The visual appearance of beer: A review concerning visually-determined expectations and their consequences for perception

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ABSTRACT

This review critically evaluates the literature concerning the impact of visual appearance cues (including colour, foam, and cloudiness) on people's perception in the beer category. The authors assess both the sensory expectations that are elicited by the visual appearance of beer, and the extent to which those expectations carry-over to influence the actual tasting experience. Beer is a particularly intriguing category to study since the differing production rules in different countries mean that there is not always the same scope to modify the colour in order to meet perceived consumer demands. What is more, there is currently disagreement in the literature concerning the impact of beer colour and foam on people's expectations of beer prior to tasting, and their multisensory flavour perception on tasting. Given how much beer is consumed annually, it is surprising that more research has not been published that assesses the undoubtedly important role of visual appearance in this beverage category. Part of the reason for this may simply be that it is difficult to create consistent experimental stimuli given the rapid transition of the head of the beer post-serving.

KEYWORDS: BEER; VISUAL APPEARANCE; COLOUR; CLARITY; EXPECTATIONS; EXPERIENCE.

1. Introduction

This manuscript presents the principal findings of a critical review of the literature concerning the role played by visual appearance cues (i.e., colour, foam, and clarity) in setting people's expectations associated with beer prior to tasting, and their perception of the multisensory flavour on tasting. Beer is the single most consumed alcoholic beverage worldwide by volume (International Wine and Spirits Record, 2018). To give an impression of the size of the market, in the year 2016 global beer consumption was estimated at approximately 186.89 million kilolitres (Kirin Holdings Company, 2017), up slightly from a figure of 183.78 million kilolitres the preceding year (Kirin Holdings Company, 2016). In concert with this increase in the consumption of beer, there has also been a marked increase in the number of innovative microbreweries operating in many countries (e.g., Hungary, North America, UK, and Italy; Fertő, Fogarasi, Major, & Podruzsik, 2018; Price, 2018) experimenting with beer. For example, Sailors Grave Brewing™ in Australia have been experimenting with the use of products such as seaweed, mushrooms, grapefruit, pumpkin, and yoghurt in their beers (http://www.sailorsgravebrewing.com/). Of relevance to the present review, the addition of such ingredients may well change the visual appearance properties of beer.

This review critically assesses the literature focusing on the influence of the visual appearance of beer on people's expectations and multisensory flavour perception, although the authors ignore any influence of the constituent components or chemical composition of the product itself on multisensory flavour perception (see Bettenhausen, Barr, Broeckling, Chaparro, Holbrook, Sedin, & Heuberger, 2018, on this theme). Importantly, there are discrepancies in the outcomes of studies in relation to how elements of visual appearance (e.g., colour) influence the expectations that are associated with, and perceptions of, beer. To better understand the role of the visual appearance of beer on people's expectations and multisensory flavour perception, it is crucial to resolve these discrepant findings. Furthermore, given its popularity worldwide, it is important to understand those factors that might influence the multisensory tasting experience, not to mention the hedonic enjoyment, while drinking beer.

Search strategies were developed for PsycINFO and Google Scholar. Manual searches of published papers and snowball searches of included studies were also performed. Searches were conducted in English through June 2019. In what follows, the authors outline the research findings exploring those visual appearance cues that influence people's expectations associated with, and the multisensory flavour perception of, beer. Although there is research exploring, for example, how (a) participants use beer colour to classify different types of beer (e.g., Nikolova, Gabrovam, Boyadzhiev, Pisanova, Ruseva, & Yanakiev, 2017), (b) training influences people's ability to sort

beers (e.g., Honoré-Chedozeau, Desmas, Ballester, Parr, & Chollet, 2019; Lelièvre, Chollet, Abdi, & Valentin, 2009[1]; Spence, 2019a), and (c) colour influences the perception of non-alcoholic birch beer (i.e., root beer) (Hyman, 1983), it is surprising how few published studies have actually assessed the expectations associated with beer, and the influence of visual appearance cues including colour on the perception of beer.

1.1 Expectations and their effects on multisensory perception

Before delving into the literature specific to beer, it has been argued that visual food and beverage cues set expectations concerning likely taste/flavour properties (Garber, Hyatt, & Nafees, 2015; Garber, Hyatt, & Starr, 2000; Rebollar, Gil, Lidón, Martín, Fernández, & Rivera, 2017; Santagiuliana, Bhaskaran, Scholten, Piqueras-Fiszman, & Stieger, 2019; Spence, Levitan, Shankar, & Zampini, 2010; Torrico, Fuentes, Gonzalez Viejo, Ashman, & Dunshea, 2019). If, upon tasting, the experience more or less matches the expectation, then the latter would seem to anchor the former (see Deliza & MacFie, 1996; Piqueras-Fiszman & Spence, 2015, for reviews). If, however, the expectation (derived from visual and/or any other cues) and the tasting experience differ, then visual cues (e.g., colour) may be discounted (i.e., considered an unreliable cue by the consumer). It should be noted that the degree of discrepancy between expectation and experience is important here. Specifically, if the discrepancy is small, the taste experience is fixed by (or anchored to) visual expectations (Geers & Lassiter, 1999; Hovland, Harvey, & Sherif, 1957; Piqueras-Fiszman & Spence, 2015; Zellner, Strickhouser, & Tornow, 2004). If the difference is large, however, then there may be an adjustment to the hedonic response such that the foodstuff is rated more negatively than would have been the case if no incongruent visual cue were present (i.e., disconfirmation of the expectation response). There is also a third possible outcome that is neither assimilation nor contrast, but a simple ignoring of the irrelevant cue. Here, if the discrepancy between expectation and experience is large, the visual cue may well be ignored as irrelevant (Shankar, Levitan, & Spence, 2010a; Shankar, Simons, Levitan, Shiv, McClure, & Spence, 2010b; Shankar, Simons, Shiv, Levitan, McClure, & Spence, 2010c; Shankar, Simons, Shiv, McClure, & Spence, 2010d; Spence, 2019b).

[1] Parenthetically, Lelièvre et al. (2009) found that when it was available as a source of information, both trained and untrained assessors used colour when asked to sort beers into groups. This was true despite the fact that trained assessors claimed to base their judgements on the chemosensory properties (i.e., taste, aroma) of the beer. Thus, as the authors conclude: "sensory training does not seem to have an effect on the criteria used to organize beer perceptions" (Lelièvre et al., 2009, p. 143).

In relation to beer, there may be a direct link between colour and taste/flavour, but beer drinkers nearly always see the colour of the beer in context, and this context could lead to a categorical judgment (e.g., that beer looks like a lager, while that beer looks like a stout). This categorical judgment (i.e., an expectation) has the potential to anchor/influence the subsequent tasting experience. Wan, Zhou, Woods, and Spence (2015) showed that glassware can be considered a context in its own right (see Spence & Van Doorn, 2017, for a review of the influence of the shape of a drinking receptacle), and that the type of glassware influenced the amount people were willing to pay for beer. Specifically, and in relation to beer[2], Wan et al. (2015) found that participants from mainland China expected to like the beer served in a dimpled beer mug (shown in a digital photograph) more than beers displayed in certain other glass types (e.g., a highball or wine glasses; see Figure 1). Wan et al. (2015) also reported that their Chinese participants were willing-to-pay more for a beer photographed in a dimpled beer mug, relative to other glasses used in the study (i.e., highball or rocks glass). Interestingly, these results were not replicated in a sample of participants from North America. The latter, for example, rated beer mugs and highball glasses as being equally appropriate receptacles for beer.

- INSERT FIGURE 1 APPROXIMATELY HERE –

1.2 Where does the colour of beer come from?

At this point, it is worth highlighting that the components of beer that give rise to its colour are distinct from those giving rise to its bitter taste. This contrasts with other beverages (e.g., tea) where colour and bitterness are derived from the same element (i.e., tannins). According to Spearot (2016), "the majority of bitterness in beer is derived from hops" (p. 3; see also Oladokun, James, Cowley, Dehrmann, Smart, Hort, & Cook, 2017; Oladokun, Tarrega, James, Smart, Hort, & Cook, 2016; Stevens & Page, 2004), whereas the colour of a traditional beer is derived, in large part, from malted barley (Bettenhausen et al., 2018; De Keukeleire, 2000; Magalhães, Dostalek, Cruz, Guido, & Barros, 2008). As such, the bitterness and colour of a beer are not necessarily connected (rather, one might think of them as orthogonal sensory attributes). Although hops are the main contributor to bitterness, Donadini et al. (2014) state that "intensely kilned or roasted dark malts, which are responsible for the deep red, red-brown and mahogany hue of beer…[are] simultaneous contributors of astringency, bitterness and some harshness to wort and finished beer" (p. 78). This is, however, the exception.

[2] Wan et al. (2015) assessed five alcoholic beverages. We have focused on their findings relating to beer.

Nevertheless, the idea that 'the colour of a beer is associated with its bitterness' seems to be pervasive amongst consumers. According to Spearot (2016), the reasons for this might be socio-historical. Specifically, brewing companies produce German-style lagers that are low in alcohol and bitterness, and light in colour (e.g., Pabst Blue Ribbon®, Heineken®). Thus, consumers associate light-coloured beers with low bitterness (i.e., they have, in a sense, picked up on the natural statistics of the drinking environment; see Saluja & Stevenson, 2018).

2. The colour of the beer

In an early study exploring the influence of colour on the perception of beer, Guinard, Souchard, Picot, Rogeaux, and Siefferman (1998) assessed which characteristics of beer were associated with its thirst-quenching quality. These researchers had 12 trained people (10 men, two women) rate the intensity of certain attributes (e.g., carbonation, bitterness) of 18 beers available in the United States. A variety of beers were used. They included (a) domestic, imported, and speciality beers, (b) lagers and ales, and (c) beers that were light and dark in colour. Although this study generated many findings, here we are interested specifically in the influence of colour on the perception of beer. Guinard et al. found that colour was negatively associated with the beer's ability to quench one's thirst. Specifically, as the beer increased on a scale from light (1) to dark (10), its rated ability to quench one's thirst decreased.

Donadini, Fumi, and Newby-Clark (2014) reported some interesting results in relation to the influence of colour when examining a range of characteristics (e.g., alcohol by volume, bitterness) on people's preferences for bottom fermented red beers (BFRBs). As BFRBs are brewed with several different types of dark malt, finished beer colours typically range from a light reddish amber to a deep copper colour (see Figure 2). Donadini et al. had 246 Italians rate eight BFRBs in a natural environment (i.e., taste tests were conducted in a tavern). In the darkest beer, bitterness and astringency were rated as being moderately high. This beer was also rated as having more burnt-like and roasted characteristics than a lighter-coloured beer (approximately third from the left in Figure 2). As mentioned above, roasted dark malts are simultaneously responsible for both the deep colour of some beers and increased bitterness (Donadini et al., 2014). The lightest sample in Donadini et al.'s study was rated as having an alcohol content, sweetness, and fruitiness that were moderately high. A panel of trained experts rated this beer as having moderate levels of astringency, but it was rated as low or very low on several other attributes (e.g., bitterness). The lightest beer was "significantly preferred over other BFRBs" (Donadini et al., 2014, p. 79). The fact that the lightest beer was thought to be low in bitterness and astringency, as well as high in sweetness and fruitiness, may go some way to explaining the findings from taste tests by Guinard

et al. (1998), who found that lighter beers were rated as being more thirst-quenching than darker beers. Unfortunately, however, colour covaried with several other variables in Donadini et al.'s (2014) study, and thus colour cannot be unequivocally said to have caused these findings.

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In his Masters thesis, Spearot (2016) found that colour influenced North Americans' perceptions of the bitterness of beer, but not in the direction that had been expected. Initially, Spearot ran blind taste tests to ensure that the perceived taste/flavour of three differently-coloured beers (see Figure 3) was equivalent. Then, with the colour of the beer visible to participants, Spearot found that participants rated lighter (i.e., yellow) beers as being more bitter than darker (i.e., black) beers, despite chemical and blind taste tests deeming them to be equivalent. Spearot claimed that when separated into groups based on 'expertise' (regular beer drinkers vs. non-regular drinkers/novices), the "novices rated lighter samples as significantly more bitter, causing the general effect observed in initial analysis to be driven by this group" (p. 67). If one visually inspects Figure 16 in Spearot's thesis, one can understand how he arrived at such a conclusion. Specifically, colour does not seem to influence experts but there does seem to be an effect for novices, whereby lighter beers are rated as being more bitter than are darker beers. However, it should be pointed out that the interaction term in Spearot's analysis was non-significant (i.e., $p = .223$). Given this fact, only the significant main effects should have been interpreted. The claim regarding simple effects should have been avoided because the non-significant interaction suggests that the effects of expertise were not different at the different levels of colour. The main effects show that novices rated the beers as tasting more bitter than did the experts, and that the lighter beer was rated as more bitter than the darker beer. Nevertheless, the statistically significant main effect demonstrates that colour can influence the perceived taste/flavour of beer. As already mentioned though, the effect was not in the expected direction. Spearot suggested that this might be a result of the growing popularity of Indian Pale Ales (IPAs) in North America. IPAs "are light, yellow beers with intense hop bitterness" (Spearot, 2016, p. ix). Parenthetically, IPAs are increasing in popularity elsewhere too (Beeson, 2018; Davis & Stanger, 2015).

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In 2017, Reinoso-Carvalho, Moors, Wagemans, and Spence reported that, prior to tasting a beer, people (predominantly Europeans from Belgium, France, and the UK) expected (a) to like light beer more than dark beer (see Figure 4 for the stimuli used), (b) the darker beer to be more bitter

than the lighter beer, (c) the darker beer to be stronger than the lighter beer, and (d) the darker beer to have more body than the lighter beer. However, people's perceptions of these attributes *after* tasting the dark and light beers were similar. That is, any expectations based on visual information disappeared after tasting, such that the ratings of dark and light beers converged (to be clear, colour had no influence on perceived taste/flavour). Here, and in a manner similar to Spearot (2016), the beers were designed to taste the same (i.e., a filtered, light [in terms of alcohol and body], and hoppy beer) even though their colours differed. As discussed earlier, it has been argued (e.g., Garber et al., 2000; Garber et al., 2015; Spence et al., 2010) that the colour cues associated with beverages help set expectations about likely taste/flavour properties. If, upon tasting, the experience more or less matches the expectation, the expectation anchors the tasting experience (Deliza & MacFie, 1996; Piqueras-Fiszman & Spence, 2015). If, however, the expectation and experience differ by too great a margin, as seems to have occurred here, then colour cues may well be discounted (Shankar et al., 2010a; Spence, 2019b).

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Recently, Reinoso-Carvalho, Dakduk, Wagemans, and Spence (2019) had a pool of predominantly Belgian participants complete one of three experiments. In a preliminary study, and consistent with their earlier work (i.e., Reinoso-Carvalho et al., 2017) and Spearot (2016), the researchers conducted blind taste tests to ensure that the perceived taste/flavour of two differently-coloured beers (see Figure 5) were equivalent. In Experiment 1, Reinoso-Carvalho et al. (2019) had their participants sample either a dark or a light beer in both blind (the colour of the beer was masked by serving it in a black, plastic cup) and sighted (transparent cup) conditions. Each person's ratings of the beer's (a) sweetness, (b) bitterness, (c) sourness, (d) alcohol strength, and (e) body were assessed. The authors also asked their participants which beer they preferred. Here, there were no main effects of beer colour (i.e., pale vs. dark) and no interactions between beer colour and tasting condition (i.e., blind vs. sighted) for any of the variables measured. There was, however, a significant main effect of tasting condition for the measured variable 'body', such that those in the sighted condition rated the 'body' higher than those in the blind condition. The effect size here was small (η^2_p = .038), and thus there is weak evidence to suggest that the presence of visual information influences the perceived body of beer (i.e., 3.8% of the variance in the ratings of the beer's body can be explained by the presence of visual cues).

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In their second experiment, another group of participants tasted both beers (i.e., pale and dark) under sighted conditions (Reinoso-Carvalho et al., 2019). Here, the participants evaluated each beer before and after tasting it (i.e., measuring expectations and perception, respectively). Reinoso-Carvalho et al. claimed that their results revealed there to be 'main effects' of time (pre- vs. post-tasting) for the dark beer. Post-tasting, people (a) liked the dark beer more, (b) rated it as being less bitter, (c) rated it as containing less alcohol, and (d) rated it as having less body, relative to their ratings before tasting. Reinoso-Carvalho et al. also found statistically significant 'main effects' of time (pre- vs. post-tasting) for the pale beer. Here, people liked the pale beer less and rated it as having more body after tasting it. 'Main effects' of beer colour (pale vs. dark) were also found for pre-taste expectations. That is, before tasting the beer, people expected (a) to like the pale beer more than the dark beer, (b) the pale beer to be less bitter than the dark beer, (c) the pale beer to contain less alcohol than the dark beer, and (d) the pale beer to have less body than the dark beer. In contrast, there were no statistically significant 'main effects' of beer colour post-tasting, suggesting that expectations based on beer colour, prior to tasting, had no influence on the perceived taste/flavour of beer.

A simple reading of Reinoso-Carvalho et al.'s (2019) Experiment 2 raises an issue with the statistical analysis that requires consideration. The authors refer to 'main effects' in this experiment, but are talking about simple effects. This is a relevant issue because, in their Experiment 2, the authors fail to report the interactions between beer colour (pale vs. dark) and time (pre-tasting vs. post-tasting), even though interactions were assessed in Experiment 1. A significant interaction between colour and time would have indicated that the effects of time were different at the different levels of colour, and thus the simple effects should have been assessed[3]. Without the interaction though, the researchers are describing two effects that appear to be different, but the difference has not been established. In an attempt to clarify this issue, the authors contacted F. Reinoso-Carvalho who provided a copy of the raw data, which the authors reanalysed. Our analysis showed that all the relevant interactions were significant, and thus simple effects analyses were warranted. Thus, Reinoso-Carvalho et al.'s interpretations of the outcomes of their study were confirmed.

Smythe, O'Mahoney, and Bamforth (2002) conducted a study that is relevant to the expectation component of Reinoso-Carvalho et al.'s (2017, 2019) work. In Smythe et al.'s (2002) study, three differently coloured beers (i.e., a pale lager with a European Brewery Convention [EBC] colour of 4.5, a lager with an EBC colour of 6, and an ale with an EBC colour of 16; see Figure 6) were

[3] This is the same problem identified in Spearot's (2016) interpretation of his analysis.

poured in three different ways in front of participants: (1) the glass was filled and then emptied, (2) the glass was filled and half-emptied, and (3) the glass was filled. People were allowed to look at the beers, but they were not allowed to smell or taste the beers, or touch the glasses. Participants were asked to rank the beers from best-to-worst, or most-to-least, on a number of attributes (e.g., bitterness, sweetness). Here, and similar to Reinoso-Carvalho et al. (2017, 2019), it was expected that the darkest beer would be significantly more bitter than the lightest beer. However, a point of difference is that Reinoso-Carvalho et al. (2017, 2019) found that people expected to like a pale beer more than a dark beer, while Smythe et al. (2002) found that the darker beer was expected to be "better in anticipated flavour, better in overall appearance, and more likely to be bought" (p. 39). The difference here may relate to cultural differences in the meaning of colour, or some other facet of sampling, as Smythe et al. (2002) recruited North Americans, while Reinoso-Carvalho et al. (2017) used a European sample.

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Another study assessing expectations was conducted by Donadini, Fumi, Kordialik-Bogacka, Maggi, Lambri, and Sckokai (2016). These researchers presented 550 participants (230 Italians, 160 Poles, and 160 Spaniards) with 40 profiles of specialty beers. The profiles consisted of short descriptions of a hypothetical specialty beer that described six attributes of the beer (i.e., malt type, adjuncts, sources of sugar, ingredients, sensory characteristics, and price). Some of the sensory characteristics were gold, red, and dark. The profiles were presented to consumers in visual and written form (see Figure 7). The participants rated their level of interest in the hypothetical specialty beer on a nine-point Likert-type scale from 1 (*Not at all interested*) to 9 (*Extremely interested*). It is worth noting that participants did not actually come into contact with any beer in this study. In relation to colour, Donadini et al. (2016) found that a gold colour was a significant and unique predictor of expected interest in specialty beers in Italians (both men and women). In Poles, the descriptors red and dark had significant, negative influences on men's interest in specialty beers. In contrast, red was a significant, positive predictor of Polish women's interest in specialty beers. Finally, gold and red colours were significant and unique predictors of expected interest in specialty beers in Spanish men, while a dark colour was a significant, negative predictor of Spanish women's interest in specialty beers.

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In summary, and in relation to consumers' expectations, there are clear differences in expectations relating to taste/flavour based on the colour of the beer. Both Smythe et al. (2002) and Reinoso-Carvalho et al. (2017) found that people expect darker beers to taste significantly more bitter than beers that are lighter in appearance (see Table 1). As such, and when developing new products, brewers might want to keep in mind that their customers will likely expect darker-coloured beers to taste more bitter than lighter-coloured beers. Thus, if they are developing a darker-coloured beer, they may want to negate this expectation by creating a discrepancy between the expectation and the experience (e.g., increase the beer's sweetness) such that the colour cue is discounted (Shankar et al., 2010a). Other researchers (i.e., Donadini et al., 2016) found that colour influenced people's expected interest in beers. Italians were interested in speciality beers that were gold in colour. Polish men were not interested in beers that were red or dark, while Polish women expressed an interest in red beers. Finally, Spanish men were interested in beers that were gold and red, while Spanish women were not interested in dark beers. Overall, the studies reviewed here seem to suggest that people expect to like lighter-coloured beers more than darker-coloured beers.

- INSERT TABLE 1 APPROXIMATELY HERE -

In relation to perception, Guinard et al. (1998) found that as beers change from light-to-dark colours, their rated ability to quench one's thirst decreases. This finding suggests that brewers should use lighter-coloured adjuncts, or malts that produce lighter-coloured beers, if they want their beers to be perceived as thirst-quenching. Donadini et al. (2014) found that their darkest beer was rated as being moderately high in bitterness, while the lightest beer was rated as being low in bitterness. This contrasts with Spearot (2016) who found that a lighter beer was rated as tasting more bitter than a darker beer. Reinoso-Carvalho et al. (2017, 2019) found no difference in the perceived bitterness of light and dark beers. A seemingly logical explanation for these differences is that Spearot (2016) sampled North American participants, Reinoso-Carvalho et al. (2017, 2019) sampled from Belgium, UK, and other European countries, while Donadini et al. (2014) sampled Italians. Spearot (2016) suggested that less bitter, pale beers dominate the US market (e.g., Budweiser®, Miller Lite®), and thus North Americans may have a preference for those beers that are low in bitterness. Thus, when they taste a light-coloured beer that conflicts with this 'low bitterness' expectation, there may be an adjustment such that the beer's rated bitterness increases (i.e., a disconfirmation of expectation response). Europeans, on the other hand, may have greater exposure to pale beers that are high in bitterness (e.g., pilsners, IPAs).

Interestingly, geographic differences should be considered when assessing the influence of beer colour on perception. For example, Germany has 'purity laws' that prevent anything other than malted grains, hops, water, and yeast from being used in the making of beer (BBC, 2016). As such, in certain countries, the colour of the beer might be more tightly linked to the product. Germany, for example, is known for its top-fermented wheat beers (Weizen), Pilsners, and Weisse beers (i.e., beers that combine malt and wheat), all of which are light yellow in colour and relatively low in bitterness. However, in other countries, the colour of the beer might reflect a much broader range of characteristics, especially given the burgeoning craft beer movement. Ireland, for example, is famous for its dark and relatively bitter stout (i.e., Guinness®, Murphy's), while some other European beers are light in colour and relatively high in bitterness (e.g., Peroni from Italy). Thus, one might expect that, pre-globalization, there would have been significant cultural variation in the meaning of colour in beer. However, given the globalization of the beer market, cultural variation may be in decline (Aizenman & Brooks, 2008; Eschevins, 2018, make similar points), but more work is needed in this area.

3. The clarity of the beer

To the best of our knowledge, only one study (i.e., Barnett, Juravle, & Spence, 2017) has been published assessing the influence of the clarity of a beer on taste/flavour perception. Barnett et al.'s study was conducted to assess the suggestion that using finings to clarify beer negatively impacts its flavour (see Moor Beer Company, 2017; Naylor, 2014; Protz, 2013). Historically, the finings used to clarify beer consisted "of an aqueous suspension of collagen from the swim bladder of fish preserved with sulphur dioxide" (Barnett et al., 2017, p. 1). More recently, though, seaweed, gelatin, and silica, amongst others, have been used to clarify beer. Barnett et al. ran two, naturalistic studies (recruiting from attendees at the 2017 Edinburgh Science Festival). In Experiment 1, they presented 117 (predominantly) British social drinkers with two beers, one that had been treated with finings and one that had not (see Figure 8). Here, though, the beers were served in black cups, and thus participants could not identify which was which (blind test). In Experiment 2, 118 participants were presented with two beers (again, one in which finings had been used, and an untreated beer) in clear glasses. Barnett and colleagues' results showed that the addition of finings had no statistically significant effect on taste/flavour ratings in either experiment, and thus finings do not change the perceived taste/flavour of beer. People did, however, prefer the 'appearance' (Experiment 2) of the beer that had been treated with finings.

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4. Foam (Head and Lacing)

Like beer colour, there are relatively few studies assessing the influence of beer foam on people's expectations of beer. Evans and Sheehan (2002) state that a "suitable head on a beer is one of the first characteristics by which consumers judge the quality of their beer; thus it is of vital importance to brewers" (p. 47). Carbonation (i.e., dissolved carbon dioxide gas), a contributor to head, can also enhance flavour and aroma perception by delivering volatile odour compounds to the consumer, and can influence mouthfeel (e.g., a highly carbonated beer will create a 'prickly' sensation on the tongue). Here, we review the literature on how head and lacing (i.e., adhesion of the foam to the glass; Evans & Sheehan, 2002) influence people's expectations associated with, and multisensory perception of, beer.

The earliest study in this field, and one that was discussed earlier, was conducted by Guinard et al. (1998) and assessed which characteristics of beer were associated with its thirst-quenching quality. Guinard et al. found that the amount of foam was negatively associated with the beer's ability to quench thirst[4]. Specifically, as the beer's foam increased on a scale from none (1) to a lot (10), its rated ability to quench one's thirst decreased.

A small group of researchers have been responsible for the bulk of the research assessing the impact of beer foam and lacing on people's expectations. Bamforth (2000), for example, conducted a series of experiments that attempted to assess the influence of different levels of head and lacing on participants' expectations relating to beer. To present participants with different foaming patterns, three-photograph sequences of beers were used to represent foam qualities at the beginning, middle, and end of a drinking event (Figure 9 contains images similar to those used by Bamforth, 2000). In their first study, participants from California (USA) and Oxford (England) were presented with two sequences of photographs (Sequence 1 was similar to A2, B2, and C1 in Figure 9, while Sequence 2 was similar to A2, B4, and C4) and asked to rate which beer looked the most appealing. In this part of the study, and with a sample of 92 people (44 from North America, 48 from the UK), Bamforth failed to find a statistically significant influence of beer foam on viewers' expectations.

- INSERT FIGURE 9 APPROXIMATELY HERE -

[4] Interestingly, Guinard et al. (1998) also found that carbonation and bubble density were positively associated with the beers' ability to quench one's thirst. Specifically, as the beer's carbonation and bubble density increased on a scale from low (1) to high (10), its rated ability to quench one's thirst increased.

In a second experiment, participants from North America were asked which of two beers (i.e., Sequence 3 had foam greater than A4 in Figure 9, but lacing similar to B2 and C2, while Sequence 4 was similar to A2, B3, and C3) had the better foam. Bamforth found that people preferred Sequence 4 with "respectable initial foam, which survived well and laced the glass" (p. 231), relative to Sequence 3 that had a large head of foam. In a third experiment, participants from Sheffield (England) and Tokyo (Japan) were presented with two beers (Sequence 5 was similar to A1, B1, and C1 in Figure 9, while Sequence 6 was similar to A2, B3, and C3) and asked to rate which would taste better. Bamforth found that people preferred the beer with 'reasonable' foam (Sequence 6), relative to the beer with no foam. In the fourth and final experiment, participants from Hull (England) and Nuremberg (Germany) were asked whether there were differences in two beers (Sequence 7 had foam greater than A4 in Figure 9, but lacing similar to B2 and C2, while Sequence 8 had foam greater than A4, but lacing similar to B4 and C4), and whether the differences mattered. Bamforth found that, although participants reported that the differences did matter, there was no clear preference for either beer.

Using Bamforth's (2000) stimuli, Donadini et al. (2011) assessed the influence of different levels of head (i.e., high, medium, and low) and lacing (present vs. absent) on Italian beer consumers' expectations relating to beer attributes and preferences (Figure 9 contains images similar to those used by Donadini et al., 2011). Participants were shown different sequences of photographs (i.e., full, half-full, empty) and asked to rate each beer on 26 attributes (e.g., bitterness, ability to quench one's thirst) using a 7-point Likert-type scale, ranging from 1 (*strongly disagree*) to 7 (*strongly agree*). Donadini et al. found, overall, that Italians thought that beer's with medium levels of head (i.e., similar to Beer A2 in Figure 9) were the most visually appealing. Beers with a moderate level of foam were deemed the most expertly poured, the most likely to be consumed, and the most likely to be purchased. The amount of foam and the presence or absence of lacing did not significantly affect expectations relating to taste/flavour attributes (e.g., bitterness, sweetness). Interestingly, Donadini et al. found that clusters emerged based largely on the frequency of drinking beer, and these clusters had different preferences for, and different expectations associated with, beer foam. For example, people who drank beer "some times per year" [sic] (p. 526) preferred large amounts of foam and lacing (i.e., more than A4 in Figure 9), while a cluster of people comprising some people who drank beer several times a week and others who consumed beer several times per month preferred the foam of Beer A2, but lacing similar to Beers B1 and C1.

At this point, it is worthwhile raising a concern about a statistical issue that appears often in research assessing beer foam and its influence on people's expectations. That is, running multiple tests inflates the risk of Type I error (see Rubin, 2012, p. 180) which, simply stated, is falsely

concluding an effect when none exists. Frequentist metrics such as *p*-values are biased against the null hypothesis (Andraszewicz, Scheibehenne, Rieskamp, Grasman, Verhagen, & Wagenmakers, 2015), and given it is commonplace to conduct several analyses in each paper in this field, the chance of false positives seems high. As such, corrections for multiple comparisons should be customary. As an example of this issue, Donadini et al. (2011) found that the amount of foam consistently influenced people's expectations regarding the attributes of beer. However, given that these authors assessed significance at the .05 level, and given that more than 26 ANOVAs were conducted, it is difficult to determine if the statistically significant differences reported are meaningful. If one investigates the effect sizes, some are small which implies that the results should be interpreted with caution.

Bamforth has collaborated with other researchers (e.g., Smythe) to investigate the role foam and lacing play in establishing people's expectations of beer. Smythe et al. (2002) presented 41 American and 50 Scottish participants with four sets of photographs which varied level of head, level of lacing, and amount of beer in the glass (Figure 9 contains images identical to those used by Smythe et al., 2002, only re-ordered). Participants were asked to rank the beers on several attributes. Participants from North America ranked the beer with the tallest head (i.e., A4) and most lacing (i.e., B4 and C4) as less well poured and less drinkable, relative to other beers. This beer was also thought to have been served in a dirtier glass, and was less likely to be purchased, than those beers with moderate levels of head and lacing. This is consistent with a qualitative finding from Bamforth (2000) where participants from Oxford commented that a beer glass without residual foam (i.e., lacing) was cleaner. According to Smythe et al. (2002), North Americans also expected the beer with the lowest levels of head (i.e., A1) and lacing (i.e., B1 and C1) to have the lowest alcohol content.

Although Scottish participants differed from North Americans in some ways (e.g., the beer with the lowest level of head and lacing was thought to be in a dirtier glass, and head and lacing did not affect Scottish participants' expectations regarding a beer's expected alcohol content), Scots and North Americans were similar in many other ways. Consistent with the North Americans, Scottish participants ranked the beer with the tallest head and most lacing as the least well poured. Scots also considered the beer with the highest levels of head and lacing to be the least drinkable, and reported being less likely to purchase it. The similarities between the cohorts do not end there. Both Scottish and North American participants ranked beers with moderate levels of head and lacing as higher for (a) foam quality, (b) quality of head, and (c) overall appearance. Whilst North Americans thought that beers with moderate levels of head and lacing appeared better than those with high levels, the Scots rated beers with moderately low levels of head and lacing as appearing

better than those with high *and* low levels of head and lacing. It is worth remembering that this is similar to Donadini et al.'s (2011) finding that Italians considered beers with medium levels of head to be the most visually appealing.

Smythe and Bamforth (2003) collaborated again and, instead of using a North American sample, had 12 Irish, 12 Finnish, 17 Belgian, and 48 Scottish participants rate images of lagers with differing levels of head and lacing (i.e., low head and lacing, moderately low head and lacing, moderately high head and lacing, high head and lacing) at different stages of consumption (i.e., full, half-full, empty) (see Figure 9). The participants were asked to choose the image from each stage of consumption that they most wanted to consume; thus creating a preference path. The participants completed this procedure five times, but each subsequent trial was conducted as if the preceding path(s) were unavailable (i.e., no path could be repeated). The findings of this study suggested that "within different stages of consumption there exists preferences for specific foam types at different geographic localities" (Smythe & Bamforth, 2003, p. 567). As an example, participants from Scotland were shown to prefer those beers with moderately low levels of head and lacing in the full- and empty-glass conditions, but showed no preference in the half-full glass condition. This finding replicated Smythe et al.'s (2002) earlier one. There is also some evidence to suggest that, universally, consistency in foam is key (e.g., a moderate level of head and lacing should be present at all stages of consumption). That said, and as acknowledged by the authors, the small sample sizes may not accurately reflect the preferences of the populations from which they are drawn.

To summarise, there are several consistent findings in relation to the effects of foam and lacing on people's expectations of beer. Two studies (Donadini et al., 2011; Smythe et al., 2002) converge on the position that a moderate level of foam is more appealing, relative to low and/or high levels of foam, for Italians, North Americans, and Scots. That said, Scots rated the beer with moderately low levels of foam and lacing as the best in overall appearance (Smythe et al., 2002). North Americans and Scots deemed the beer with moderate levels of head and lacing as having the higher quality foam (Smythe et al., 2002). This beer was also deemed the most expertly poured by Italians (Donadini et al., 2011), North Americans and Scots (Smythe et al., 2002). Italians (Donadini et al., 2011), Scots (Smythe et al., 2002), Brits, and the Japanese (Bamforth, 2000) considered beers with moderate levels of foam to be the most drinkable, although several dependent variables are being subsumed into one here (i.e., most likely to be consumed, most drinkable, best tasting). Finally, Italians and British participants were more likely to purchase beers with moderate levels of head and lacing.

There are also consistencies across cultures in relation to high levels of head and lacing. For example, both Guinard et al. (1998), using a sample from North American, and Smythe et al. (2002), using participants from Scotland, found that the more foam on a beer, the less thirst-quenching it was expected to be. North American and Scottish participants converged on the idea that the beer with the tallest head and most lacing was the least well poured, the least drinkable, and the least likely to be purchased (Smythe et al., 2002). Finally, North American (Smythe et al., 2002) and British (Bamforth, 2000) participants felt that the beer with the tallest head and most lacing had been served in a dirtier glass (i.e., beer without lacing was served in a cleaner glass). That said, Scottish participants thought that the beer with the lowest level of head and lacing was served in a dirtier glass (Smythe et al., 2002).

Given the number of factors that can influence beer foam (e.g., the quality of the barley and hops, production processes, packaging, ethanol concentration), brewers may want to control as many of these factors as possible such that a moderate level of head and lacing is the probable outcome. The evidence seems to suggest that, universally, a moderate level of foam, relative to either no foam or an excessive amount of foam, has a positive influence on certain expectations (e.g., a beer's expected quality and drinkability).

- INSERT TABLE 2 APPROXIMATELY HERE -

6. Conclusions

This review was performed with the aim of appraising the available research concerning the influence of visual appearance on people's expectations associated with, and the multisensory perception of, the taste/flavour of beer. To recap, the research suggests that people generally *expect* lighter beers to taste less bitter. However, the influence of colour on *perceived* bitterness is less predictable. One study (Donadini et al., 2014) found that the lightest beer was rated as being low in bitterness, while another (Spearot, 2016) found that the lightest beer was rated as tasting more bitter than a darker beer; a finding that might be explained by geographic differences. Interestingly, two other studies (i.e., Reinoso-Carvalho et al., 2017, 2019) found no difference in the perceived bitterness of light and dark beers. In relation to a beer's clarity, Barnett et al. (2017) reported that the addition of finings had no statistically significant effect on taste/flavour ratings, but people preferred the appearance of the beer that had been treated with finings. Lastly, there is some evidence to suggest that, universally, a moderate level of head and lacing has a significant, positive influence on certain expectations (e.g., a beer's expected quality and drinkability).

As the craft beer movement and the number of innovative microbreweries experimenting with beer continue to grow (for reviews of the history in this area, see Bell, 2017; Elzinga, Tremblay, & Tremblay, 2015), the authors hope that this review will serve as a useful resource for craft beer brewers to inform their brewing (e.g., beer colour) procedures. The authors also hope it is useful for those marketing beer. The available literature has not provided clear evidence to suggest that the beer's colour influences the perceived taste/flavour of beer, but that expectations can be shaped by visual appearance. The authors suggest that considerable efforts are still needed to demonstrate that the perception of beer can be influenced by a beer's visual appearance, especially given experimentation with possible colours seems to be expanding. The Japanese beer company 'Abashiri', for example, has a blue beer in market (Rainey, 2014). In particular, this review has highlighted (a) the fact that the visual appearance of beer is multifaceted, and thus investigating its influence on consumers' expectations and perception is worthwhile, and (b) the need to delve deeper into culture and how it interacts with visual cues to influence perception in specific, targeted beverage categories.

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Figure 1. A selection of the visual stimuli presented to the participants in Wan et al.'s (2015) online study. Top row, left-to-right: Narrow wine glass, wide wine glass, stemless wine glass. Bottom row, left-to-right: Highball glass, rocks glass, dimpled beer mug.[5]

[5] It is worth noting the absence of foam on the beer in Wan et al.'s (2015) study, thus creating a somewhat unnatural looking beer. While the colour of the liquid in these pictures is certainly 'beer-like', the overall impression is not as strongly tied to the beer category as perhaps it might be.

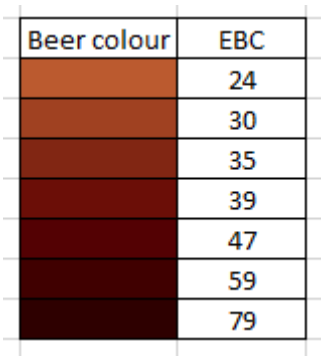

Figure 2. The beer colours here range from (in European Brewery Convention [EBC] units) EBC 24 to EBC 79. The beers used in Donadini et al. (2014) ranged from EBC 23.6 to EBC 78.2.

Figure 3. The light, medium, and dark beers used in Spearot's (2016) study.

Figure 4. The dark and pale beers used in Reinoso-Carvalho et al.'s (2017) study. Reprinted from *Frontiers in Psychology*, *8,* Reinoso-Carvalho, Moors, Wagemans, & Spence, The influence of color on the consumer's experience of beer, 2205, (2017), with permission from Elsevier.

Figure 5. The dark and amber beers used in Reinoso-Carvalho et al.'s (2019) study. Reprinted from Food Quality & Preference, 74*,* Reinoso-Carvalho, Dakduk, Wagemans, & Spence, Dark vs. light drinks: The influence of visual appearance on consumer's experience of beer, 21-29, (2019), with permission from Elsevier.

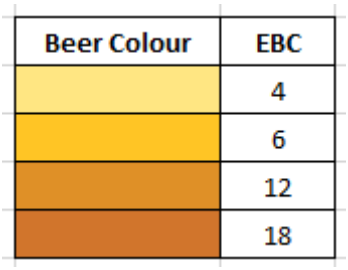

Figure 6. The beer colours here range from EBC 4 to EBC 18. The beers used by Smythe et al. (2002) were EBC 4.5, EBC 6, and EBC 16.

Figure 7. An example of a profile used in Donadini et al.'s (2016) study. Reprinted from Food Research International, 85, Donadini, Fumi, Kordialik-Bogacka, Maggi, Lambri, & Sckokai, Consumer interest in speciality beers in three European markets, 301-314, (2019), with permission from Elsevier.

Figure 8. The clear (i.e., finings used) and cloudy (i.e., finings not used) beers used in Barnett et al.'s (2017) study. Reprinted from Beverages, 3*,* Barnett & Spence, Assessing the impact of finings on the perception of beer, 26, (2017), with permission from Beverages.

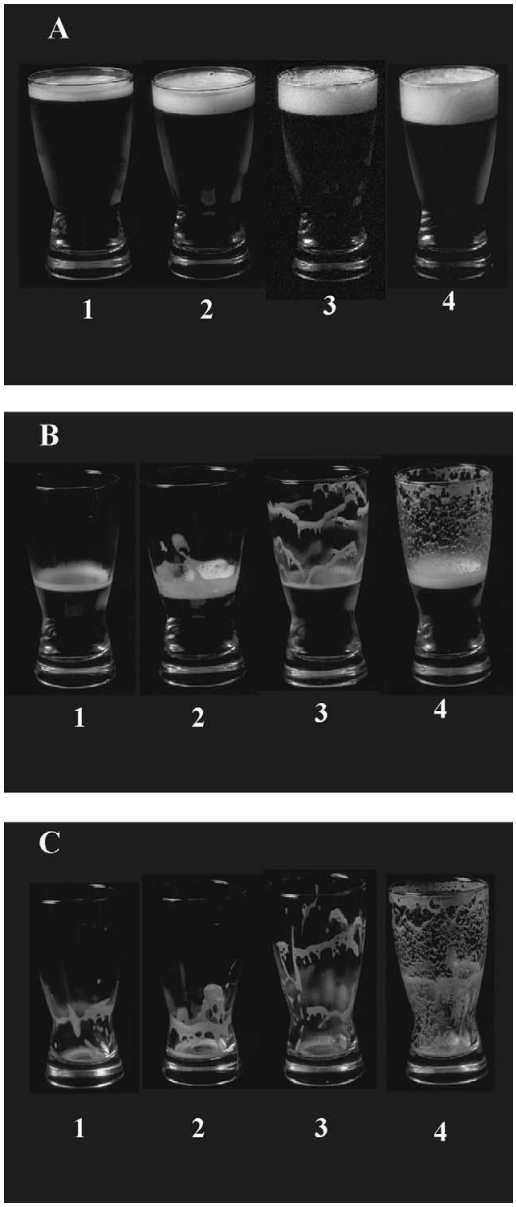

Figure 9. The low, moderately low, moderately high, and high foam and lacing beers used in Smythe and Bamforth's (2003) study. Reprinted from Food Quality & Preference, 14, Smythe & Bamforth, The path analysis method of eliminating preferred stimuli (PAMEPS) as a means to determine foam preferences for lagers in European judges based upon image assessment, 567-572, (2003), with permission from Elsevier.

Table 1. Summary of the studies assessing the influence of colour on people's expectations and perceptions of beer.

Authors	Year published	Sample size	Population(s) sampled	Colour attributes manipulated	DVs	Main findings
Expectations						
Smythe et al.	2002	18	North America	3 beers with EBC colours of 4.5, 6, & 16	Participants ranked beers from best-to-worst, or most-to-least, on 18 attributes (e.g., drinkability)	Darkest beer expected to be more bitter, to contain more alcohol, more likely to be purchased, & better in (a) anticipated flavour, and (b) overall appearance.
Donadini et al.	2016	550	Italy, Poland, & Spain	Colour descriptors (i.e., gold, red, and dark)	Level of interest in the beer (9-point Likert-type scale with anchors "Not at all interested" and "Extremely")	Gold colour positively predicted expected interest in Italians, and in Spanish men. Red had a negative influence on Polish men's interest, but positively predicted Polish women's (and Spanish men's) interest. Dark negatively influenced Polish men's and Spanish women's interest, but positively predicted Polish women's interest.
Reinoso-Carvalho et al.	2017	136	Mostly European residents (majority from Belgium, France, & UK)	2 beers with EBC colours of 17.5 (pale) & 50 (dark)	Participants rated the expected taste, flavour, and liking of the two beers.	People expected (a) to like light beer more than dark beer, (b) darker beer to be more bitter than lighter beer, (c) darker beer to be stronger than lighter beer, & (d) darker beer to have more body than lighter beer.

Reinoso-Carvalho et al.	2019	153	European residents (predominantly Belgium)	2 beers with EBC colours of 2.0 (amber) & 76.5 (dark)	Participants rated expected liking, sweetness, bitterness, sourness, alcohol content, and body using 7-point Likert scales.	People expected (a) to like pale beer more than dark beer, (b) pale beer to be less bitter than dark beer, (c) pale beer to contain less alcohol than dark beer, and (d) pale beer to have less body than dark beer.
Perception						
Guinard et al.	1998	12	North America	18 different beers (i.e., domestic, imported, & specialty) naturally varying in terms of colour	Intensity of beer attributes (e.g., carbonation) on 11-point Likert-type scales.	As the beer's colour increased on a scale from light (1) to dark (10), its rated ability to quench one's thirst decreased.
Donadini et al.	2014	246	Italy	8 bottom-fermented red beers differing in EBC colour (i.e., ~23.6, ~28.1, ~28.7, ~32.7, ~37.8, ~44.4, ~48.6, ~78.2).	Participants rated intensity of beer attributes (e.g., sweetness) on 9-point Likert-type scales.	Darkest beer was rated as (a) moderately high on bitterness & astringency, and (b) having more burnt-like & roasted characteristics. Lightest beer was rated as having a moderately high alcohol content, sweetness, & fruitiness. It was also rated as having low or very low levels of several other attributes (e.g., bitterness), and was significantly preferred over other BFRBs.
Spearot	2016	85	North America	SRM colour (~13, ~30.7, ~55.1). Converting to EBC colours, these are ~24.8, ~58.6, and ~105.2, respectively.	Participants rated several attributes of each beer (e.g., bitterness) using 15-point Likert scales. They also rated their liking of each beer.	The lightest beer was rated as more bitter than the darkest beer.

Reinoso-Carvalho et al.	2017	136	Mostly European residents (the majority from Belgium, France, & the UK)	2 beers with EBC colours of 17.5 (pale) & 50 (dark)	Participants rated perceived taste, flavour, & liking of the two beers.	People's perceived the taste/flavour attributes of the beers as being similar (e.g., pale & dark beers were not significantly different in rated bitterness).
Reinoso-Carvalho et al.	2019	166 (Exp 1); 153 (Exp 2)	97% European residents (predominantly Belgium)	2 beers with EBC colours of 2.0 (amber) & 76.5 (dark)	Participants rated perceived liking, sweetness, bitterness, sourness, alcohol content, & body using 7-point Likert scales.	There were no main effects of beer colour in Exp 1 (i.e., pale vs. dark) & no interactions between colour & tasting condition (i.e., blind vs. sighted). In Exp 2, there were no significant 'main effects' of beer colour post-tasting.

Table 2. Summary of the studies assessing the influence of foam on people's expectations of beer.

Authors	Year published	Sample size	Population(s) sampled	Foam attributes manipulated	DVs	Main findings
Guinard et al.	1998	12	North America	18 different beers (i.e., domestic, imported, & specialty) naturally varying in foam.	Ability to quench thirst on 11-point Likert-type scale.	As the beer's foam increased on a scale from none (1) to a lot (10), its rated ability to quench one's thirst decreased.
Bamforth	2000	Exp 1: 92; Exp 2: 73; Exp 3: 83; Exp 4: 72	Exp 1: North America & England; Exp 2: North America; Exp 3: England & Japan; Exp 4: England & Germany	Exps 1 & 4: Amount of lacing; Exps 2 & 3: Amount of head & lacing.	Exp 1: Preference for lacing; Exp 2: Preference for foam; Exp 3: Which beer tastes better?; Exp 4: Do differences matter?	Exp 1: No preference. Exp 2: Preference for normal level, relative to a lot, of foam. Exp 3: Preference for normal level of, relative to no, foam. Exp 4: Difference matters, but no preference.
Smythe et al.	2002	91	North America & Scotland	Amount of head & lacing	Participants ranked beers from best-to-worst, or most-to-least, on 18 attributes (e.g., freshness, drinkability, bitterness)	North Americans: Most head & lacing = less well poured, less drinkable, less likely to be purchased, & served in dirtier glass. Least head & lacing = lowest alcohol content. Moderate head & lacing = higher quality foam, head, & overall appearance. Scots: Most head & lacing = less well-poured, thirst-quenching, drinkable, appealing, & less likely to be purchased. Moderately low levels of head & lacing = better poured, overall flavour, brewed, head, overall appearance, more drinkable, more likely to be purchased, & higher quality foam. Least head & lacing = least fresh, & served in dirtier glass.

Smythe & Bamforth	2003	89	Ireland, Finland, Belgium, & Scotland	Amount of head & lacing	Preference (i.e., beer they most wanted to consume)	Some evidence suggesting that, universally, a moderate level of head & lacing should be present at all stages of consumption.
Donadini et al.	2011	101	Italians	Amount of head & lacing	26 attributes (e.g., bitterness)	Overall, Italians thought that beer's with medium levels of head were the most visually appealing