging shapes and demonstrated that, in general, people prefer round packaging shapes more than their angular counterparts. One may also wonder whether such a general preference would make people associate rounder packaging shapes,

overall, with sweeter tasting foods, as compared to the other tastes. This would point to a more abstract network of meaning which codes specific sensory dimensions. I would argue that this notion provides a crucial future direction for researchers interested in the communication of taste information via the inclusion of specific design elements. In a future study, one may follow Bar and Neta's (2006) experimental design, by including a large number round and angular products that later be grouped together in order to see whether specific taste ratings arise for round and angular packages, overall.

8.1.2 A framework colour/flavour correspondences

The experiments reported in Chapter 5 moved on to assessing flavour/colour correspondences and their application to packaging design. Across three experiments, a significant effect of participants' cultural background and context (e.g., packaging and receptacle type) was documented for the case of flavour/colour and odour/colour correspondences. This, in turn, points to the idea that these correspondences may be mediated, at least in part, by the statistical regularities of the environment, and potentially, the semantic congruence that arises from the exposure to colours in context (e.g., Elliot & Maier, 2012). In Experiment 8, the way in which people matched odours to colours in the UK and France, was assessed. While most of the associations remained the same across the two countries (adding new information to previous research comparing seemingly more different cultures, see Levitan et al., 2014, for an example), some specific differences were documented that reflected the culturally-dependent nature of odour/colour correspondences. Specifically, the colours selected for caramel and mint chlorophyll differed. For the first two, differences were observed in the secondary shades

of the colours that were selected (pale yellow in UK, *vs*. orange in France for caramel), and for the latter, in terms of the main colour selected (blue-green in the UK and green in France). Experiment 8 also revealed a correlation between odour pleasantness and intensity and colour saturation and brightness, which adds evidence to the claim that affect and intensity are a relevant component driving colour/odour correspondences (Schifferstein & Tanudjaja, 2004). Once again, the different sensory information that conveys the same hedonic information may tend to go together, and picked up from the regularities of the environment.

In Experiment 9, a matching task was used in order to assess colour/flavour label associations in three countries: Colombia, China, and the UK. Several differences were observed between the three countries, however, independently of the country, participants associated cucumber with green and tomato with red. It was suggested that previous experiences with the flavour stimuli, or the objects from which those flavours are derived, would presumably influence such matchings. Crucially, those pairings that are consistently found in the statistical regularities of the environment, were reflected in the matching task across countries (e.g., Aslam, 2006; Piqueras-Fiszman et al., 2012). Such regularities are coded into a semantic system that includes information about the category as a whole (e.g., flavour), as well as its different features (e.g., red for the case of tomatoes), and therefore reflecting the attributes that tend to go together (Humphreys & Forde, 2001).

Experiment 10 furthered the results of Experiment 9 by assessing colour/flavour associations and the role of receptacle type, in the context of beverages, in China and the USA. Once again, a number of differences were found, thus suggesting that the cultural background of the participants and the type of receptacle in which a beverage is shown

can influence participants' associations. The results of this experiment may shed some light on why abstract and concrete packaging shapes would be associated differently to flavour categories (see Chapter 3). The interaction between cultural background and receptacle reveals that within cultures, specific colour/receptacle associations exist (see Kauppinen-Räisänen & Luomala, 2010). As specific receptacles are used for particular purposes (e.g., alcoholic beverages, juices, fizzy drinks), the flavour that people attribute to a colour depends on the type of receptacle that is used in a particular cultural context.

Taken together, the results of Experiments 8-10 demonstrate that colour/flavour and colour/odour associations are influenced by the cultural background of the participant and the specific context in which they are evaluated (e.g., product category or receptacle type). Importantly, those pairs of cross-sensory stimuli that happen to be present across environments, or that correspond to natural pairings that are found in the environment, may be shared across cultures. In that sense, colour/flavour and odour/flavour correspondences can be acquired by means of a process of associative learning, that is, by picking up the statistical regularities of the environment (Connolly, 2014; Madden et al., 2000; Taft, 1997). It is worth mentioning that these associations may well create a concrete network of meaning that differentially ties attributes such as colours and flavours as a function of their co-occurrence in specific contexts (Elliot & Maier, 2012, for the contextual nature of colour meaning). Such regularities may change from one context to another next, while some may be constant across countries (e.g., tomatoes seem to be red for Colombian, French, Chinese, and British people, see also Piqueras-Fiszman & Spence, 2011; Piqueras-Fsizman et al., 2012).

One key question that remains to be answered from Chapter 5 concerns the mechanism that explains the associations between odours-flavours and colours. The literature on

object recognition may shed some lights here. Colour is undoubtedly an informative cue about an object's identity. Previous research has suggested that colour diagnosticity, or the extent to which a colour is associated with an object, influences object recognition (e.g., Bramão, Reis, Petterson, & Faísca, 2011; Tanaka & Presnell, 1999). Whether an object is highly- or lowly-diagnostic (or symptomatic) is thought to depend on the co-exposure of objects and colour. In the context of colour/flavour associations, colour diagnostics are key, as food colour provides relevant information about the state of the food itself (e.g., ripeness of a fruit). Further, food objects in the natural world and the supermarket tend to be associated with specific colours (e.g., 'a red apple') (Lewis, Pearson, & Khuu, 2013). Importantly, it has been suggested that even when people are presented with colour diagnostic achromatic stimuli, such stimuli are perceived as slightly tinted in their related colour (an effect that appears to be stronger for highly colour diagnostic, e.g. pictures of fruits, see Olkkonen, Hansen, & Gegenfurtner, 2008). Moreover, research from Price and Humphreys (1989) demonstrated that colour can facilitate the classification and naming of objects of structurally similar categories such as natural objects. These ideas point to the fact that stored knowledge about an object is key not only in object recognition but also the way in which people associate colours and flavours, as the strength of an association may depend on elements such as an object colour-diagnosticity. Presumably, those flavour objects that correspond to natural categories, in contrast to artefacts, may have a stronger colour identity.

Whilst it is likely that such colour/flavour and colour/odour correspondences based on concrete objects (e.g., a specific flavour) are partly based on the co-occurrence of colours and odours-flavours in foodstuffs they have also been shown to be mediated by affect as shown in Experiment 8 (see also Schifferstein & Tanudjaja, 2004), or the association of

those dimensions that happen to be shared across objects (and thus more abstract, e.g., odour intensity and colour brightness). Indeed, one may think here that both semantic knowledge and more abstract cross-object knowledge (e.g., common hedonic properties, or intensity) may both interact in the above correspondences. Two points may be considered in this regard: 1. The level of semantic congruence (based on experience) of different sensory information is a key aspect in colour/flavour associations (see also Chapter 6). 2. As mentioned before, it is likely that the way in which people associate sensory dimensions that do not necessarily belong to a specific object identity or meaning can also be grounded in affect (e.g., Shenhav et al., 2013), and therefore affect may always explain, to a certain degree, the way in which people associate information across the senses (see also Marks, 1996). Indeed, people from different countries can have different food (e.g., Prescott & Bell, 1995) and colour (e.g., Ou et al., 2012) preferences, which in turn could explain the crossmodal associations (as suggested by Bremner et al., 2013). While the aforementioned points seem reasonable in explaining why people match colours and odours, it is also possible that people match flavour stimuli and colours as a function of colour and flavour intensity, or colour brightness and other attributes of flavour stimuli. Indeed, research has revealed that chromatic information can provide complementary information about the identity of food objects (Spence et al., 2010), while colour intensity can be systematically matched, for example, to foods' trigeminal sensations (Shermer & Levitan, 2014), and potentially, intensity of any sensation.

The contribution of semantic, hedonic, or intensity matching can potentially be isolated experimentally. However, it our daily lives, we may rely in all those sources of information together when relating colours and flavours. Notably, the way in which the colour/flavour matching tasks were conducted in the present thesis most likely reflects

semantic congruency effects since discrete colours and flavours were used. Therefore, the results may have revealed the most common associations that people are exposed to in their daily lives, which in turn, may explain both culture- and context-related differences. As for the experiment in which colour/odour associations were tested, while semantic congruence effects may have well been found (matching an odour to its source's colour), the correlation between odour pleasantness and colour saturation also indicates the role of affect over-and-above the semantic congruence effect.

By using taste and flavour words throughout this dissertation, it is clear that crossmodal associations are coded in language categories and that elements that belong to the same category (cucumbers, green), or that are congruent, tend to have a closer semantic relationship. Again, these results point back to the idea suggested by Parise and Spence (2013) that the different types of correspondences are not mutually exclusive. One suggestion here would be for future research to focus on the interaction between the different classes of correspondences introduced by Spence (2011).

From this dissertation, it is noticeable that the semantic association between colours and odours, and colours and flavours vary as a function of country. This, together with the evidence reported in Chapter 6, suggests that the strength of the association between colours and flavours is influenced by the statistical regularities to which participants are exposed, and the way in which they construct meaningful objects from them.

8.1.3 Taste/flavour-vision correspondences and visual and taste information processing

8.1.3.1. The role of colour/flavour congruence on visual and taste information processing

Based on the results reported in Chapter 5, Chapter 6 presented three experiments designed to assess the way in which packaging colour and flavour label congruence (e.g., red colour and tomato flavour label) and incongruence (e.g., red colour and cucumber flavour label) would influence flavour information search in food products. In addition, the experiments in Chapter 6 were designed to assess whether participants' search times would vary as a function of more or less naturally co-occurring colours and flavours. Experiment 11 demonstrated that people find flavour labels more rapidly when the packaging colour is congruent than when it is not I.e., when it is incongruent). Experiment 12 ruled out a confounding of Experiment 11 by demonstrating that the more frequent presentation of congruent pairings used in Experiment 10 was not solely responsible for the congruency effect. Finally, Experiment 13 revealed that when the packaging colour was incongruent, those flavour words that were more strongly associated with a specific colour yielded slower RTs and more errors (that is, they revealed Stroop interference) than those that were less strongly tied to a specific colour. The experiments presented in Chapter 6 developed three novel elements: 1. Studying colour/flavour words association and association strength, 2. The Stroop paradigm is extended to the case of visual search, and 3. This paradigm is introduced to the context of multisensory packaging design.

Colour can interfere with participants' responses to flavour concepts that are semantically unrelated to colours, in a Stroop-like fashion (e.g., Durgin, 2000; MacLeod, 1991; Nijboer

et al., 2006; Richter & Zwaan, 2009). A particular flavour word can activate object-related representations that then exert a top-down influence on the search tasks (Eimer, 2014). In other words, participants' semantic knowledge about the target can influence the way in which participants select a target among the distractors (Belke, Humphreys, Watson, Meyer, & Telling, 2008; Meyer, Belke, Telling, & Humphreys, 2007). When the actual object fits the participant's expectations, facilitation can be observed; otherwise interfere may be seen.

Once again, it is worth highlighting the results from Experiment 13. Search efficiency was influenced by both colour/flavour word congruence and association strength. These results are particularly intriguing given that colour is preattentively processed and can, in turn, produce near-flat slopes when used as a guiding feature (Wolfe & Horowitz, 2004). In Experiment 13, it appears that although colour could have guided search, it did not result in efficient search slopes. However, research has also suggested that when a mismatch is found (e.g., an incongruent color after a flavor cue) by the participants, a deeper search is performed, which can influence RTs (Grossberg et al., 1994). Moreover, in Experiment 13 the target-distractor similarity could vary from trial to trial (the distractors could have had the same colour of the target-associated colour). As suggested by Wolfe (2014), the smaller the difference between targets and distractors along a preattentive feature, the less efficient the search (not to mention distractor heterogeneity, see also Duncan and Humphreys, 1986). The results of Experiment 13 will require a closer inspection with further experimental data.

As mentioned in Section 8.1.2, due to the nature of the tasks, it is most likely that the effects reported in Chapters 5 and 6, reflect the semantic congruence between colours and flavours. The most common relations to which people are exposed to, lead to the

associations between specific colours and flavours. It is worth highlighting that the strength of the association between a word and a specific colour does influence the strength of the interference a colour would exert on naming the word (e.g., Berthet et al., 2011; Proctor, 1978). In Chapter 6, it was hypothesized that those flavours that were more frequently associated with a specific colour across cultures (as shown in Chapter 5), would potentially reflect a stronger semantic association and consequently have differential effects in the visual search task for flavour words. This hypothesis was confirmed in Experiment 13, since interference was higher for such flavour words. The strength of the association between colour and flavour words is crucial when searching for flavour information in food products. A particular flavour word can thus activate a representation that may then exert a top-down influence that interferes with semantically-unrelated information (Eckstein, 2011; Macleod, 1991; Theeuwes, 2010).

As suggested by Berthet et al. (2011), an alternative explanation to the response interference found in their results and those I report in Experiment 13, is the spreading activation theory (Anderson, 1983; Collins & Loftus, 1975; Quillian, 1967). Here, the idea is that a semantic network with nodes representing exemplars with weaker and stronger associations may be activated differently. So for example, a node with a stronger colour identity could be tomato which, as shown in Chapter 5, is more strongly associated with red, independently of the cultural background of the participants. In addition, tomatoes tend to be red in most of its presentations. On the other hand, a node with a weaker colour identity could be chicken, in that, in the context of crisps may be associated by some with orange, but, overall, foods with chicken not always come in orange, it is also an animal, and so on. With the aforesaid in mind, a flavour word may activate such representations differentially as a function of its colour identity in a semantic network.

In the context of consumer behaviour, the incongruency theory (Mandler, 1982), which is not necessarily incompatible with the interference or spreading of activation accounts, has been widely used in order to understand the way in which consumers react when congruent or incongruent information is presented. This theory proposes that processing will be more demanding for consumers when they are presented with information that is inconsistent or incongruent (i.e., low probability of occurrence) with their previous expectations, as compared to when presented with congruent information (Heckler & Childers, 1992; see also Miller & Kahn, 2005). So, for example, when the name of a flavour (e.g., tomato) is presented with the incongruent packaging colour (e.g., blue), people require more demanding processing in order to resolve this incongruency. In contrast, if the flavour word is presented with a congruent colour (e.g., red), processing will be less demanding. In particular, this theory proposes a number of effects on consumer behaviour, depending on the level of congruency. For example, while people may react negatively when the information is very incongruent, they will react fairly favourably when it is congruent, and more positively when the information is moderately incongruent. The latter, according to Mandler (1982), may be due to the positive feelings that will follow the consumer's process of finding a way to make sense of the incongruence (and actually be able to do it).

The aforementioned accounts would all seem to agree that people form associations between colours and flavour words based on their prior experience. Furthermore, when information is presented in a way that is incongruent with such prior experience, it will affect the fluency with which this information is processed. It would therefore be interesting for future research to assess, for example, the frequency of co-occurrence of colours and flavours across product categories, and in different countries, in order to

assess the regularities of the marketplace. With those two elements one may clarify the contribution of both the environmental regularities, and those of the marketplace. Potentially, both interact when associating colours and flavours in general, and in specific cultures and contexts (e.g., a product category).

8.1.3.2. The role of taste/shape congruence on visual and taste information processing

In Chapter 7, the final empirical chapter of this dissertation, two experiments designed to assess whether taste/shape correspondences influence classification of, and search for, both abstract and packaging shapes, were presented. In Experiment 14, participants were shown to categorize as sweet those packages whose shape, name, and typeface were round more frequently than those which include such features in their angular form. The latter were more frequently categorized as sour. Based on the results reported in Chapters 2-4, a congruency effect was observed in that people categorized and rated a product's packaging as being more likely to contain either a sour or sweet product as a function of the roundness/angularity of the different design elements. Such results not only add evidence to the ideas discussed in Section 8.1.1, but also indicate that the roundness/angularity of the different design elements can modulate the classification of products as a function of their likely taste (see also Becker et al., 2013).

Finally, Experiment 15 assessed whether shapes would influence the perception of a taste's quality (sweet, sour), intensity, and hedonics; however, the results failed to reveal any effect of shape in the perception of taste. As this contrasts with the results of another recent study by Liang et al. (2013), a number of points should be mentioned here: 1. Liang et al. suggested that the shapes used in their experiment hedonically primed participants,

thus enhancing the recognition of sweetness. That said, it may be the case that the timing and stimuli used in the present study did not prove to be an efficient prime. 2. Alternatively, however, it is also possible that whilst shape priming may work for near-threshold stimuli, it may not be as effective for suprathreshold stimuli. 3. Finally, another possibility is that, in more realistic contexts in which, say, receptacles are used, shapes may influence expectations but not necessarily the perception of the taste. This latter point becomes significant in light of the results of Becker et al. (2011) who only found an effect of packaging angularity in taste perception in those who were sensitive to design.

The results presented in Chapter 7 suggest that taste/shape correspondences may act more at the decisional level (Experiment 14) rather than at a perceptual level, which contrasts with other types of correspondences documented, for example, between vision and audition (e.g., Spence, 2011). However, further research may be needed here as the results of the latter contrast with the results obtained by Liang et al. (2013). One possible explanation for these contrasts concerns whether the experimental materials used in Experiment 14 were actually representative of an ecologically valid situation. Possibly, if one manipulates the actual shape of the cup, or changes the logo (round or angular) of a soft drink, a more ecological approach can be taken.

8.1.4 Common framework for taste/shape and flavour/colour correspondences

Based on the summary of findings and discussion presented in Sections 8.1.1-8.1.3, it is possible to argue that the way in which people match taste/flavour and visual information, or tastes and shapes and colours and flavours, cannot be explained by a single factor and may, in turn, depend by a number of factors such as those summarized in Figure 8.2,

which in turn may guide the expectations of taste information by means of visual attributes.

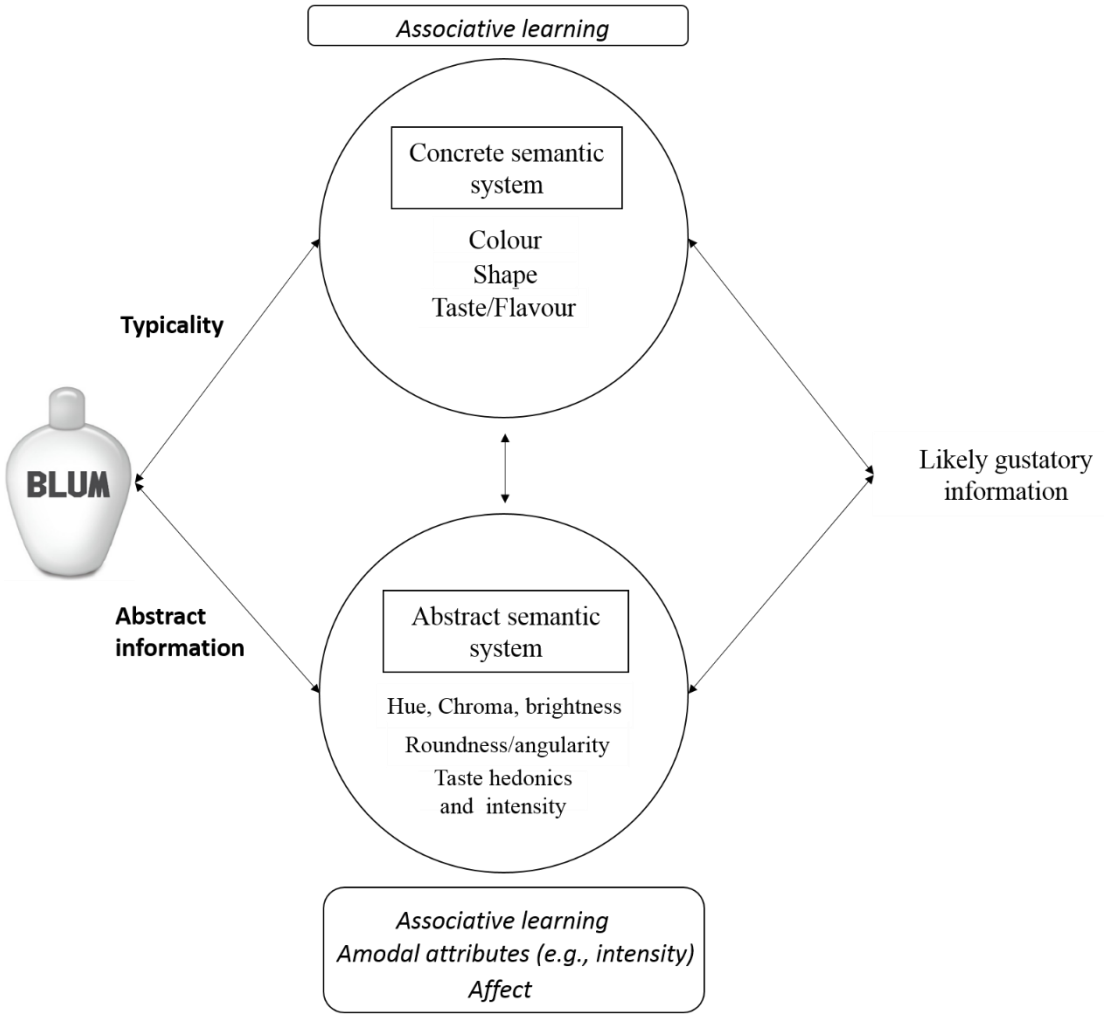


Figure 8.2. Various elements influencing the way in which people associate taste and visual information in the context of product packaging, which provide guidelines for conveying such information.

It is here where I take a different approach from those who argue that semantic congruence should be taken in as crossmodal correspondences (e.g., Piqueras-Fiszman &

Spence, 2012; Piqueras-Fiszman et al., 2013). In addition, while I take certain elements from Parise & Spence (2013) in the way in which I will define crossmodal correspondences, I will bring in some new ideas to their proposed model. Note that the focus of the following analysis concerns the communication of taste/flavour information by means of visual attributes.

Parise and Spence (2013) defined crossmodal correspondences as those mappings between two or more features from different senses (e.g., loudness and lightness). In addition, they suggest crossmodal correspondences generally occur across polar dimensions (e.g., dimensions that can be quantified as "more or less than", such as saturation, pitch, elevation, roundness/angularity, intensity, valence) and can induce congruency effects, at either perceptual or decisional levels. Parise and Spence make a distinction between semantic congruence or knowledge and crossmodal correspondences. While the first is thought to provide redundant information about the same object in the environment (e.g., "a dog" and "the bark of a dog"), the latter generally refers to complementary (non-redundant) cues which reflect the apparently arbitrary associations people make (such as "sweetness" and "roundness"). This latter distinction is critical in light of the present thesis. When processing a product's packaging, semantic knowledge will undoubtedly interact with more abstract attributes such as those polar dimensions that happen across objects that do not necessarily belong to a specific identity or meaning, though they can be matched to it (e.g., taste quality).

Where I take distance from Parise and Spence (2013) concerns the implications of their taxonomy of crossmodal correspondences. While I think that their classification in terms of structural, statistical, linguistic (and possibly affective) is useful, it is difficult to separate the different types and potential mechanisms from one another (as they are not

mutually exclusive). That said, based on the literature review and the experiments reported in the present thesis, I also built the proposed framework from theories such as that of Martino and Marks (2001), and develop it by proposing a hierarchical approach to crossmodal correspondences. In other words, in this view, certain types of correspondences (e.g., structural) are thought to provide the building blocks that provide the foundation upon which the others may be able to take shape. Consequently, it can be hypothesized that crossmodal equivalence may build from the so-called amodal attributes (Bahrick & Lickliter, 2000, 2004; Lickliter & Bahrick, 2000, 2001, 2004, structural correspondences in Spence, 2011 and Parise & Spence, 2013, terms) such as stimulus intensity (e.g., Lewkowicz & Turkewitz, 1980; Marks, Szczesiul, & Ohlott, 1986), as well as from an organism's response (i.e., affect), resulting from such (cross)sensory stimulation (Collier, 1996; Shenhav et al., 2013). In effect, it has been suggested that early in life people react to quantitative changes in stimulation (e.g., Bonn & Cantlon, 2012; Walsh, 2003). Moreover, research has pointed to common hedonic mechanisms across all the senses (e.g., Royet et al., 2000). Such quantitative processing and affective mechanisms may set the foundations for the relationships between the senses. With experience, people pick-up on many of the statistical regularities of the environment, and with language, a semantic space with abstract (across objects and categories) and concrete (object and category-related) representations (e.g., Martino and Marks, 2001, for a similar proposal). The first can be understood as crossmodal correspondences based on Parise and Spence (2013) definition, while the latter may rather correspond to what Spence (2011) call semantic congruence.

When communicating taste/flavour information by means of visual attributes, stored concrete (semantic) knowledge about products and/or flavours should indeed be taken

into account (see Chapter 3 and 5). That is, people's previous experience with a specific object, such as a product or product category, and its associated features, will undoubtedly guide people's expectations and classification of a package (Schoormans & Robben, 1997; cf. Humphreys & Forde, 2001). Both concrete information (semantic knowledge about the object) and more abstract information, generally dimensions found across objects' sensory features (crossmodal correspondences), provide the basis of my proposal for taste/flavour communication via visual attributes in the context of packaging design (see also Haverkamp, 2014, for a similar theoretical approach, namely, synesthetic design). That proposal is presented in Figure 8.2. According to this proposal, two interacting systems, namely, a concrete semantic system (semantic knowledge) and an abstract semantic system (crossmodal correspondences) may act in parallel and interact while relating information across the senses.

In the concrete system, people may learn which attributes tend to go together in specific, concrete, situations. So for example, some people may learn that, chicken labelled crisps are typically presented in orange packaging in one country but not another, while most people will learn that cucumbers tend to be green (note that the association strength or object colour-diagnosticity can differentially influence the associations). When a colour is consistently used in relation to a specific flavour (across cultures or within a specific product context) people may learn that such attributes go together for a specific product (e.g., crisps).

In parallel, the abstract system (crossmodal correspondences) may be acquired through basic mechanisms of quantitative processing, affect, and the so called amodal attributes such as stimulus intensity (taste intensity, colour brightness). In addition, people may learn that two cross-sensory dimensions go together because they co-occur (statistical)

across several specific taste/flavour objects (colour and ripeness) or because they shared a common feeling (possibly taste and shape affect). So, for example, people may learn that sweet taste and flavours are generally matched with reddish colours because there is a high prevalence of such attributes (e.g., ripeness of fruits, see Maga, 1974). Thus people may extract such commonality over-and-above the specificity of a specific flavour object.

Note that the two systems may interact and hence influence each other, depending on the level of abstractness/concreteness of the visual information. When an object is concrete for a particular person, or at least semantically similar to known objects, that person may partly associate taste/flavour information as a function of the semantic knowledge of such objects. On the other hand, the abstract (and potentially novel), people may rely on the network of meaning that has been built from the abstract semantic space of polar dimensions. It is worth mentioning that congruence in the concrete semantic network of meaning can influence information processing (both visual and taste) as a function of the strength of the association between sensory attributes (a colour can influence the discrimination of a related flavour). However, it is less clear how congruence of information from the abstract system influences gustatory and visual information processing. Whilst it likely operates at the level of expectations as shown in Chapter 7, further research will be needed in order to clarify the circumstances under which congruence exerts a perceptual visual and taste-related effect. This proposal does not aim to provide a comprehensive framework for cross-sensory correspondences, but rather aims to illustrate the different studies reviewed in this thesis, as well as the empirical information provided. For example, the two semantic systems mentioned may indeed belong to a single semantic system with different levels of information (e.g., Humphreys & Forde, 2001). Hopefully, however, this proposal could provide some guidelines for

communicating taste/flavour information by means of multisensory packaging design, that is, taking into account taste-flavour/visual correspondences when designing a product's packaging.

8.2 Limitations and future studies

The studies in which taste/shape correspondences (Experiments 1-5) were assessed have four specific limitations that should be mentioned here. First, taste hedonics was not manipulated across the experiments. In that sense, the results reflected the specific variations of the participants' liking of the specific tastes. Second, Experiment 5 only included two tastant concentrations, which may represent a limitation in that it has been suggested that taste concentration and liking have tastant-dependent relationships (e.g., Moskowitz, 1982). For example, a common finding reported in the literature is that sweet liking and perceived intensity follow an inverted U-shape function in which people report liking sweetness until a medium intensity, from which liking starts to go down as intensity increases from that point (e.g., Moskowitz et al., 1974). It would be interesting to assess whether the sweet/round association changes when the intensity is high enough that it is perceived as unpleasant. The third limitation may well apply to other experiments in this thesis as well. Namely, that when taste words, instead of tastants are used, individual differences in mental imagery may influence performance in unpredictable ways (e.g., Lacey & Lawson, 2013). In other words, what one participant associates with the word sweet may differ from what another participant may imagine, which may reflect differences, for example, in taste liking and/or intensity. Finally, a fourth limitation that may also apply to the colour/flavour experiments reported refers to the confusion that

may arise by using taste and flavour words. For example, there is evidence to suggest that people can confuse taste terms such as “sour” and “bitter” (e.g., O’Mahony, Goldenberg, Stedmon, & Alfrod, 1979; see also Spence, Smith, & Auvray, 2015, for the confusion between taste and flavour). While the results of Experiment 4 and 5 revealed a very similar pattern of results using real tastants instead of taste words, it is worth taking these confusions into account in future studies.

It will also be important to look at other individual differences in taste perception and their influence on taste/shape associations. It has been documented that taste hedonics and perceived intensity can vary from person to person (e.g., Hayes & Keast, 2011; Looy, Calleghan, & Weingarten, 1992). What is more, the status of a taster (e.g., supertasters, non-taster, see Hayes & Keast, 2011) is related to different sensory-discriminative properties for certain bitter tastes (Yeomans et al., 2007), which may be reflected in a potentially different matching between bitter tastes and roundness/angularity. By accounting for such differences, one may hope to obtain a better understanding of the way in which taste hedonics and perceived intensity relate to taste/shape associations. Here, a number of questions could be empirically assessed such as: Are there any differences in bitter/shape correspondences as a function of taster status? Or do sweet likers and sweet dislikers differ in a taste/shape matching task? Are there gender differences in the crossmodal correspondence between taste and shape (see Spence, Velasco, and Knoeferle, 2014)? By clarifying the influence of those individual differences on the crossmodal correspondences between taste and shape, it would possible to control for potential confounds in the experiments presented in Chapter 2. Note however, that the results were consistently replicated. Moreover, by assessing such individual differences it may be possible clarify the influence of shape congruence on taste perception and the

hedonic mechanism of the correspondences. What is more, other shape features such as symmetry/asymmetry (see Palmer, Schloss, & Sammartino, 2013, for a review on object features and aesthetic preferences) or volume/size (e.g., Cytowic & Wood, 1982; Deroy & Valentin, 2011) may also be relevant for crossmodal correspondences between shapes and taste.

As for the associations between concrete packaging shapes and tastes, a number of questions remain to be answered. For example, to what extent does previous experience with a product class or category interact with abstract symbols on a package in visualizing a taste? The results of Experiment 14 shed some light on this question by suggesting that by aligning the different visual elements on either the round or angular side of the continuum would lead to specific taste categorization. Nevertheless, the packages used were novel (designed specifically for the experiment). It would be interesting in the future to assess how a known packaging shape (e.g., a can of tuna or a soft drink can) interacts with abstract shapes in setting a consumers' expectations. Another way of doing this would be to assess participants' familiarity with a packaging shape and see whether it correlates with taste ratings. Nevertheless, Experiment 14 has several limitations that are worth discussing. The free choice task used in that experiment provides some interesting means to assess the frequency at which people categorise a package as a function of a taste quality. However, the nature of the task makes it difficult to interpret the RTs as a number of data points would be lost at random. A possible way of moving forward and testing the contribution of the congruency between the different design elements could be via redundancy gains. This concept refers to the extent to which multiple 'redundant' (or congruent) signals can enhance participants responses to a given stimuli (e.g., Gondan, Götze, & Greenlee, 2010). Here, for instance, it would be possible to assess whether

variations of unimodal (e.g., shapes, typefaces) and multimodal (e.g., adding sounds) packaging signals would impact the detection, categorization, and visual search of a packages as a function of their congruence with a taste quality.

The experiments involving colour also have certain specific limitations. For example, Experiments 9 and 10 were conducted online. This does not allow one to control for potential colour differences as a function of screen features and settings. While the names of the colours were also provided, it may be the case that this introduced additional variance to the tasks. Importantly though, such effect may have been attenuated by the large sample sizes. In addition, it is worth mention that one of the main interest of the experiments reported in this dissertation was to keep the ecological validity as high as possible. For example, when processing packaging colours online, it is of interest to evaluate colours as they appear to a diverse range of audiences with different computer characteristics and unknown settings.

Moreover, the particular colour/flavour (name) combinations used in Chapter 6 were selected based on the experimental evidence provided in Chapter 5. With that in mind, future research may want to look at how colour/flavour associations vary as a function of product classes and categories, and how that may provide a context for different effects on flavour information processing on a products' packaging (i.e., would red be associated with tomato in a yogurt, say?). Another interesting direction for future research concerns target/distractor similarity since it has been shown to influence search times (e.g., Duncan & Humphreys, 1989). In effect, products are generally presented on supermarket shelves grouped by brands and thus by their visual appearance. Since the position of the target and distractors was always randomized and the distractors were randomly selected from a pool of distractors, some trials included two or more packages with the same colour;

thus it is difficult to say whether target/distractor similarity exerted any influence on the search process. Besides, brand schemes can have a significant effect on the way in which people learn to map colours and products (see Labrecque & Milne, 2013). Here, it is worth mentioning that, when people go to a supermarket, they may have in mind certain products before they start searching. It would be interesting to assess how holding information in working memory can influence selective attention, by manipulating, the congruence between the colour and taste (verbal or pictorial) information. Previous research has already suggested that information held in working memory does influence the allocation of attentional resources (e.g., Higgs, Rutters, Thomas, Naish, & Humphreys, 2012; Soto, Hodsoll, Roshtein, & Humphreys, 2008)

Finally, it is at this point that the interaction between colours and shapes interact when providing information about taste/flavour. While this specific point was not empirically addressed in this dissertation, it is worth mentioning that foods and drinks often come, or are presented in, a number of shapes and colours, which can influence people's expectations about them. Previous research has demonstrated the existence of interactions between colour and shape in the connotative meaning of geometrical shapes (e.g., Sommer, Sommer, & Cho, 2009). For example, Woods et al. (2013) documented the fact that their participants matched roundness with red (see also Kandinsky, 1925, for an early notion of colour/shape associations). This finding is particularly intriguing in that previous studies have also documented the existence of the association between red and sweetness (e.g., Spence et al., 2014; Velasco et al., 2013).[12] Future research may aim to explore the interaction between roundness and redness in the context of crossmodal

[12] The two studies referenced here were conducted during my D.Phil. research as well but will not be included in the present dissertation.

correspondences with taste information. Another interesting future direction here would be to assess whether the abstractness/concreteness of a shape provides context for colour meaning (e.g., Nicholson & Humphrey, 2004).

8.3 General conclusions

As should have become clear from the various experiments reported in this thesis, people associate tastes/flavours and visual information in a manner that is non-random. Specifically, people associate tastes and shapes and flavours/odours and colours. People rely somewhat on taste hedonics and intensity when matching them to shapes (that share such properties). However, this, initially, does not seem to extend to more concrete packaging shapes, presumably because the latter activate semantically-related representations concerning a class of product or product category. Such correspondences have been shown to influence the way in which people classify visual information as a function of its visual properties. However, presenting shapes that are congruent or incongruent with a specific taste does not change the way in which participants rate the taste (or at least it did not in Experiment 15).

On the other hand, the way in which people match flavours and odours to colours may reflect the co-occurrence of pairs of stimuli in specific contexts, though Experiment 8 also revealed a relationship between colour and odour features such as pleasantness and saturation. From the studies presented in Chapters 5 and 7, it is clear that the cultural background of the participants and the context in which a colour is presented (e.g., packaging or receptacle) can influence colour/flavour correspondences. Nonetheless, it is far less clear (also from the studies on taste/shape correspondences) the way in which the

putatively different mechanism that explain the range of human crossmodal correspondences interact in creating the associations that people report. Potentially, amodal attributes set the foundations of the way in which people perceive and relate sensory stimuli in a specific environment (with its statistical regularities) throughout life. That, together with the acquisition of language, may define a network of meaning that influence multiple levels of information processing, in which abstractness/concreteness, experience, and context may play a key role.

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APPENDIX A

Experiments 16-20: The sound of temperature: What information do pouring sounds convey concerning the temperature of a beverage

A.1 Introduction

According to Gibson (1966), while perceiving the world, we obtain potentially useful information from the sounds that result from the interactions taking place between different environmental stimuli. In 1977, Gibson introduced the term 'affordances' in order to define those stimulus qualities that are relevant to the perceiving organism and which *afford* actions for it in the environment (independently of the organism's awareness, or otherwise, of those affordances). However, although provocative, it is fair to say that since Gibson put forward his original proposal, relatively few empirical studies have been conducted in order to assess his ecological approach to auditory perception (see Spence & Zampini, 2006, for a review).

That said, Gaver (1993a) took up Gibson's proposal and developed the idea of an ecological approach to audition. Gaver's suggestion was that the way in which people perceive environmental auditory stimuli does not necessarily correspond to elemental physical dimensions; perception, in turn, may be built-up by integrating different dimensions of unisensory experience into complex, often multisensory, percepts. The sounds that people are exposed to in their everyday lives are often rather complex in nature; people are rarely exposed to unique physical properties of auditory stimuli. This

means that the human perception of meaningful environmental sounds has to rely on the decoding of multidimensional stimuli that may be organized into complex perceptual units that are potentially relevant to the listener. Gaver also suggested that people's everyday listening may not be based solely on the physics of sound but, consistent with Gibson (1966), on an ecological physics approach in which human perception is based on what is relevant to the listener (what the organism affords from the environment).

Over the course of the last few decades, a variety of research has demonstrated that the environmental information that we process is typically multisensory in nature (Bremner, Lewkowicz, & Spence, 2012; Calvert, Spence, & Stein, 2004; Stein, 2012), and that much of what we perceive via the senses is interconnected at both the perceptual and semantic levels (Chen & Spence, 2010, 2011; Martino & Marks, 1999, 2001; Spence & Driver, 2004). This research has drawn the attention of practitioners in many different fields, including those sensory marketers interested in enhancing the multisensory properties of their products/services to impact upon consumer perception and behaviour (e.g., Hultén, 2011; Hultén, Broweus, & van Dijk, 2009; Krishna, 2012; Spence, 2011b, 2012a).

In recent years, both academic researchers as well as a growing number of sonic branding practitioners have become increasingly interested in trying to understand and quantify the impact of auditory cues on our multisensory experiences. The objective here has been to try to enhance the customer experience of a given product or service (e.g., see Spence, 2012a; Spence & Shankar, 2010, for reviews). The automotive industry, for instance, provides one of the best (and certainly best-funded) examples of sonic design in recent decades (e.g., Spence & Zampini, 2006). Sonic designers and researchers have tackled everything from the sound of the car engine to the satisfying clunk of the car door when it closes (e.g., Miśkiewicz & Letowski, 1999; Parizet, Guyader, & Nosulenko, 2008).

Recently, some manufacturers have even gone so far as to emphasize the distinctive sound of their car doors closing in their advertisements (e.g., see the recent campaign by VW for their Golf cars with the strapline 'It sounds just like a Golf'). There is currently also a lot of interest around trying to understand the kinds of sounds that electric cars should make (e.g., Bergeron, Astruc, & Masson, 2010; Miśkiewicz & Letowski, 1999; Ashmead et al., 2012).

The ideas and insights that were initially introduced in the automotive sector have progressively been extended to a variety of other product categories. So, for example, several studies have now highlighted the fact that the sound of a variety of products such as crisp packets (Spence, 2012b; Spence, Shankar, & Blumenthal, 2011), coffee makers (Knöferle, 2012), toothbrushes (Zampini, Guest, & Spence, 2003), and aerosol sprays (Spence & Zampini, 2007), can have an impact on a consumer's perception of the pleasantness of the product. Moreover, recent research has demonstrated that auditory (as compared to visual) cues primarily influence people' perception of the noisiness and annoyance of a variety of products such as alarm clocks and whistling kettles (e.g., Fenko, Schifferstein, & Hekkert, 2011; see also Byron, 2012). After all, product-related auditory cues can convey relevant information to the consumer; in fact, pretty much all of our product interactions will generate some sort of auditory feedback, and independently of our awareness of them, they can influence our multisensory perception (see Spence, 2012a). This is, or so it would be argue here, one of the main reasons why sounds need to be taken into account when designing multisensory products/services (see Byron, 2012; Spence & Zampini, 2006; Wolkomir, 1996).

When it comes to the perception of food and drink products, auditory research has also provided relevant information about the impact of auditory cues on people's multisensory

experiences. Most studies in this area have primarily focused on the influence of eating (mastication) sounds, food-related sounds, and background noise in food perception (see Spence, 2012b, for a review). For instance, Zampini and Spence (2005) conducted various experiments showing that the perception of the carbonation of a fizzy drink could be modified simply by enhancing or cutting certain frequency components and/or speeding-up the popping sounds that people heard while holding the drink.

To date, researchers have demonstrated that what the consumer hears can influence their perception of a host of different products and brands (see Byron, 2012; Spence & Zampini, 2006). Such effects may be attributable to the fact that the sounds that result from our interaction with the environment often convey important information about the nature of the objects with which we are interacting (e.g., Gaver, 1993a; Giordano & McAdams, 2006; Grassi, Pastore, & Lemaitre, 2013).

Although the latest research has started to clarify the influence of auditory cues on the perception of product, further research is still needed in this area. For instance, think of the sound that your morning coffee makes when poured into your favourite mug, or the sound of cold water being poured into a glass. Have you ever wondered whether it would be possible to discriminate whether a liquid is hot or cold based solely on the sound it makes when poured into a receptacle? In a preliminary online survey, 60 people were asked this question, and found that only 48% (that is, slightly less than half) responded in the affirmative. To the best of my knowledge, the only clue to suggest that people can, in fact, discriminate the temperature of a liquid on the basis of its sound comes from a passing comment from Barb Stuckey (2012) in her book, *'Taste what you're missing'*, in which she states that people can differentiate between hot and cold liquid pouring sounds (see also http://www.barbstuckey.com/, accessed on 20/01/13).

Intriguing evidence from Cabe and Pittenger (2000) suggested that based exclusively on auditory information, people are able to determine the level of the water being poured into a vessel. Based on the idea that the fundamental resonant frequency (FRF) of the air column in a receptacle-like tube is related to the level of the water, the authors conducted a series of experiments that were designed to assess how sensitive people are to acoustic information when filling various receptacles with water. Cabe and Pittenger demonstrated that people can accurately recognize changes in water filling based on auditory cues (e.g., the FRF does indeed convey useful information). These results therefore suggest that physical variables such as the FRF can convey information about the degree of fullness of a vessel.

Gaver (1993a) suggests that the sounds of pouring liquids depend on the deformation of the returning forces of the materials, and the establishment and alteration of the reverberating cavities in the liquid's surface. In other words, both the attributes of the liquids and the materials with which they interact contribute to the resultant sound. What is more, these sounds provide people with information about the interaction of materials (and locations). In particular, and following Gaver's early proposal, the sounds that liquids make when poured convey useful information about a variety of attributes such as the viscosity, rate, amount, and the height of the liquid in a container.

It is possible to think that changes in the temperature of a liquid, and consequently in its physical properties result in changes in the sonic properties of the liquids when they are poured from one receptacle into another, since the interaction between both the liquid and receptacle (e.g., materials, see Gaver, 1993b) would likely result in a different sonic profile. For instance, take water, depending on its temperature, the density varies. If water at different temperatures, as in cold water (i.e., $5^{o}C$, 999.9 kg/m^3) or boiling water

(approximately 958 kg/m^3) is served into a glass receptacle, the resonance would vary, as a function of the interaction between the materials and their respective properties. The sound that boiling water makes when poured is related both to changes in the water temperature and its interaction with a particular material (Aljishi & Tatarkiewicz, 1991). This suggests that the interaction between a liquid (with a particular temperature, hot vs. cold; e.g., Parthasarathy & Chhapgar, 1955) and a receptacle (a paper cup will sound very different to porcelain, say) can produce characteristic sounds that can potentially be discriminated by people.

In order to collect further data on this topic, three experiments are reported in Appendix A with the aim of assessing: 1) Whether people can discriminate the temperature of water based on the sound it makes when poured into a variety of cups/beakers made of glass, porcelain, paper, and plastic vessels (Experiment 16); 2) If there are any implicit associations between sounds and temperature-related attributes (Experiment 17); and 3) Whether it is possible to influence temperature discrimination by artificially modifying the sonic properties of the pouring water; in other words, it is assessed whether it is possible to make a liquid pouring sound that is rated as colder or hotter than the actual temperature of the liquid (Experiment 18).

A.2 Experiment 16

A.2.1 Methods and materials

A.2.1.1 Participants

33 participants (26 female and 7 male) aged 18-57 years (M=25.7, SD= 8.5) from the UK took part in the experiment. All of the participants reported having a normal sense of audition.

A.2.1.2 Apparatus and materials

The participants were presented with the sound recordings of hot and cold water being poured into a glass, porcelain, paper, and plastic receptacles (see Figure A.1); this resulted in a total of eight audio recordings (the recordings can be access here https://soundcloud.com/xmodal/sets/the-sound-of-temperature). These recordings were made by Condiment Junkie (London, UK, http://www.condimentjunkie.co.uk/), using a Sennheiser 416 directional shotgun microphone located 25cm from the vessels. 200ml of water were poured into each vessel at a height of 10cm from a plastic measuring jug at a flow rate of 40 ml/s. The cold water fresh from the fridge was poured at a temperature of 6-8ºC whereas the hot water had a temperature of 82-84ºC. The receptacles were located with their base squarely on the table (as shown in Figure A.1).

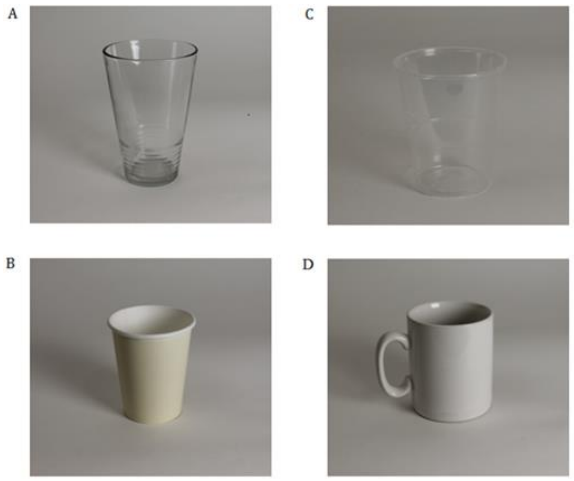


Figure A.1. Containers used to make the recordings of the hot and cold liquids being poured in Experiments 16-18: A) Glass, B) Paper cup, C) Plastic cup, and D) Porcelain mug.

A.2.1.3 Procedure

The participants were seated 50 cm in front of a 17'' CRT personal computer with a resolution of 1024x768 pixels (60 Hz refresh rate), and were given a set of JVC HA-D424 headphones. The sounds were presented at a level of 70 dB. The stimuli were presented and the responses were collected using the E-Prime Software 2.0.

At the start of the experiment, the participants were told that they would be listening to several liquid pouring sounds and that they should press one of two keys on the computer keyboard in order to respond to the sounds: pressing the 'a' key in response to hot liquids, and 'l' in response to cold liquids. Each of the sounds was presented 4 times randomly giving rise to a total of 32 randomized trials. A repeated measures experimental design was utilized. Each trial terminated when the participant's response was registered or else when 10,000ms had elapsed from the start of the trial. Each sound was presented for 5000ms followed by an additional 5000ms in case the participants had not already

responded. The response procedure was as naturalistic for participants as possible. The experiment was conducted in a quiet room under normal illumination and sound conditions.

A.2.2 Results and discussion

A Pearson's Chi Square test (Agresti & Finlay, 2009) performed on the association between the hot and cold responses and the sounds that were presented revealed a significant result, $X^2 = 242.018$, df=7, $p<.001$, thus suggesting the existence of a crossmodal association between the sound and the perception of the temperature of the water that was being poured. The participants were able to determine whether the water was hot or cold, at a level that was significantly better than chance (M= 72.5%), on the basis of nothing more than the sound it made when poured into one of the drinking receptacles. The effect size of these results was calculated using the Cramer's V statistic and a medium association was obtained (V=.472, $p<.001$). Pairwise comparisons (with the p values adjusted using the Bonferroni method) were performed in order to assess whether the majority of the participants correctly determined the temperature of each of the eight sounds tested (see Figure A.2). The results of the pairwise comparisons demonstrated that the participants' responses (hot or cold) differed significantly in the expected direction; that is, the majority of the participants' responses were accurate in terms of discriminating the actual temperature of the water ($p=.005$, for all comparisons).

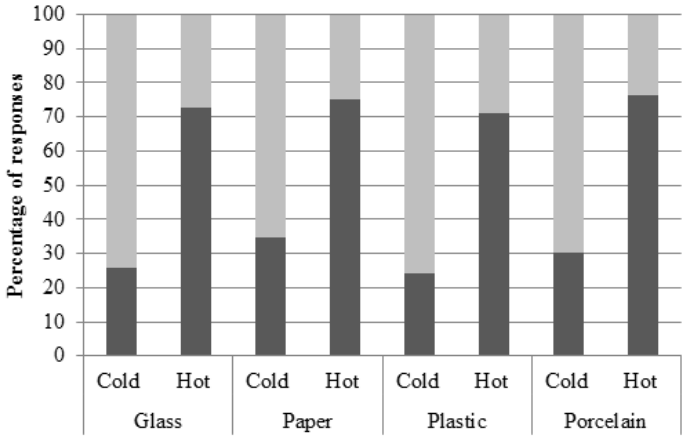


Figure A.2. Percentage of hot (dark gray) and cold (light gray) responses (Experiment 16) for each sound as a function of the actual temperature of the liquids and the materials of the receptacles into which the liquids were poured. The participants' overall selection of one of the two possible responses was significant for all conditions (i.e., the adjacent bars in each pair were significantly different from one another).

As the participants were allowed to respond as soon as they had decided whether the water was hot or cold, reaction times (RTs) varied across trials. Therefore, accuracy of the participants' responses as a function of the response time is presented in Table A.1. Average RTs in Experiment 16 were 2650ms (*SD*= 1410 ms). In general, it is possible to see that, independently of the time taken for participants to respond, they were able to accurately discriminate the temperature of water.

Table A.1. Mean percentage of correct responses as a function of RTs to the sounds of pouring water in Experiment 16.

		Glass cold	Glass hot	Paper cold	Paper hot	Plastic cold	Plastic hot	Porcelain cold	Porcelain hot
Accuracy	M %	74.24	72.73	65.15	75.00	75.76	71.21	69.70	76.52
RTs	M	2.80	2.67	2.48	2.39	2.93	2.61	2.67	2.68
	SD	1.45	1.37	1.27	1.25	1.88	1.47	1.32	1.33

The results of Experiment 16 are consistent with anecdotal reports regarding the ability of people to distinguish the temperature of pouring liquids' sounds (see Stuckey, 2012). Furthermore, they provide the first empirical support for the notion that people can discriminate the temperature of a liquid based on the sound that it makes while being poured into a vessel[13]. Based on the finding that people can explicitly discriminate the temperature of pouring water, it was decided to use a variant of the Implicit Association Test (IAT, see Parise & Spence, 2012; Piqueras-Fiszman & Spence, 2011) in the next experiment in order to assess whether such water pouring sounds are automatically and implicitly associated in the mind of the perceiver with the notion of a particular temperature.

[13]In a follow-up study, I assessed whether the results obtained in Experiment 16 were a carbonated soft drink to be used instead of still water. Thirteen participants (8 females and 5 males, M= 28.15 years, SD= 10.3) took part in an experiment that used the same procedure as in Experiment 16. However, in addition to discriminating the temperature of the pouring sounds, the participants were also asked to rate, using a 10-point Likert scale ranging from -5 (cold) to 5 (hot), how cold or hot they perceived the 4 sounds (2 hot and 2 cold) of the carbonated beverage poured into a glass receptacle to be. The results of the discrimination task demonstrated the existence of an association between the sounds and the perception of temperature of the drink (X^2 = 76.364, df=3, p<.001). An ANOVA performed on the temperature ratings (using the Greenhouse-Geisser correction), revealed a significant difference between the ratings (F(1.688, 20.252)= 15.353, p<.001). Post hoc analysis (using the Bonferroni correction) suggested that the participants rated the sounds of the hot carbonated sample (both sounds, M1= -1.54, M2= 1.44) as hotter, when compared to the sounds of cold (M1= 2.23, M2= 1.52) sample (both, p<.05 for all comparisons).

A.3 Experiment 17

A.3.1 Methods and materials

A.3.1.1 Participants

Seventeen participants (12 female and 5 male; mean aged of 28.22 years, SD= 9, range 20-57 years), took part in Experiment 17.

A.3.1.2 Apparatus and materials

The stimuli were presented via a personal computer running E-Prime 2.0 (Psychology Software Tools, Inc.). Four different auditory stimuli and two word attributes were presented. The auditory stimuli included the sound of the hot and cold water being poured into the glass and porcelain receptacles (as used in Experiment 16), and the word attributes included "Hot Drink" and "Cold Drink".

A simplified version of the IAT (see Parise & Spence, 2012; Piqueras-Fiszman & Spence, 2011), based on the original test designed by Greenwald, McGhee, and Schwartz (1998), was used. The participants completed two versions of the IAT, one for the sounds of water poured into the glass receptacle and one for the sounds made when water was poured into the porcelain receptacle instead. Two possible combinations were presented in each IAT: Combination 1, in which participants had to pair the words attributes and sounds that were congruent ("Hot Drink" and the sound of the hot pouring water, and "Cold Drink" and the sound of the cold pouring water) and Combination 2, in which the participants had to pair the word attributes and sounds that were incongruent ("Hot Drink" and the sound of a cold pouring water, and "Cold Drink" and the sound of a hot pouring water). Here, the

congruency term refers to the matching of words and sounds of the same type (e.g., both hot or both cold). The mapping of the stimuli was modified across blocks (see Table A.2).

Table A.2. Blocks of trials used in each block of the IAT conducted in Experiment 17.

Block	Procedure	Left response key	Right response key	Number of repetitions	Number of trials
1	Combination 1	Hot sound – "Hot drink"	Cold sound – "Cold drink"	5	20
2	Reversed combination 1	Cold sound – "Cold drink"	Hot sound – "Hot drink"	5	20
3	Combination 2	Cold sound – "Hot drink"	Hot sound – "Cold drink"	5	20
4	Reversed combination 2	Hot sound – "Cold drink"	Cold sound – "Hot drink"	5	20

A.3.1.3 Apparatus and materials

The participants were instructed to read the instructions carefully and to listen to the sounds, at least twice, before beginning the task. At the beginning of each block of experimental trials, a slide with instructions was presented in which the participants were informed about how to match the stimuli and the appropriate responses for the following trials. In each of the blocks of trials one sound (e.g., hot or cold) and one of the pair of words (e.g., "Hot Drink" or "Cold Drink") was assigned to either the left or right response key (see Table A.2). Note that the experimenter never explicitly labelled either of the two sounds (e.g., as hot or cold).

Each trial began with either the word attributes or the sounds, presented from the centre of the screen. The word attributes were displayed for 1500ms or until a response had been recorded. The auditory stimulus was presented until the participants responded or until 5000ms had elapsed (the duration of each liquid pouring sound), at which point the trial

was terminated. Four different blocks of trials (see Table A.2) were created each consisting of 20 trials (each stimulus was repeated 5 times). The RTs and accuracy of participants' responses were collected in each trial. The RTs and the error rates (%) were analysed using paired-samples t-tests. Furthermore, the d-measure, introduced by Greenwald et al. (1998), and used to assess the IAT effect, was calculated using the procedure proposed by Lane, Banaji, Nosek, and Greenwald (2007). Note that this measure has also been implemented in previous studies that have used the variant of the IAT reported in this study (e.g., see Parise & Spence, 2012).

A.3.2 Results and discussion

The participants responded in every trial. The mean RT and the mean accuracy (%) of participants' responses obtained in Experiments 17 are summarized in Table A.3. The RTs were analysed using a two-way RM-ANOVA, with the factors of receptacle (glass and porcelain), and congruency (congruent and incongruent combinations). A significant main effect of receptacle type was found ($F(1, 16)= 4.639$, $p<.05$); however, the analysis did not reveal a significant main effect of congruency, although participants' responses were numerically somewhat faster in the congruent condition than in the incongruent condition. Pairwise comparisons were conducted to assess the differences between receptacles. Participants' RTs were faster for the sounds of water being poured into the porcelain receptacle as compared to when it was poured into the glass receptacle ($p<.05$).

Table A.3. Mean RT in seconds (s) and mean accuracy of participants' responses in Experiment 17.

Receptacle	Combination 1	Combination 2	D-measure
Glass			
RT(s)	1244	1310	0.25
Accuracy (%)	89	77	
Porcelain			
RT(s)	1019	1104	0.18
Accuracy (%)	94	88	

Paired-samples t-tests were conducted to assess any differences in the accuracy of participants' responses regarding the congruent vs. incongruent stimulus-response mappings. The paired-samples t-tests revealed a significant difference regarding the sounds of water being poured into the glass receptacle ($t(16)= 2.521$, $p<.05$), demonstrating that the participants found it easier (that is, they made less errors) when responding in the congruent as compared to the incongruent combinations. Taken together, these results provide support for the idea that participants found it easier to match the putatively congruent word attributes and sounds (e.g., the sound of hot water with the phrase "Hot Drink") as compared to those that are incongruent (e.g., the sound of hot water being poured with the phrase "Cold Drink").

Regarding the d-measure values obtained in Experiment 17, the larger the value, the stronger the crossmodal association. Since the d-measure represents the effect size of the association between the variables, it is possible to say that there was a small effect.

However, taking into account the small sample size used in Experiment 17, this already provides some evidence regarding the existence of an association between the sounds of the pouring liquids and the notion of a particular temperature. The results of the IAT suggest that the sounds of pouring liquids may be automatically and implicitly associated with the notion of a particular temperature (or at the very least with a distinction between hot and cold beverages). Based on the results of Experiments 16 and 17, it is therefore possible to consider the possibility that, simply by modifying the sonic properties of the sounds of the pouring liquids (specifically, water), the perception of temperature would change as well. Therefore, a third and final experiment was conducted in order to assess whether it is possible to artificially modify the perception of temperature based on the pouring sounds that a person hears.

A.4 Experiment 18

A.4.1 Methods and materials

A.4.1.1 Participants

Twenty four participants (19 female and 5 male) aged (19-57 years, M= 28.4, SD= 8.3) took part in the experiment.

A.4.1.2 Apparatus and materials

The stimuli consisted of 4 sounds: Two of the sounds recorded and used in the previous experiments (that is, cold and hot water being poured into the glass, and the two sounds

modified by Condiment Junkie. The sounds of the water poured into the glass receptacle were modified by changing the equalization (EQ) of the sounds; using opposite settings for each sound. The EQ of the Hotter sound was increased around 200Hz and decreased around 5-6kHz. The EQ of the Colder sound was decreased around 200Hz while being increased around 5-6kHz. The two original pouring sounds were modified in order to obtain a putatively 'hotter' and 'colder' sound, and to assess whether people's perception of hot or cold would change based on the modification of their sonic properties.

A.4.1.3 Procedure

Each sound file was presented randomly five times, giving rise to a total of 20 trials. At the beginning of each trial, a white screen was presented and the sounds were presented for 5000ms. After each stimulus had been presented, the participants were instructed to rate how cold or hot they perceived each of the sounds to be on an 11-point Likert scale ranging from cold to hot (-5 to 5, respectively).

A.4.2 Results and discussion

The mean ratings on each scale are shown in Figure A.3. A RM-ANOVA (using the Greenhouse-Geisser correction) was performed on the data. A significant main effect of sound was observed on participants' ratings of the temperature of the water ($F(2.009, 46.216) = 207.47$, $p < .001$). Pairwise comparisons revealed that the sound that was modified to be hotter was indeed rated as significantly hotter than the original sound of the hot pouring water ($p < .001$). Both the sound of the water that was modified to be hotter and the sound of hot water were rated as significantly hotter than the sound that was modified so as to be colder ($p < .001$, for both comparisons), and the original sound of the cold pouring water ($p < .001$, for both comparisons). The analysis of the data did not,

however, reveal any differences between the ratings regarding the sound that had been modified so as to sound colder and the original cold pouring water sound. These results therefore suggest that by artificially modifying the sonic properties of the sounds of pouring liquids, the perception of the temperature of a hot a liquid can be modified.[14]

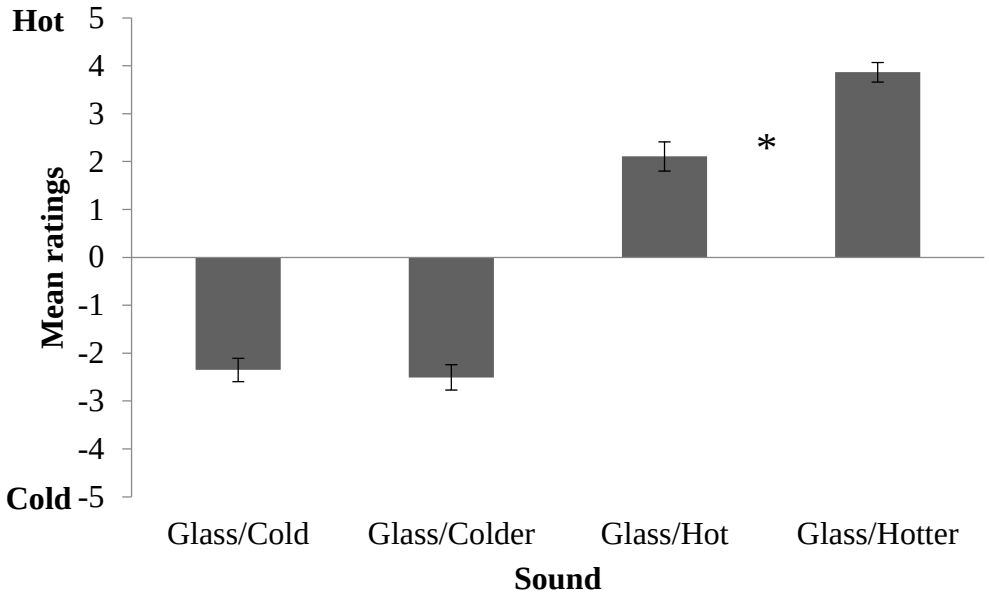


Figure A.3. Mean temperature ratings for the hot and cold liquids and the artificially modified version of these sounds, used in Experiment 18. The error bars show the standard errors of the means. The hot liquids were rated as significantly different from one another (*=<.001).

[14] Additional evidence here was obtained from a follow-up study conducted at the Edinburgh Science Festival, 2013, in which around 120 participants were asked to close their eyes and were presented twice with the four sound recordings used in Experiment 18. The participants were asked to respond which was the coldest, the second coldest, the second hottest, and the hottest of the pouring sounds when they were all presented the second time round. The responses were collected using an automated electronic manual response system; for each sound, automated polling was stopped once more than more 100 responses had been collected. The sounds were presented in the following order: second hottest, second coldest, coldest, and hottest. The results indicated that the festival audience were able to discriminate which sound was hotter (colder) than the others: the coldest was categorized as coldest by 64% of the participants, the second coldest by 54%, the second hottest by 49%, and the hottest by 83%. After conducting a Pearson Chi Squared test, it was determined that there was an association between the sounds heard and the corresponding relative temperatures of the liquids (X^2=338.540 df=9, p<.001). Participants selected the expected responses at a level that was significantly above chance (p=.05).

A.5 General discussion

In Appendix A, a series of three experiments designed to assess how the sounds of pouring liquids convey information regarding the temperature of a liquid were reported. The results of Experiment 16 demonstrated that people are able to tell, at a level that was significantly better than chance, whether the recording of water being poured into a receptacle involved water that was hot versus cold. The results of Experiments 17 further show that the crossmodal association between the pouring sounds and the perception of the temperature affected participants' performance in a speeded discrimination task, thus hinting at the automaticity of this particular effect (and possibly also that the temperature of a sample of water may be coded implicitly when we hear it being poured). In Experiment 18, participants' estimates of the temperature of water based on the sound it made when poured into a receptacle were shown to be influenced by artificially changing the sonic properties of the audio recording.

Taken together, these results therefore provide some of the first empirical evidence to support the claim that people can accurately discriminate, both explicitly and implicitly, the temperature of liquids on the basis of the sound that they make when being poured into a vessel (e.g., a cup or glass). Whether these results provide evidence to support Gibson's (1977) proposal concerning the *affordances* that are present in the case of auditory perception or should rather be accounted for in terms of an associative learning account (Spence 2011), still needs further research (assuming the issue is resolvable). According to an associative learning account, an organism may simply learn the associations between statistically related inputs in the environment; people come to learn that clusters of environmental features go together. In other words, the mere exposure of

an organism to the environment may lead to the internalization of its natural statistics and regularities even if they are presented in different sensory modalities (e.g., Spence, 2011a). Hence we may come to recognize both the Gibsonian and the associative learning approaches agree in that people can actually extract a variety of information about the cross-modal associations that exist in the environment. Nonetheless, although people may not be conscious of the qualities of the sound that convey information regarding the temperature of the pouring liquids, these qualities can nevertheless be perceived and provide potentially relevant information about the physical attributes of the source from which they originate.

Even though the IAT is a widely used psychological test that is often utilized to assess people's implicit attitudes and associations in a variety of subject areas in the psychological sciences (see De Houwer, 2009, for a review), it is important to bear in mind that the task itself may not necessarily provide the perfect measure of implicit processing that its advocates sometimes claim. This is because previous attempts to replicate certain findings based on this measure and the low effect sizes that have sometimes been reported (LeBel & Paunonen, 2011). However, as noted by Greenwald and Sriram (2010), the brief version of the IAT may nevertheless still provide some useful information when it comes to trying to study implicit processes.

Experiment 18 has certain limitations that future studies should take into account. For instance, the sound recordings were presented at a level (70dB) that is louder than the actual level at which pouring liquids would typically be heard. This may limit the generalizability of the results obtained here. In future research, it would therefore be interesting to see whether similar results would be obtained should the audio recordings be played back at a naturalistic level. In addition, the shape and size of the various

receptacles into which the water was poured were somewhat different, which may have influenced the resulting sound that was heard. Nonetheless, it is important to point out that the fact that people were able to discriminate the temperature of water regardless of the receptacle provides evidence for the idea that people can discriminate the temperature based on sonic cues. Future research should aim to more systematically assess how temperature is perceived in different liquids when poured into receptacles that are made out of different materials (but have a fixed size).

The results of Experiments 16-18 provide evidence for the idea that the changes in the temperature of a liquid (water) and consequently its physical properties result in changes in the sonic properties, as well as the perceived temperature. Nonetheless, given the fact that changing the temperature of a liquid will change its density (e.g., Serway & Jewett, 2009), future research may need to assess any effect of varying just the temperature or the density of a liquid, on the way in which people perceive pouring liquids. By doing this, it would be possible to further investigate and describe the effects of the particular physicochemical variations of water on the perception of the temperature. Future research could also include liquids that have different densities (e.g., everything from mercury through to water) in order to determine how other properties may impact upon temperature perception.

The idea that temperature is a multisensory construct (Fenko, Schifferstein, & Hekkert, 2010; Wastiels, Schifferstein, Heylighen, & Wouters, 2012) could be of particular interest to those working in the marketing of beverages (it is has been proposed that temperature is a relevant element in this context, see Delwiche, 2003). Moreover, the understanding of the sonic properties of food and drinks and their influence on product perception may be used as a potential tool for the design of enhanced food experiences, for instance, by

emphasizing the apparent temperature (e.g., emphasizing the hotness or coldness) of a beverage (Spence, 2012b) . It has been demonstrated that the temperature of served water can, for instance, influence the perception and acceptance of a variety of foods (Mony et al., 2013); by using multisensory cues to a drink's temperature, it may in the future be possible to enhance a diner's experience.

One could even think of new dishes (e.g., Blumenthal, 2008) in modernist restaurants (Myhrvold & Young, 2011) where sensory congruence/incongruence might be used (e.g., expecting a particular temperature in a liquid by its pouring sound and obtaining a different temperature, see Piqueras-Fiszman & Spence, 2012, for a review on the use of sensory congruence/incongruence in modernist cuisine; cf. Barnett-Cowan, 2010; Spence & Piqueras-Fiszman, 2014). However, further research would clearly be needed on this topic in order to determine which sense dominates (vision or hearing) if one were, say, to see a hot liquid being poured into a receptacle while hearing the sound of a cold liquid being poured.

The results of Appendix A could also be extended to contexts such as the media (e.g., radio or television), and products such as electronic drinks dispensers and household appliances (see Knöferle, 2011; Spence, 2011b; Spence & Zampini, 2006) in which these findings may be used for commercial purposes. During our everyday interactions, we often see steam rising from the surface of a food or beverage product (e.g., imagine a freshly poured hot beverage). People normally use such visual cues in order to guide their estimates (or expectations) concerning a drink's likely temperature. One particularly interesting question here for future research will therefore be to investigate what happens when such visual cues to the temperature of a food or beverage are placed in conflict with the temperature of the sound of that product (be it a hot or cold drink being poured into a

receptacle, as here, or the sizzle of the hot plate as the waiter brings the steak to your table; see Spence, 2012b; Wheeler, 1938). It is easy to imagine how such results could be of interest to advertising and other types of marketing communications in that the sounds they use may reflect some design properties of the products presented (Ashby & Johnson, 2002).

To conclude, while most people believe that hot and cold are primarily thermal properties, based on tactile (and/or oral-somatosensory) inputs to the skin, in fact, like many other attributes, the consumer's perception of this quality can be modulated by means of the (sometimes subtle) cues presented to the other senses as well. One could even imagine creating caricatured sounds that enhance the perceived temperature of a drink product which could be used to enhance the multisensory appeal of the product or brand. It would also be very interesting to see whether changing the 'temperature' of pouring sounds would even change the perceived temperature of a drink for consumers (cf. Zampini & Spence, 2005).

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APPENDIX B

Experiment 19 Crossmodal effect of music and odour pleasantness on olfactory quality perception

B.1 Introduction

Researchers have demonstrated that olfactory perception can be influenced by inputs from the other senses presented prior to and/or at the same time (see Calvert et al., 2004; Stein, 2012, for reviews). In fact, a variety of crossmodal correspondences - the name given to the tendency for people to match the information presented in one sensory modality to that presented in another (see Spence, 2011, for a review) - have been documented between olfaction and the other senses (e.g., Deroy et al., 2013; Stevenson et al., 2012). So, for example, to date, crossmodal associations have been demonstrated between odour and pitch (Belkin et al., 1997; Deroy et al., 2013), brightness (Kemp & Gilbert, 1997), colours (e.g., Demattè et al., 2006a; Maric & Jacquot, 2013; Schifferstein & Tanudjaja, 2004), basic tastes (Urdapilleta et al., 2006), and even tactile stimuli (Demattè et al., 2006b).

Deroy et al. (2013) suggested that people may use descriptors or attributes that are normally associated with other sensory modalities such as pitch, brightness, and sweetness to describe olfactory stimuli/percepts because of the various crossmodal correspondences that exist between the senses. It is interesting to note, though, that the crossmodal interactions that link olfactory and auditory stimuli have received far less attention than, for example, those that exist between vision and audition (Seo & Hummel, 2011). Nonetheless, over the last couple of decades, researchers have started to document

the existence of a number of crossmodal correspondences between olfactory and auditory stimuli. For instance, Belkin et al. (1997) provided one of the first examples of olfactory-auditory correspondences, showing that people would match a series of odours varying in quality, to sounds that differed in terms of their pitch (cf. Piesse, 1862). These results were later extended by Crisinel and Spence (2012) who also found that people tended to match certain odours to the timbres of particular musical instruments (see also Crisinel et al., 2013).

While the crossmodal correspondence between specific olfactory stimuli and, say, particular colours could be explained by their co-occurrence in foodstuffs (think only of the red colour of strawberries and the associated aroma), it is far harder to think of an environmental explanation that could explain why people would reliably (or consistently) associate specific musical parameters with particular olfactory stimuli and why these associations would, in turn, influence information processing (see Belkin et al., 1997; Deroy et al., 2013). In their recent review, Deroy et al. suggested that one potential explanation for the existence of crossmodal correspondences between auditory and olfactory stimuli may sometimes be related to the hedonic properties of the stimuli presented in the two modalities (see also Stevenson et al., 2012). As Marks (1978, p. 181) indicated, sensory qualities "talk over their common feeling". This notion has also been supported by recent research pointing to the idea that the emotional (hedonic) similarity between olfactory and auditory information may be crucial to both crossmodal correspondences and multisensory information processing (see Crisinel & Spence, 2012b; Hanson-Vaux, Crisinel, & Spence, 2012; Seo et al., 2011).

Seo and Hummel (2011) reported two experiments in which they assessed the effect of auditory stimulation on the perceived pleasantness and intensity of odours. In their first

study, they investigated whether auditory cues that were semantically congruent with the olfactory stimuli (sounds that were better matched crossmodally to the odours, i.e., the smell of potato chips while listening to the sound of crunching crisps) would modulate the perceived intensity and pleasantness of the odour. In their second experiment, the authors evaluated whether odour intensity and pleasantness could be influenced simply by manipulating the hedonic valence of the auditory stimuli.

Seo and Hummel (2011) reported that olfactory stimuli (such as the smell of coffee) were rated as more pleasant when paired with congruent sounds (i.e., when listening to the sound of drinking coffee in this example) as compared to incongruent sounds, and that the hedonic valence associated with the sounds can be transferred crossmodally, and thus influence people's odour evaluations. Interestingly, however, no crossmodal effect on the perceived intensity of the odours was reported. Seo and Hummel suggested that the results of their first study may have been attributable to the existence of a crossmodal congruency effect (e.g., Shams & Seitz, 2008), while the results of their second experiment could be explained in terms of some form of halo/horn effect (e.g., see Kappes et al., 2006; Thorndike, 1920). This evidence points to a hedonic similarity account. It may be case that there is a crossmodal transfer of the hedonic evaluation of the information presented in one sensory modality onto the information processed in the other.

Seo et al. (2014) recently extended Seo and Hummel's (2011) results to more music. In three experiments, the authors demonstrated that people match a variety of odours and background music, also that congruent (to odours) background music (i.e., Christmas carols) would enhance the rated pleasantness of certain odours, and that congruent sounds had an impact upon odour familiarity and identification. For example, participants liked the smell of cinnamon more when it was presented together with (congruent) Christmas

carols as compared to incongruent sounds. The authors suggested that the association between cinnamon and Christmas is very typical for the German participants whom they tested. The statistical regularities of the environment and co-occurrence of multisensory stimuli can thus lead to specific crossmodal associations (Shams & Seitz, 2008).

Further research is still needed in order to clarify the potential influence of auditory cues in odour perception, and its underlying mechanisms, since the crossmodal interactions between these senses are likely to operate at various different levels of human information processing (see Deroy et al., 2013). In the present study, any effect of the pleasantness of the music on the perceived pleasantness and/or intensity of the odours was assessed. In addition, I also wanted to assess whether having congruent (vs. incongruent, in terms of the perceived pleasantness) auditory and olfactory stimuli would influence the perception of other odour qualities such as sweetness, brightness, acidity, and dryness, which are attributes commonly used to describe fragrances (e.g., in the context of perfumery; Zarzo & Stanton, 2009) and have been shown to be crossmodally associated to odours (Stevenson et al., 2012)

In the present study, crossmodal congruency based on a matching of the hedonic qualities of the stimuli is manipulated. There is an intriguing question here as to whether and why changing what one hears can change an observer's experience of an olfactory stimulus. There is a need to clarify both the nature of the specific associations that exist between odours and sounds, and the influence that auditory cues may exert on the perception of odour attributes in, for example, the case of fine fragrances.

B.2 Methods and materials

B.2.1 Participants

Thirty three untrained participants (20 females, M age = 31.9 years, SD age = 10.65, range = 18-58 years) took part in this experiment. The participants gave their informed consent and completed two questionnaires in order to assess any potential sensory dysfunction prior to their taking part in the study: An adapted version of the Hearing Handicap Inventory for the Elderly (HHIE-S) for auditory functioning (Ventry & Weinstein, 1983) and the Multi-Clinic Smell and Taste Questionnaire (MCSTQ-Sc, olfactory section) for olfactory dysfunction (see Nordin et al., 2003) were used, and only those participants who did not report any dysfunction were included. The experiment lasted for approximately 40-50 minutes. The participants were compensated for their time with £8.

B.2.2 Apparatus and materials

Six odours, 1 from *Le Nez du Café* (Brizard and Co, Dorchester, UK) and 5 from *Le Nez du Vin* kits (Brizard and Co, Dorchester, UK), were selected as the olfactory stimuli. These kits have been designed to help those who would like to learn more about coffee/wine to experience a number of the characteristic odours commonly found in the different kinds of coffee/wine. In addition, they have been previously used in research involving crossmodal associations to odours (e.g., Crisinel & Spence, 2012; Hanson-Vaux, Crisinel, & Spence, 2012). The samples were selected based on a preliminary experiment (see below) and consisted of odours identified as lemon, orange, and bilberry (all rated as pleasant), and musk, dark chocolate, and smoked (all rated as unpleasant).

The selection was based on a preliminary study in which 12 participants (7 females and 5 males, M_{age} = 24.9 years, SD_{age} = 5.7 *range* = 19-40) rated both the pleasantness and

intensity of a variety of odours from Le Nez du Café (Coffee Blossom, Garden Peas, and Smoke) and Le Nez du Vin (Apricot, Bilberry, Cinnamon, Dark Chocolate, Orange, Lemon, Musk, Smoked, and Toast) kits. The ratings were made on VAS anchored between *not at all* (0) and *very* (100), which were presented using the E-Prime 2.0 software (Psychology Software Tools, Inc.). A summary of the results for the perceived pleasantness and intensity ratings are shown in Fig. B.1A and B.1D, respectively. It is important to note here that although it may seem surprising to find that the participants found the smell of dark chocolate to be unpleasant, previous research has also documented that certain odours (e.g., parmesan cheese, truffle, and pepper, see Seo et al., 2010), when presented out of (a food-related) context, can be perceived as unpleasant (Deroy et al., 2013).

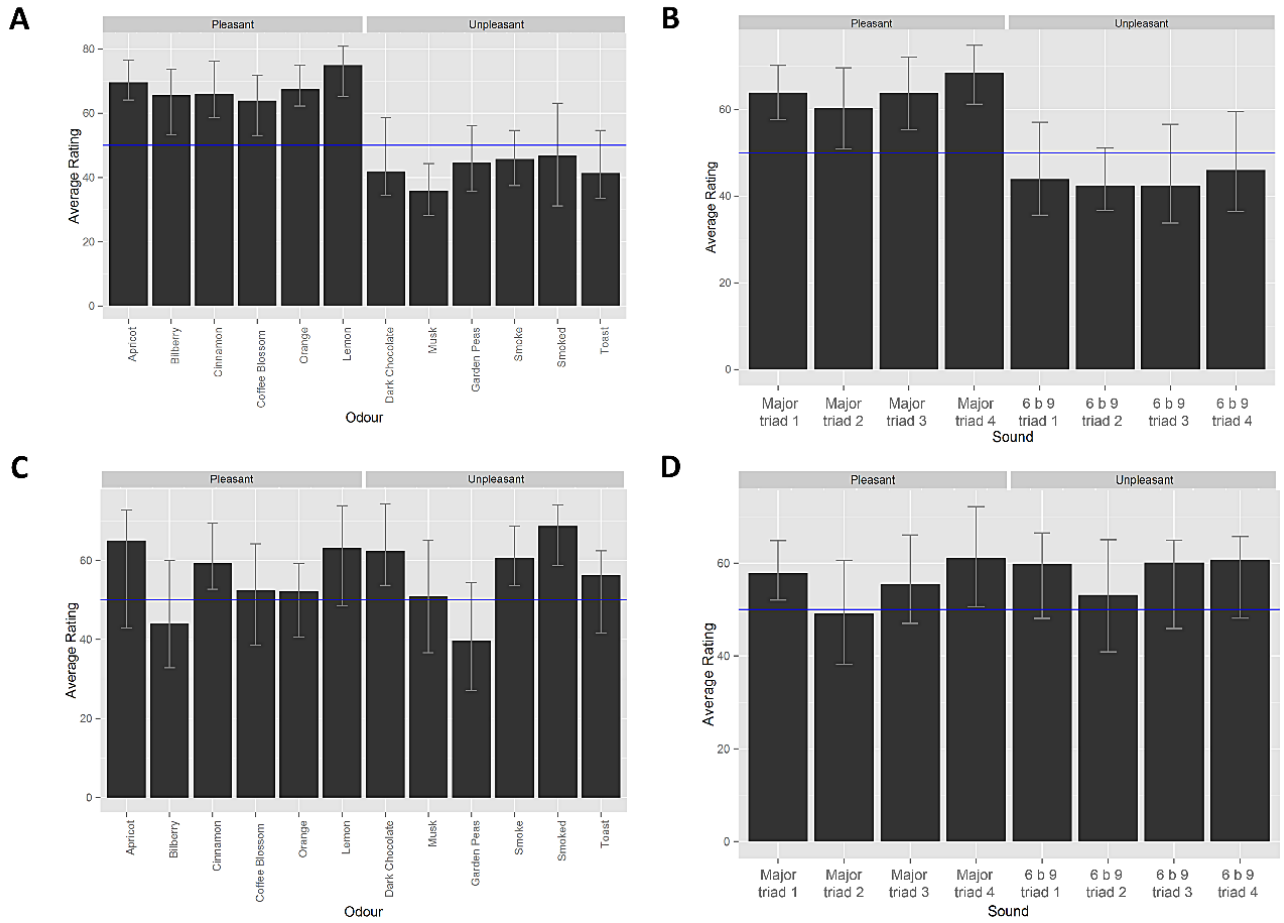


Figure B.1. Participants' average (Harrell-Davis estimator of the median; Vélez and Correa, 2014) pleasantness ratings for the odours (A) and for the auditory stimuli (B), and intensity ratings for the odours (C) and sounds (D) in the experiment presented in Experiment 19. The ratings were performed on a scale ranging from 0 (not at all) to 100 (very). The error bars represent 95% bias-corrected-and-accelerated bootstrap confidence intervals.

The selected odours were those that were given the most extreme hedonic ratings (in terms of either their pleasantness or unpleasantness). The intensity ratings of the selected odours were analysed by means of a RM-ANOVA in order to determine whether participants perceived the intensity of the odours differently. The ANOVA did not reveal any statistically significant difference between the ratings.

In addition to the selected odours, a no-odour (baseline) condition was also included, which consisted of participants sniffing an odourless empty bottle. All of the samples were presented in small glass bottles, covered with opaque paper and hidden in black containers in order to prevent the participants from seeing the colour of the sample liquids (cf. Crisinel & Spence, 2012).

The auditory stimuli were created with the software Finale (Finale 2012, MakeMusic®, Inc.). They consisted of three musical fragments played on the piano with the very same melodies but different, in terms of their dissonance (i.e., pleasantness), triad chords accompaniments. The dissonance of the triads went from the most consonant fragment (major triad) to the most dissonant fragment (6 ♭9 triad), giving rise to six musical fragments (three consonant, three dissonant). These musical fragments can be heard at https://soundcloud.com/xmodal/sets/sounds-odours. The sounds were designed on the basis of previous research suggesting the existence of an association between different dissonant and consonant musical pieces and pleasantness/unpleasantness (see Blood et al., 1999; Sammler et al., 2007). White noise (70 dB) was used as a putatively neutral stimulus. The sounds were edited in Audacity (Audacity®, the Free, Cross-Platform Sound Editor) to last for exactly 10s, and were presented over headphones (Sony MDR-NC6 Noise Cancelling) at a loudness level of 70 dB.

The consonant and dissonant auditory stimuli were assessed in a preliminary study in order to determine whether they were rated as expected; either pleasant (consonant) or unpleasant (dissonant). The same participants who had taken part in the odour pre-test also took part in this pre-test. The participants rated the pleasantness of the odours using a VAS (from 0 = Not at all, to 100 = Very). The mean pleasantness and intensity ratings

are highlighted in Fig. B.1B and B.1D, respectively. The participants rated each of the musical pieces as either pleasant or unpleasant as expected.

B.2.3 Procedure

A within-participants experimental design was utilized with two factors: Music (pleasant, unpleasant, and white noise) and odour (pleasant, unpleasant, and no-odour). The participants sat approximately 60 cm from a computer (with a screen resolution of 1366x768 pixels, and a screen refresh rate of 60 Hz), in order to perform the task. The instructions and response scales were presented on the computer monitor, and were also presented verbally in order to avoid any confusion.

Forty nine different combinations of olfactory and auditory cues (7 odours and 7 sounds, including the no-odour and white noise conditions) were presented in a random order to the participants. The auditory stimuli were presented for 10 s. Approximately 5 s after the onset of the auditory stimuli, the odour was presented, for the next 5 s, under the participant's nose by the experimenter at the same moment as an instruction on the screen said 'Please sniff the odour once'. The participants were asked to sniff the odour just once in order to control that the total number of sniffs per session was the same across participants.

After the presentation of the stimuli, the participants had to rate a number of odour attributes (pleasantness, intensity, sweetness, brightness, acidity, and dryness) on a VAS anchored between Not at all and Very much. Note that participants were not instructed about how they should interpret the different attributes included. However, some of these are commonly used attributes when describing fragrances (e.g., in the context of perfumery; Zarzo & Stanton, 2009) or have been shown, in the olfactory domain, to be

crossmodally matched to odours (Stevenson et al., 2012). What is more, there has been growing interest in odours taking on taste properties such as sweetness or sourness (Stevenson & Boakes, 2004), and dryness (Zarzo & Stanton, 2009), while brightness has been shown to be crossmodally associated to odours of different qualities (see Cohen, 1934; von Hornbostel, 1931; Kemp & Gilbert, 1994, 1997). To minimize any olfactory desensitization, there was a 15 s gap between the odour presentations, which together with the time participants took to respond to the scales made up to approximately 25 s between odour presentations. White noise was presented during this time (cf. Seo & Hummel, 2011).

B.3 Results and discussion

Average ratings obtained by participants for each odour-music combination were estimated using the Harrell-Davis estimator of the median (Vélez & Correa, 2014). Note that a number of assumptions for parametric tests were violated (e.g., the data was not normally distributed), thus, a robust analysis, the rank-based ANOVA-type statistic[15] (ANOVA, see Noguchi et al., 2012), was used to analyse the results. Average ratings were submitted to this ANOVA with the factors of music (pleasant, unpleasant, or white noise), and odour (pleasant, unpleasant, or odourless) for each of the odour attributes that the participants had to rate (pleasantness, intensity, sweetness, brightness, acidity, and dryness). Figure B.2 displays the average ratings obtained and Table B.1 shows the results of the analyses.

[15] Note that effect sizes have not proposed for this type of ANOVAs.

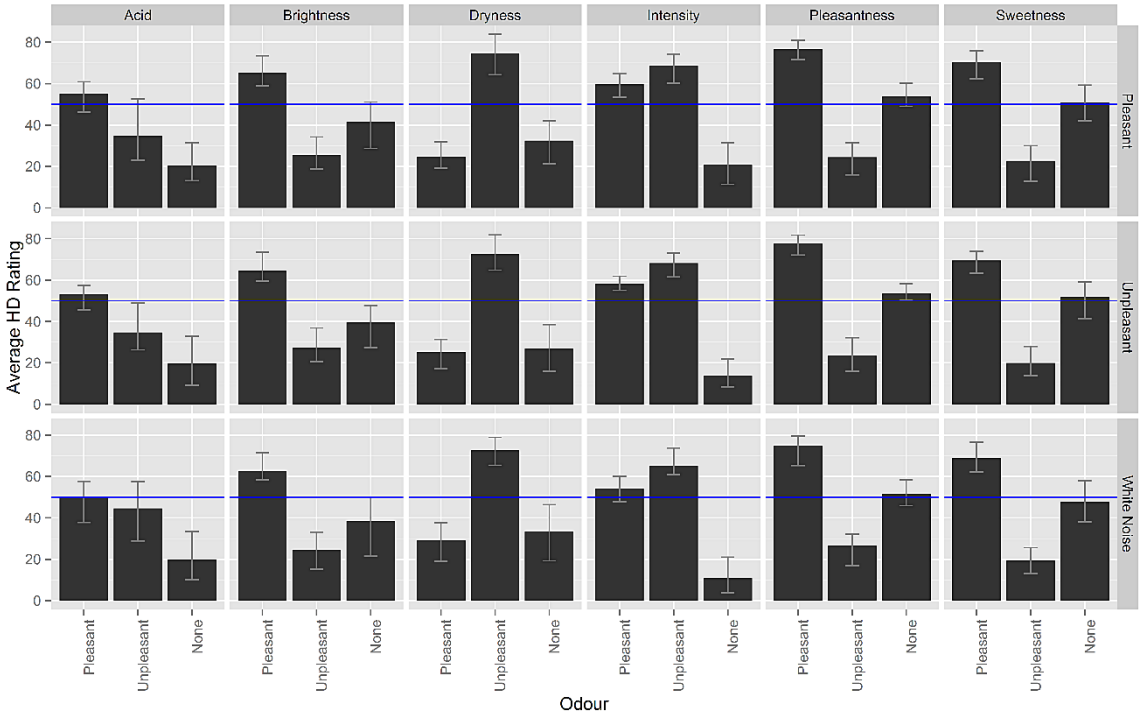


Figure B.2. Average ratings (Harrell-Davis estimator of the median) for each attribute in each odour and musical condition in Experiment 19. The error bars represent 95% bias-corrected-and-accelerated bootstrap confidence intervals (Efron, 1987).

Table B.1. Results of the ATS performed on each of the attributes assessed in the experiment presented in Experiment 19. M = music, O = odour, WN = white noise, PM = pleasant music, UN = unpleasant music, NO = neutral odour, PO = pleasant odour, and UO = unpleasant odour. FDR = false discovery rate and M_{HD} = Harrell-Davis estimator of the median. The *p*-value of the FDR should be taken as the adjusted final *p*-value obtained.

Odour attributes	**ANOVA-type statistic analyses and two-sample permutation tests**		
	Main effects	**Interactions**	**Pairwise comparisons (M_{HD}) [p-value $_{FDR}$]**
Pleasantness	M: $F_{1.69,\infty}$ =4.41, *p*=.016 O: $F_{1.87,\infty}$ =89.28, *p*<.001	M×O: $F_{2.81,\infty}$=.74, *p*=.519 (ns)	M: WN (50.23) vs PM (54.04): *p*= .18 [.33] WN (50.23) vs UM (53.42): *p*= .22 [.33] O: PM (54.04) vs UM (53.42): *p*= .41 [.41] NO (52.69) vs PO (76.74): *p*<.001 [.001] NO (52.69) vs UO (25.50): *p*<.001 [.001] PO (76.74) vs UO (25.50): *p*<.001 [.001]
Intensity	M: $F_{1.77,\infty}$ =1.07, *p*=.33 O: $F_{1.53,\infty}$ =81.94, *p*<.001	M×O: $F_{3.57,\infty}$=1.15, *p*=.32 (ns)	O: NO (13.96) vs PO (57.61): *p*<.001 [.001] NO (13.96) vs UO (67.54): *p*<.001 [.001] PO (57.61) vs UO (67.54): *p*<.001 [.001]
Sweetness	M: $F_{1.83,\infty}$ =3.16, *p*=.046 O: $F_{1.81,\infty}$ =57.12, *p*<.001	M×O: $F_{2.85,\infty}$=1.12, *p*=.33 (ns)	M: WN (44.21) vs PM (47.61): *p*= .28 [.42] WN (44.21) vs UM (47.90): *p*= .22 [.42] O: PM (47.61) vs UM (47.90): *p*= .51 [.51] NO (50.14) vs PO (69.65): *p*< .001 [.001] NO (50.14) vs UO (20.55): *p*< .001 [.001] PO (69.65) vs UO (20.55): *p*< .001 [.001]

Dryness	M: $F_{1.68,\infty}$ =3.70, p=.031 O: $F_{1.71,\infty}$ =63.75, p<.001	M×O: $F_{1.76,\infty}$=1.05, p=.34 (ns)	M:	WN (42.85) vs PM (41.06): p= .36 [.79] WN (42.85) vs UM (38.46): p= .79 [.79]
			O:	PM (41.06) vs UM (38.46): p= .68 [.79] NO (31.34) vs PO (25.71): p= .89 [.89] NO (31.34) vs UO (73.14): p<.001 [.001] PO (25.71) vs UO (73.14): p<.001 [.001]
Acidity	M: $F_{1.97,\infty}$ =.74, p=.47 O: $F_{1.52,\infty}$ =11.27, p<.001	M×O: $F_{2.89,\infty}$=2.29, p=.07 (ns)	O:	NO (19.61) vs PO (53.80): p<.001 [.001] NO (19.61) vs UO (36.85): p<.001 [.001] PO (53.80) vs UO (36.85): p<.001 [.001]
Brightness	M: $F_{1.94,\infty}$ =1.56, p=.21 O: $F_{1.92,\infty}$ =42.63, p<.001	M×O: $F_{2.30,\infty}$=.33, p=.74 (ns)	O:	NO (40.13) vs PO (63.54): p<.001 [.001] NO (40.13) vs UO (25.59): p=.002 [.002] PO (63.54) vs UO (25.59): p<.001 [.001]

Pairwise comparisons for the music factor failed to reach statistical significance. Although less conservative multiple comparisons tests can be used (and these do indeed reach statistical significance) the analyses are kept since they evidenced a statistically significant main effect of music on the pleasantness (p = .016), sweetness (p = .046), and dryness (p = .031) ratings. The odours that were presented after white noise were rated as less pleasant, less sweet, and drier, as compared to the other conditions.

In addition, Kendall tau correlations were performed between the different scores for each attribute for pleasant odours in the pleasant music and white noise conditions, and for

unpleasant odours, in the unpleasant music and white noise conditions (see Figure B.3 for a summary of the results).

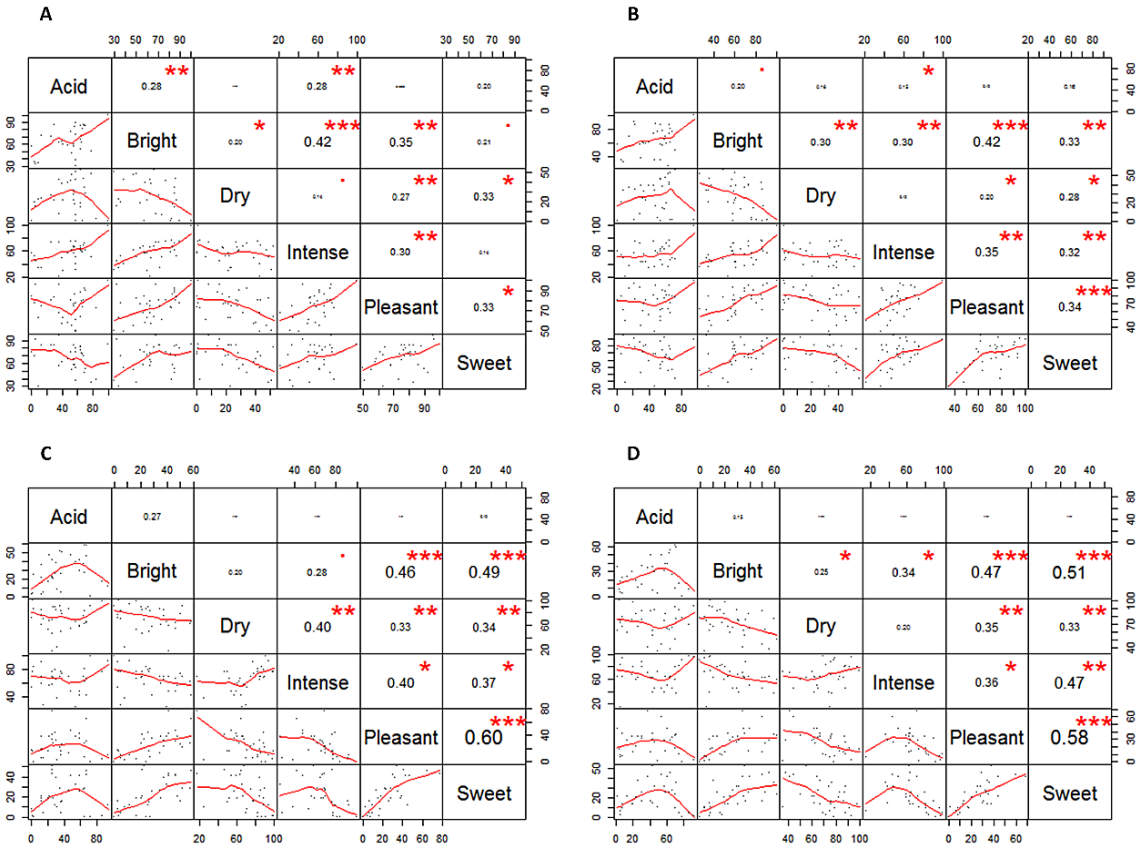


Figure B.3. Correlations between the ratings for the attributes in the pleasant music and pleasant odours (A), the white noise and pleasant odours (B), the unpleasant music and unpleasant odours (C), and the white noise and unpleasant odours (D) conditions in Experiment 19. The value within each box represents the Kendall tau coefficient and the *p*-values should be interpreted as follows: • = *p*<.5, * = *p*<.05, ** = *p*<.01, * = *p*<.001. In order to be coherent with the nonparametric tests used, locally weighted scatterplot smoothing (LOESS) lines (a non-parametric regression method) are shown instead of the traditional parametric straight lines (parametric regression method).**

Independently of the music condition, positive correlations were observed between brightness and pleasantness, brightness and sweetness, and pleasantness and sweetness. Moreover, a positive correlation was also documented between intensity and pleasantness

in the pleasant music and white noise conditions for the pleasant odours, whereas a negative correlation was found between these attributes in the unpleasant music and white noise conditions, for the unpleasant odours. A positive correlation was found between acidity and brightness in all conditions except for the unpleasant music and unpleasant odours condition. In addition, a negative correlation was found between intensity and sweetness in the unpleasant music and white noise conditions for unpleasant odours, while a positive correlation between these attributes was found in the white noise condition for the pleasant odour. Taken together, then, these results suggest that although certain relationships seem to be unaffected by the music condition (e.g., the relationship between pleasantness and sweetness), certain others may change as a function of the condition (e.g., the relationship between intensity and pleasantness).

The main aim of the present study was to assess whether musical pieces rated as pleasant or unpleasant would influence odours rated as either pleasant or unpleasant. Interestingly, when white noise was played in the background, a significant effect on participants' ratings of the odour (relative to the other music conditions) was observed. When the odours were presented together with the white noise they were rated as less pleasant and as less sweet than in the other auditory conditions. This result provides evidence for the idea that white noise can have an effect on odour perception (when compared to a condition in which background music was played) and in particular it can influence participants' hedonic ratings and perceived odour quality (e.g., sweetness).

Although, to the best of my knowledge, little previous research has been conducted to assess the influence of white noise on olfactory perception, suggestive evidence from its influence on the other senses may shed some light on understanding its effects in the present study. Ferber and Cabanac (1987), for instance, conducted a study in the taste

domain in which the hedonic valence of sucrose (but not of sodium chloride) solutions were shown to increase (meaning that people reported liking the solutions more) when listening to either loud noise or music. The sweet solutions were rated as significantly more pleasant when the participants were in the presence of the loud background noise or music (both presented at 90dB over headphones) than when tasting in silence or while listening to quiet music (70 dB) instead. Interestingly, despite the fact that each person was allowed to listen to the music that they liked (that is, they were encouraged to bring their own preferred music into the study), it was the presumably unpleasant white noise that actually gave rise to the largest sweetness enhancement effects. Ferber and Cabanac suggested that this particular crossmodal effect may have been mediated indirectly via the modulatory effect of noise on participants' arousal/stress levels which, in turn, may have affected their taste perception. It is important to note that this study only used 10 participants.

On the other hand, Masuda et al. (2008) reported that white noise had an effect on people's ratings of the perceived moistness of pretzels. In addition, and more relevant to the aims of the present study, Woods et al. (2011) conducted two experiments designed to assess the effect of background noise on food perception and found that the perceived sweetness and saltiness of a variety of different foodstuffs, were lower in the white noise condition as compared to the other sound condition. Woods at al. concluded that background noise reduced the perception of taste attributes (see also Spence et al., 2014). It may be the case, then, that background white noise, or the hedonic value associated with it, not only affects the perception of taste but also olfactory attributes (Spence, 2014).

It is worth noting that white noise has been used as a neutral sound condition in previous studies on odour-sound interactions (Seo & Hummel, 2011; Seo et al., 2014). It may be

the case that context can play an important role in guiding participants' ratings (e.g., Martino & Marks, 2001); in other words, the combination of auditory stimuli that are used in the very same experiment may influence the way in which participants evaluate the different odours. It is possible that, although the results of the pre-test suggested that people perceive them as either pleasant or unpleasant, when adding background noise, the relative hedonic value of the sound changes, and thereafter, its influence on odour perception. In addition, it may be the case that the musical pieces utilized were not sufficient to evoke a distinctive hedonic response, which was the case for white noise (more salient).

In a follow-up study, a new group of participants were asked to rate the consonant and dissonant musical pieces on a hedonic scale (as done in the preliminary experiment) but in this case white noise was included, in order to assess whether participants' ratings would be the same. The sounds were presented randomly four times to a group of 20 participants (8 females, M_{age} = 36.5 years, SD_{age} = 9.9, *range* = 23-55 years) who rated both their intensity and pleasantness in VAS scales anchored with *not at all* and *very much*. A RM-ANOVA (Greenhouse Geisser-corrected) indicated a significant difference between the ratings, $F(2.248, 42.721) = 53.751$, $p < .001$, $\eta_p^2 = .739$. Pairwise comparisons using the Bonferroni correction revealed that participants rated white noise as significantly more unpleasant as compared to any of the other musical pieces ($p < .001$, for all comparisons). It is worth noting that no significant difference between the intensity ratings was found. Note that these results contrast with the preliminary experiment in which a difference was found between consonant and dissonant sounds, though white noise was not included. The aforementioned results point to the fact that the context created by particular sets of stimuli can influence participants' ratings of those stimuli,

which is consistent with the idea that context plays a key role in crossmodal correspondences (Martino & Marks, 2001).

Why should music and background sounds influence the perception of olfactory stimuli? As mentioned before, one possibility here is that the hedonic value (Deroy et al., 2013; Kenneth, 1923; Marks, 1978) of a stimulus presented to one sensory channel extends to the information presented in another (e.g., "halo effect", see Seo et al., 2011; Spence & Piqueras-Fiszman, 2014). Another possibility is that the information presented to one sensory modality captures more attention and thus influences the perception of the information in another modality (e.g., Boyle, Bentley, Watson, & Jones, 2006; Woods et al., 2011). These accounts are not necessarily incompatible in that participants may attend information to one modality and if it is hedonically congruent with the other modality being evaluated, this may then strengthen its hedonic value. If it is not congruent (neither semantically nor hedonically), it may then interfere. Notably, further research is still needed in order to clarify the underlying mechanisms of such phenomenon.

Elsewhere, Spence and Shankar (2010) conducted a study in which they found that people's rating of chocolate samples was unaffected by listening to consonant vs dissonant triads. It is also plausible that under certain circumstances, particular consonant and dissonant sounds may not influence participants' perception of odours/flavours (though see Sampler et al., 2007, for a study on how music can influence emotion).

The results also contribute to the existing body of research suggesting that there is a relationship between pleasantness and odour qualities (e.g., Dravnieks, Masurat, & Lamm, 1984; Stevenson & Boakes, 2004). That is, unpleasant odours were rated as dryer and more intense, as compared to the other odours, while pleasant odours were rated as

sweeter and brighter, as compared to the others (see Zarzo & Stanton, 2009, for opposite uses of the descriptors sweet and dry when describing odours). Although the results presented here are limited in that only three odours per condition were included, these results may shed lights on the relationship between odour hedonics and quality. For instance, our results are in line with previous research (see Distel et al., 1999; Henion, 1971, for examples) suggesting that unpleasant odours are perceived as more intense (though matched in terms of their intensity in the pre-test); however, the association between pleasantness and intensity can be complex, and can vary as a function of the odours (e.g., Rouby et al., 2009); in other words, pleasantness and intensity can vary together and the direction of this variation depends upon the nature of the stimuli used, and the perceiver. On the other hand, previous research has suggested that people generally tend to prefer sweet smells (i.e., the smell of caramel, strawberry, vanilla, etc.; Stevenson & Boakes, 2004), which is also reflected in our results.

It is important to note that although the results reported in Experiment 19 contribute to the growing literature on the crossmodal influences in odour perception, a number of limitations should be mentioned. First, the main experiment did not include a no-sound condition, which limits the results to white noise as compared to dissonant and consonant sounds. Moreover, since participants were not explicitly informed about how to interpret each of the attributes used in this study (e.g., bright, dry), it is possible that their interpretation was not the same across participants (e.g., Kaeppler & Mueller 2013; though see Koulakov et al., 2011). In addition, although it is documented that white noise can influence olfactory perception and that this may be attributed to its hedonic value (as compared to consonant and dissonant sounds), research is still needed to clarify whether these effects are a product of some kind of “halo effect”, an attentional shift, or a

combination of both. Future research may help to address this element and to extend the results to other food-related and non-food odours.

As a final note, it is worth mentioning that suggestive evidence from Wesson and Wilson (2010) indicates that the rat's olfactory tubercle responds to tones, and that certain units in this structure show superadditive or suppressive responses when tones and odours are presented at the same time. Interestingly, animal studies suggest that there may be a strong evolutionary relationship between olfaction and audition (e.g., Cohen et al., 2011). This has been explained in terms of the idea that in natural environments animals may experience both olfactory and auditory stimuli at the same time in a variety of situations (e.g., while eating). Further research is undoubtedly needed in order to clarify the neural mechanisms that underlie olfactory-auditory interactions in humans, scientists are now starting to point to the fact that auditory-olfactory crossmodal integration can potentially serve a variety of heretofore little considered functions (e.g., social perception of action, see Aglioti & Pazzaglia, 2011).

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APPENDIX C

Experiment 20 Tasty search: Flavour facilitates the search for congruent visual objects

C.1 Introduction

The last few years have seen a growth of interest in trying to understand how information presented to the different senses interacts when people are searching for, and attending to, specific visual objects (e.g., Chen & Spence 2010, 2011; Iordanescu, Guzman-Martinez, Grabowecky, & Suzuki, 2008; Iordanescu, Grabowecky, Franconeri, Theeuwes, & Suzuki, 2010). In everyday life, people are exposed to a variety of related and/or unrelated information from different sensory modalities while searching for specific visual targets. Just imagine yourself looking for a particular fruit on the vegetable stall at the market. The information available to your senses will play a key role in the way in which your attention is directed toward these objects (e.g., Calvert, Spence, & Stein, 2004; Spence & Driver, 2004).

Most of the research that has been published to date documenting crossmodal influences on visual search has focused on the impact of auditory stimuli. For example, it has been proposed that the spatiotemporal alignment of audiovisual information influences attention (Driver & Spence, 2004; Spence, 2010). Semantically congruent sounds (i.e., the barking of a dog) can also enhance visual attention to congruent visual objects (i.e., an image of a dog, see Chen & Spence, 2010; Iordanescu et al., 2008). The congruence of stimuli across different sensory modalities has been pointed to as a key aspect of

multisensory learning, one that can influence both uni- and multisensory information processing (Barenholtz, Lewkowicz, Davison, & Mavica, 2014; Shams & Seitz, 2008).

To date, far less research has been conducted in the context of smell, taste, and flavour interactions during visual search. What is more, although there is a large body of literature covering the influence of the visual aspects of foods and drinks on the perception of taste and flavour (e.g., Spence, Levitan, Shankar, & Zampini, 2010; Shankar et al., 2010b), further research is still needed in order to clarify the extent to which flavour stimuli influences visual perception and attention (e.g., Seo, Roidl, Muller, & Negoias, 2010, for an example from the olfactory domain). To the best of my knowledge, there have as yet been no studies that have assessed the role of flavour stimuli on the efficiency of visual search.

Interestingly, a number of recent studies have reported that orthonasally-presented odours can influence visual perception and attention (Castiello, Zucco, Parma, Ansuini, & Tirindelli, 2006; Chen, Zhou, Chen, He, & Zhou, 2013; Robinson, Mattingley, & Reinhard, 2013, Seo et al., 2010). The literature on olfactory influences on visual search is relevant here since both ortho- and retronasal olfaction are key elements in driving flavour expectations and perception, respectively (Stevenson, 2009), with distinct but also interacting effects on human cognition (e.g., Bojanowski & Hummel, 2012; Hummel, 2008; Small & Prescott, 2005).

Chen et al. (2013) conducted a series of experiments, using both dot-probe and visual search tasks, demonstrating that congruent olfactory stimuli (i.e., lemon), presented orthonasally, influenced participants' visual attention toward related objects (i.e., the image of a lemon). They concluded that olfactory stimuli can help to highlight the

saliency of related visual objects (see also Robinson et al., 2013; Seigneuric, Durand, Jaung, Bandouin, & Schaal, 2010; Seo et al., 2010) and proposed that, from an evolutionary standpoint, this mechanism may have evolved to assist in the localization of food sources. Indeed, we often experience food-related olfactory/flavour and visual sensations together in our daily lives (Kuang & Zhang, 2014).

Importantly, previous research has documented different functions of, and neural responses to, ortho- and retronasal olfactory stimuli (e.g., Small, Geber, Mak, & Hummel, 2005; Rozin, 1982; Sakai, Kobayakawa, Gotow, Sait, & Imada, 2001) but it is also known that there is neural convergence of the two systems (e.g., Bajonowski & Hummel, 2012; De Araujo, Rolls, Kringelbach, McGlone, & Phillips, 2003). With that in mind, and taking into account that retronasal smell is a key aspect in flavour perception, a study designed to assess any influence of flavour congruence on visual search is presented.

C.2 Methods and materials

C.2.1 Participants

Twenty-four participants (7 male; mean age of 26 years), who reported normal (or corrected-to-normal) smell, taste, and vision and no history of dysfunction in any of these senses, took part in the study and were paid £5 in return. The participants were instructed not to wear any fragrance on the day of their session and not to have a meal, coffee, or to smoke in the 30 minutes preceding their session.

C.2.2 Apparatus and materials

The participants were tested in a within-participants experimental design with target congruency as the only factor (neutral, incongruent, or congruent). Note that half of the trials did not contain a target and were considered catch trials.

Six pictures of fruits were used as targets (apple and orange) and distractors (strawberry, papaya, grapes, and banana). The pictures of the strawberry and the papaya approximately matched the colour of the targets (orange-coloured orange and red apple) and were chosen in order to avoid a single feature search based on the colour feature. Due to the different shapes of the fruits, their size varied slightly in terms of width (2.6-4.2° of visual angle) and in height (3.2-4.8°). Each visual search display included four pictures of fruits (see Figure C.1). In the congruent, incongruent, and neutral conditions, the search displays were presented with either of the two possible target fruits and three randomly selected distractor fruits. In the catch trials, the search display was arranged without any target stimuli. Each fruit picture was positioned on one of the four corners of a square with the side of length 10.9° (distance from the centre of the screen to the centre of the picture 7.8°). The position of each stimulus was randomly selected on each trial. The visual stimuli were presented against a white background. The flavour stimuli that were used included apple juice (Innocent, London, *apple juice*), orange juice (Innocent, London, *orange juice smooth*), and purified water, all presented at room temperature.

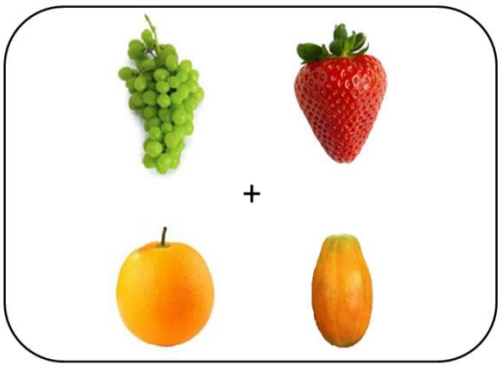


Figure C.1. Sample search display with a target present (the orange). Stimuli not drawn to scale.

The instructions as well as the visual search displays were presented on a 23'' monitor (Model U2312HM, Dell, Austin, Texas) with a refresh rate of 60 Hz. The distance between participants and the screen was kept constant (55 cm) with a chinrest. A two-sided *taste box* was constructed from cardboard, one side was used to place the taste stimuli and the other to deliver the tastes to the participants (see Figure C.2). In the preparation of each experimental session, 13 glasses (one glass of water for the training trials and 12 glasses for the experimental blocks) of 20 ml were filled with 10 ml of one of the three liquids (three glasses of orange and apple juice, and 4 glasses of water) and placed behind an opaque visual shield. On the other side, the participants would see black straws numbered below from 1 to 13, each corresponding to a specific glass.

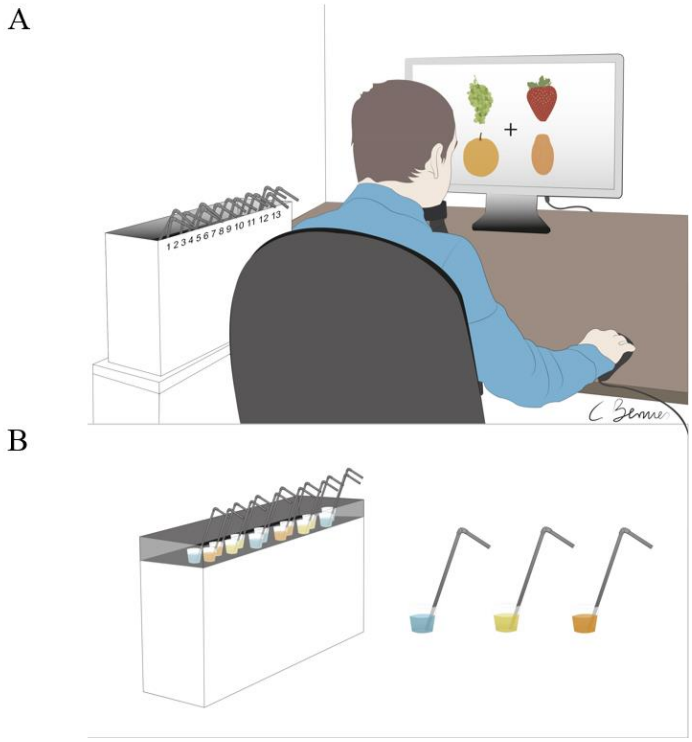


Figure C.2. Schematic illustration of the A) experimental set-up and B) taste box in Experiment 20.

C.2.3 Procedure

Each trial started with an empty screen (100 ms) which was immediately followed by the cue display (1000 ms). The latter contained a cue word (*Courier New*, point size: 22) indicating the identity of the target in the subsequent search display (1000 ms). The two displays were separated by a screen containing a fixation cross for 500 ms. Within 2000 ms, the participants had to indicate the presence or absence of the target in the search display, as rapidly and accurately as possible by pressing either of two mouse buttons.

The participants completed twelve blocks of 24 experimental trials each. At the start of each block of trials, they had to suck on one of the straws until they had all the fluid in their mouth. For the duration of the subsequent experimental block, the participants were

asked to keep the liquid in their mouth. After each block of trials, the participants expectorated into a glass and cleansed their mouth twice with purified water. For each participant, the sequence of three tastes was kept constant throughout the experiment in order to avoid the same taste being given in successive blocks. The sequence of tastes was, however, balanced across participants following a Latin-square.

Half of the 24 trials included a visual target (experimental trials) while the other half did not (catch trials). In the neutral condition, the participants had a sip of purified water while they were searching for either an apple or an orange. In the congruent condition, the participants held orange juice (or apple juice) in their mouth while searching for an orange (or apple). In the incongruent condition, the participants had to respond to the presence of an apple while holding the orange juice in their mouth or vice versa. Note that in those blocks where the participants had to keep a sip of juice in their mouth, only 25% of the trials were congruent, 25% of the trials were incongruent, and 50% of the trials were catch trials. The sequence of trials was randomized.

C.3 Results and discussion

Only those trials in which the target was present and the participants responded correctly were considered in the analysis of the reaction time (RT) data. Additionally, all of those trials with RTs shorter than 200 ms as well as those trials with RTs 1.5 interquartile ranges above the third quartile of each participant's individual RT distribution (Tukey, 1977) were excluded from the data analyses. In total, 9.6% of all trials were excluded from the analysis (7.6% error rate). Further, on average participants made 6.2% (SD = 4.5%) errors in the catch trials.

RTs. A RM-ANOVA with target congruency (congruent vs. neutral vs. incongruent) as factor and RTs as dependent variable was performed. A significant main effect of congruency was found, $F(2, 46) = 7.316$, $p < .002$, $\eta_p^2 = .241$. Given the literature on this area (Chen et al., 2013; Iordanescu et al., 2008, 2010), it was expected that RTs would be significantly faster in the congruent condition as compared to both control and incongruent conditions. Therefore, simple contrasts were computed and indicated significantly faster RTs for the congruent ($M = 523$ ms, $SD = 71$ ms) as compared to the neutral ($M = 546$ ms, $SD = 83$ ms), $F(1, 23) = 12.232$, $p = .002$, $\eta_p^2 = .347$, and incongruent ($M = 535$ ms, $SD = 77$ ms), $F(1, 23) = 5.718$, $p = .025$, $\eta_p^2 = .199$, conditions (see Figure C.3)[16]. The participants responded more rapidly when the fruit juice (i.e., flavour) in their mouth was congruent than when it was neutral or incongruent.

[16] In order to test for the standard visual search pattern, the mean RT of the catch trials was tested against the mean RT of the neutral condition; the *t*-test revealed a significant difference, $M_{Diff} = 31$ ms ($SD = 39$ ms), $t(23) = 3.905$, $p < .001$, with participants responding more slowly when the target was absent.

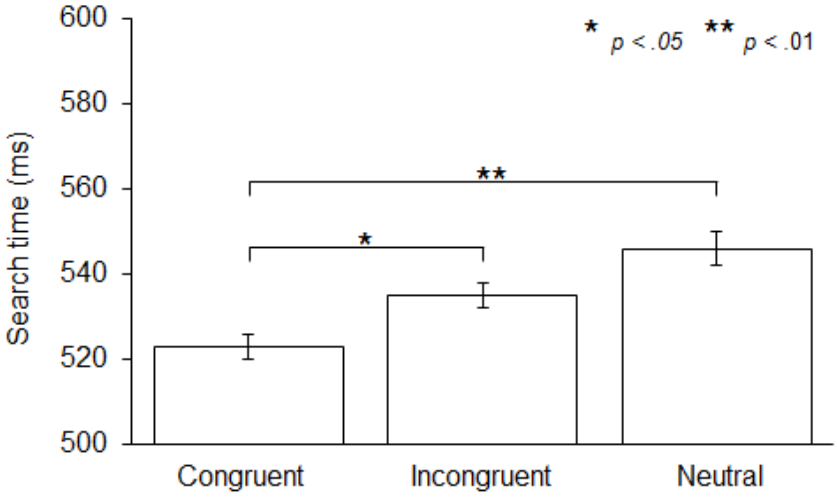


Figure C.3. Search times (in ms) in Experiment 20 when a visual target was presented while participants had a congruent, incongruent, or neutral taste in their mouth. The error bars represent the standard error of the mean.

ERs. The same ANOVA, in contrast to RTs using the Greenhouse-Geisser correction due to sphericity being violated, with error rates as the dependent variable revealed a significant main effect of target congruency, $F(1.332,30.636) = 5.518$, $p = .018$, $\eta_p^2 = .193$. Simple contrasts indicated a significant difference between congruent ($M = 6.2\%$, $SD = 4.5\%$) and neutral ($M = 9.9\%$, $SD = 8.7\%$) condition, $F(1,23) = 5.680$, $p = .026$, $\eta_p^2 = .198$, but failed to reveal any difference between the congruent and incongruent ($M = 5.0\%$, $SD = 5.5\%$) conditions. The participants missed the target less often when they held either of the juices in their mouth.

Experiment 20 provides the first demonstration of the influence of flavour on visual attention. Our results reveal that participants responded significantly faster to fruit images when they had a congruent flavour in their mouth, as compared to either an incongruent flavour or water. These results are consistent with the literature on crossmodal interactions and attention, which suggests that congruence between information presented

to vision and another sensory modality (i.e., audition, olfaction) can influence search times for visual objects (e.g., Chen et al., 2013; Iordanescu et al., 2008, 2010). Our results are also in line with those reported by Parma et al. (2011, 2013, and 2014) and Castiello et al. (2006) in which they demonstrated that both flavours and odours affect the visual guidance of motor behaviour when reaching and grasping congruent vs. incongruent objects.

But just how should the finding that flavours facilitate visual search be explained? Flavours and visual objects are commonly experienced together in everyday life, thus leading to crossmodal associations between these senses (Spence et al., 2010). Research on audiovisual (Iordanescu et al., 2008, 2010) and olfactory-visual interactions (Chen et al., 2013) and attention all point to the idea that facilitation may arise at the visual instead of semantic level of information processing (see also Chen et al., 2013; Zhou, Zhang, Chen, Wang, & Chen, 2012). Thus, by enhancing target sensitization (a top-down influence), as well as by the crossmodal interaction between the two modalities (Talsma et al., 2010), which then results in the formation of a more salient representation of the target object. An alternative explanation, which is not necessarily incompatible with the latter account, is that the information presented to the different modalities leads to a kind of multisensory Stroop effect in which competition between the (incongruent) information presented to different sensory modalities leads to interference (e.g., White & Prescott, 2007).

Flavours result primarily from complex interactions between olfaction, taste, and trigeminal inputs (e.g., Prescott, 2012; Small & Prescott, 2005; Spence, in press). Thus, it is the combination of these factors that exert their effect on attention. This idea may account for the absence of a difference between the congruent and incongruent conditions

in the ER results reported here, in that both juices may share some of those inputs as compared to water (i.e., sweetness). Alternatively, this specific result may relate to the idea that the mere presence of carbohydrates in the mouth (whether or not they are subsequently ingested) can influence performance (Chambers, Bridge, & Jones, 2009). Future research is indeed needed to clarify the extent to which the different features that create flavour sensations contribute to a facilitatory effect on attention.

The present study provides the first evidence that a complex flavour experience can enhance participants' performance in a visual search task. These results are remarkable, given the fact that the flavour sensations were task-irrelevant and could not be used strategically to facilitate task performance and taking into account that identical trials were compared against each other (same visual stimulus, different flavour). These results point to the fact that the association between flavours and the visual objects with which they are associated is robust. Indeed, from an evolutionary point of view, humans may be prepared to learn the association between what they are eating and the (edible) food source. Our results also demonstrate that visual attention can benefit from it.

C.4 References

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