The influence of training and expertise on the multisensory perception of beer: A review

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ABSTRACT

This review critically evaluates the literature documenting the impact of training on people's perception of beer. In certain circumstances, training has been shown to improve people's ability to match and identify beers, and to discriminate between beers and between the distinctive attributes of beer. However, a reasonably consistent finding is that the benefits of beer training do not seem to generalise to novel beers (i.e., those not experienced during training). As such, training would appear to improve the capacity to label perception and/or people's recognition memory for beers, rather than necessarily influencing perception itself. Given how much beer is consumed annually, it is surprising that there has not been more published research into the role that training plays in this particular beverage category. Part of the reason for this may relate to (a) the limited role of experts in this field (e.g., primarily restricted to product testing and quality control; as compared to their much more prominent role in the world of wine), (b) the fact that training is an expensive and time-consuming process, and (c) it is wrongly assumed that the effects of training are similar across different beverage categories (e.g., beer and wine). We suggest that further efforts are therefore required before it will be possible to confidently conclude that training lowers the perceptual thresholds, and enhances the perceptual discrimination abilities, of beer experts above those of novices.

KEYWORDS: BEER; TRAINING; PERCEPTION; EXPERTISE; EXPERIENCE.

Introduction

Prior research examining the factors that influence the multisensory perception of flavour in beer has focused predominantly on visual information cues (e.g., cloudiness [Barnett, Juravle, & Spence, 2017] and colour [see Van Doorn, Timora, Watson, Moore, & Spence (under review), for a recent review]). It is, however, also important to determine whether training and/or experience influence the multisensory perception of flavour in beer. Investigating 'experience' is important because it may be exposure to beer itself, as much as the training in the assessment of beer, that is responsible for any documented change in people's ability to identify and describe beer (cf. Hughson & Boakes, 2009, for a study demonstrating the effects of 'mere exposure' – rather than formal training – on the ability to discriminate between wines).

The brewing industry relies on experts (i.e., trained assessors) for product development, but primarily to maintain product quality (Chollet & Valentin, 2001, 2006). As claimed in an article that appeared in The Wall Street Journal (Passy, 2012), cicerones (the beer world's equivalent to the sommelier in the world of wine) are finding themselves increasingly in demand as experts who can guide people's decisions regarding which beer to pair with which food/flavour. Training experts is, however, a time-consuming and hence expensive business, and one might wonder whether training actually improves an individual's ability to categorize and identify beers, discriminate and identify flavours, and/or pair beers with food. That is, are beer experts really able to differentiate between beers better than novices? Are the perceptual and verbal (i.e., descriptive) abilities of individuals who have undergone training in beer better than those of untrained individuals? Are they reliable? It is worth noting in relation to such questions that previous beer-related research has not provided consistent outcomes. Intriguingly, this contrasts with the seemingly more consistent influence of training on people's abilities to identify and describe wines (see Findlay, Castura, Schlich, & Lesschaeve, 2006; Herdenstam, Hammaren, Ahlstrom, & Wiktorsson, 2009; Honoré-Chedozeau, Desmas, Ballester, Parr, & Chollet, 2019; Parr, White, & Heatherbell, 2004; Tempere, Cuzange, Malak, Bougeant, de Revel, & Sicard, 2011; Tempere, de Revel, & Sicard, 2019; Valentin, Chollet, & Abdi, 2003; Spence, 2019, for a recent review of perceptual learning in the world of wine), and thus to better understand the role of training on the perception of beer, it is crucial to resolve these apparently discrepant findings. Furthermore, given the global popularity of beer (see Kirin Holdings Company, 2017), it is important to understand whether the use of trained individuals is worthwhile as a means of maintaining product quality, which may become a question of increasing relevance given developments and capabilities of instrumental measures (e.g., an electronic tongue; see Podrażka, Bączyńska, Kundys, Jeleń, & Witkowska Nery, 2018, for a recent review of electronic sensors relevant to the beer category).

We present the findings of a critical review of the literature concerning the role that training and experience play in people's perception of beer. We review the claims that have been made, and the experimental data that has been collected, concerning (a) the abilities of trained and untrained individuals to categorize and identify beers, and (b) the role that training plays in analytic tasting abilities (i.e., the detection, discrimination, and identification of flavours). Although several studies have used either trained (e.g., Daems & Delvaux, 1997; Guinard, Souchard, Picot, Rogeaux, & Siefferman, 1998; Guinard, Yip, Cubero, & Mazzucchelli, 1998) or untrained panels (e.g., Caporale & Monteleone, 2004; Gains & Thomson, 1990; Reinbach, Giacalone, Ribeiro, Bredie, & Frøst, 2014), here we focus on the effects that exposure to beer and training have on perception and/or cognition (i.e., on the development of knowledge structures that are linked to expected flavour profiles). Thus, we will assess papers directly comparing the abilities of trained and untrained participants.

At this point, it is worthwhile highlighting the lack of definition regarding what, exactly, constitutes a beer 'novice' (i.e., an untrained participant). Some studies (e.g., Valentin et al., 2007) consider novices to be those individuals who do not receive any training, while others consider them to be people who (a) cannot pass a discrimination task (e.g., Peron & Allen, 1988), or (b) rate low on some measure of beer knowledge (e.g., Giacalone, Ribeiro, & Frøst, 2016). If it is merely someone who has not received formal sensory training, this is problematic as the 'novice' may have been drinking beer daily for decades (i.e., there is scope for considerable individual differences; cf. Hughson & Boakes, 2009, for a similar argument made with respect to the role of mere exposure in the development of wine expertise). Without a clear definition, systematic differences in the amount of exposure to beer could potentially mask significant effects (i.e., differences between the training and 'novice' conditions). We touch on this issue in relation to specific studies throughout this paper.

The papers in this review were compiled by developing search strategies for Google Scholar, PsycINFO, and Food Science and Technology. Manual searches of published papers and snowball searches of included studies were also performed. The initial search was conducted in English through June 2018, and studies not published in English were excluded (one paper). After removing irrelevant papers and deleting duplicates, we were left with the 12 papers that are reviewed here. To the best of our knowledge, this provides an exhaustive review of the published research (in English).

This review is necessary and novel in that, to date, no one has critically assessed the value of training beer experts, which is important with regard to product development and maintaining

product quality. This review differs from other recent reviews (Spence, 2019; Spence & Wang, 2019) in the conclusions that are drawn and the underpinning literatures that are reviewed. The latter two papers focused on reviewing perceptual learning in the world of wine and wine expertise, respectively. Most relevant to the themes of the present review, Spence (2019) claims that the two literatures assessing perceptual training in the world of wine and beer "have ended-up coming to many of the same conclusions" (p. 36). We argue here that the observed effects of training often differ substantially as a function of the product type (see Spence & Wang, 2019, for a similar conclusion). Until now, there has been no clearer example of this than Croijmans and Majid's (2016) study comparing expertise in coffee and wine. These authors found that wine experts were more consistent than were coffee experts or novices in their descriptions of wine aromas and flavours, but coffee experts showed no such advantage when describing coffee.

Taken together, therefore, the evidence from the literature that is reviewed here suggests that training and experience can change people's ability to describe beers (i.e., there is greater consensus in the terms used by experts), but the evidence for an improvement in the perceptual abilities of those who have undergone beer training is weaker (e.g., identification of off-flavours; the ability to discriminate between beers). This is novel in that it contrasts with much of the literature on wine perception and, by comparing these two literatures, we show that the results of, and hence perhaps aims for, training are quite different. This review also raises questions regarding whether the mechanisms underlying expertise are universal (e.g., wine training enhances one's conceptual knowledge regarding the sensory qualities of identifiable grape varieties [Spence, 2019], whereas beer categories may be too ill-defined to acquire conceptual knowledge). We begin by reviewing the experimental literature on beer training.

The effects of beer training

Peron and Allen (1988) assessed the influence of different training methods on the ability of non-discriminating 'novices'[1] to identify and describe different beers. The participants in Peron and Allen's study were allocated to one of four groups: (a) those who received experience in tasting beers (i.e., perceptual training for five minutes), (b) those who received verbal training (13 minutes) in the terminology used to describe beers (e.g., bitter, hoppy), (c) those who received both forms of training (i.e., verbal+taste), and (d) a control group who received no training at all. The

[1] The non-discriminating novices failed to identify the odd-one-out in more than one of three triangle tests (where two beers were identical while the third was different), and either did not drink beer or else drank only a single brand of beer.

researchers found that experience tasting beers improved novices' sensitivity to, and ability to detect, beer flavours identical to those that they had learned (i.e., they were able to match beers), but neither verbal training nor verbal+taste training improved performance. The authors also found that none of the forms of training were effective in modifying the novices' use of terminology. This result, along with the finding that the verbal+taste group did not improve their sensitivity to, or ability to detect, flavours even though the taste-alone group did, might be a consequence of the very limited period of training used in this study. Specifically, verbal training included watching an eight minute video outlining the brewing process and defining seven beer-related adjectives and five minutes to study the definitions of the adjectives, while participants in the verbal+taste condition watched the same video and were given five minutes to *both* study the definitions of beer-related adjectives and taste the samples of beer.

In addition to the exceedingly short period of training, there is another concern regarding Peron and Allen's (1988) findings. Specifically, only 10 people took part in each of the four conditions, and thus (a) the experiment is likely underpowered (a power analysis suggested that a sample size of approximately 180 individuals would have been more appropriate), and (b) the small sample may not accurately reflect the abilities of the population from which it was drawn. Thus, if the authors provided more training to more people, some of the non-significant results may well have become significant (avoiding a Type II error which, simply stated, is falsely concluding no effect when one exists). Here, one particularly incompetent non-discriminating novice could have a major influence on the group results. What can be said is that a very brief period of perceptual training alone (i.e., tasting beers) improved the participants' ability to match beers (e.g., rate stimulus and reference beers as being similar if, in fact, they were similar), and identify the odd-beer-out in triangle tests. That said, it would be interesting to know how long-lasting the beneficial effects of training identified by Peron and Allen (1988) were (e.g., hours, days, or weeks). If they were short-lived, one would have to wonder whether such short periods of training are worthwhile. Furthermore, it should be noted that a defining feature of perceptual learning in the spatial senses (e.g., vision) is that the benefits of training last for weeks, or longer, after the conclusion of training (see Green, Banai, Lu, & Bavelier, 2018, for a recent review).

In Chollet and Valentin's (2001) study, a trained group (N = 22) received one hour of training per week for 11 weeks in the detection and identification of flavours that had been deliberately added to beer (i.e., almond, apple, banana, bread, butter, cabbage, caramel, cardboard, cheese, honey, lilac, metallic, musty, phenol, and sulphite), and in the evaluation of the intensity of characteristic compounds (e.g., hops, malt). An untrained group (N = 18) received no training. The two groups tasted 12 beers. Six of the beers were commercially available, while the other six 'supplemented'

beers consisted of one of the commercial beers with a flavour added (i.e., honey, caramel, banana, metallic, bread, or lilac). The beers were served in black plastic tumblers under red illumination (blind condition) and the participants (a) tasted all of the beers and then sorted them into groups based on their perceptual similarity, (b) matched six beers to another participant's verbal description of those beers, and (c) selected two-to-five terms from a list that they felt best described each of the beers. The results revealed that untrained participants sorted beers in a manner that was similar to the trained participants. The untrained participants were also able to match commercial beers to verbal descriptions as well as the trained participants. However, when matching supplemented (or modified) beers, the participants who had been trained performed better than those who had not. For example, beers supplemented with lilac and a metallic note were identified as having off-flavours by the trained group and deemed to be 'unpleasant', while the untrained group failed to detect these flavours and instead described these beers as 'light' and 'insipid'. Given the findings, untrained participants were able to identify differences in beers and to communicate those differences to others almost as well as were the trained participants, although they used descriptors that were less efficient and less precise than those used by trained participants when doing so.

Chollet and Valentin's (2001) finding that untrained participants were able to match beers to descriptors as well as trained participants is a reasonably consistent observation in this field (see Lelièvre et al., 2008, for a similar finding). However, the literature on wine expertise suggests that trained individuals often outperform novices on this task (e.g., Gawal, 1997; Honoré-Chedozeau et al., 2019; Hughson & Boakes, 2002; Lawless, 1984; Solomon, 1990; Tempere et al., 2019). Thus, the key point that emerges is that the benefits of training in one category (e.g., beer) may not mirror the benefits of training in another (e.g., wine). Given their results, Chollet and Valentin (2001) went on to suggest that the major benefit of training is to enhance and align the use of a precise, descriptive terminology across tasters. Note that similar claims have also been made previously in the world of wine (Solomon, 1990). This finding is consistent with the work of Clapperton and Piggott (1979). The latter researchers had four panels of people, varying in their knowledge of brewing and their experience in beer flavour assessment[2], assess the odour, flavour, and after-taste of four beers (two lagers and two ales). Knowledge and experience related to beer increased people's ability to discriminate between the beers, and increased the number of terms that people

[2] Clapperton and Piggott (1979) make mention of "20 trained and experienced assessors from the Foundation" (p. 275), and later in the article go on to mention that some people had been trained for "3 years or more" (p. 277).

used to describe them. Clapperton and Piggott also reported that the experts they tested were very reliable, but did not report how reliable less well-trained individuals and novices were.

The findings reported by Clapperton and Piggott (1979) and Chollet and Valentin (2001) contrast with those of Peron and Allen (1988). The latter researchers found that training did not modify novices' use of terminology. A seemingly logical explanation for this difference is that Peron and Allen's training period was exceedingly short (approximately 10 minutes). Chollet and Valentin (2001), by contrast, trained people for one hour per week for 11 weeks and Clapperton and Piggott (1979) mention training lengths of six months and three years. Thus, differences in the length of training may help to explain the differences in the number of descriptors used, and the consistency and precision with which these terms were used. This seems consistent with claims regarding expertise in other fields (e.g., Ericsson, Prietula, & Cokely, 2007) suggesting that long periods of deliberate practice (i.e., practice at a task where the focus is on correcting mistakes) are required to become an expert. Problematically, the stimuli used by Clapperton and Piggott, as well as the instructions provided to participants, varied across panels. Specifically, the novice and less-experienced panellists were told the aims of the study, whereas the expert panels were not. Furthermore, three panels (including the two expert panels) received beers in black tumblers at 20°C, while the other two panels received their beers at room temperature[3] in either a clear glass or a white plastic cup. It is known that changing the colour of a cup influences the taste of various drinks (see Piqueras-Fiszman & Spence, 2012; Van Doorn, Wuillemin, & Spence, 2014; see Spence, 2018, for a review). As certain aspects of the methodology varied across groups, it is difficult in hindsight to untangle the roles played by expertise or differing stimuli, just as it is difficult to determine how beers served at unusually high temperatures might have influenced perception. It is perhaps also worth noting that beer culture has changed quite dramatically in recent years - see the emergence of the craft beer movement (Elzinga, Tremblay, & Tremblay, 2015, for a review of the history in this area) - even in the UK where Clapperton and Piggott's (1979) study was conducted. Consequently, the situation today may be very different from the one they were studying four decades ago.

In a later study, Chollet and Valentin (2006) attempted to assess how the duration of training influenced people's multisensory perception of the flavour and aroma of beer. Participants completed either 11, 44, 61, or 72 hours of training, or were novices (i.e., beer consumers who had no formal training). Parenthetically, and depending on the amount of experience these 'novices'

[3] Although 'room temperature' is not defined in Clapperton and Piggott's (1979) study, one assumes it is approximately 20°C.

had, researchers in other fields (i.e., wine) might well be tempted to refer to them as 'intermediates' (e.g., Hughson & Boakes, 2009). Participants in Chollet and Valentin's (2006) study were asked to detect and identify flavours and off-flavours added to beer by the experimenters (i.e., almond, apple, banana, bread, caramel, cabbage, cardboard, cheese, honey, lilac, metallic, musty, phenol, or sulphite), and evaluate the intensity of the general characteristics of beer (e.g., bitterness, malt flavour). The authors also took a longitudinal approach and compared the perceptual abilities (e.g., ability to discriminate between two beers and aroma detection) and performance (e.g., aroma identification) of trained participants at different points in time (e.g., before and after 15 hours of training). The results suggested that the participants acquired a lexicon of beer descriptors and the capacity to describe different beers to others early-on in the training process, but the development of perceptual abilities is delayed (i.e., acquired after 44 hours of training). This finding contrasts with research investigating the impact of training in wine perception. Specifically, Zucco, Carassai, Baroni, and Stevenson (2011) demonstrated that people develop perceptual abilities relatively early in the training process, but the development of semantic expertise is delayed. This again implies that the benefits of training in one category may not mirror those in another. Chollet and Valentin (2006) also found that perceptual abilities did not extend to beers that had not been used in the training process. This result is similar to a finding from Chollet, Valentin, and Abdi's (2005) study where one hour of training per week for two years in the detection and description of (a) the general characteristics of, and (b) off-flavours (i.e., cardboard, butter, cabbage, and lilac) in beer improved the ability of 19 participants (relative to 20 novice beer consumers) to discriminate between the aromas of familiar, but not unfamiliar, beers.

There is a concern with the claim that "perceptual abilities are acquired later" (Chollet & Valentin, 2006, p. 189). Specifically, Chollet and Valentin found that people were no better at discriminating beers after completing 15 hours of training, relative to their ability prior to training. Furthermore, training did not significantly modify the types of beers that were grouped together. That said, when Chollet and Valentin assessed inter-individual variability, they found that there was significantly less disagreement regarding which beers should be grouped together after training. These researchers also claimed that, in their aroma detection task, after 15 hours of training "the isoamyl acetate threshold in beer tends to decrease" (Chollet & Valentin, 2006, p. 190). Note that isoamyl acetate is an off-aroma that smells like banana. Problematically, this conclusion does not seem to be justified as the difference between thresholds here was claimed to be significant at $p = .090$ (i.e., non-significant by conventional significance testing). As such, the claim that this finding contrasts with those of earlier researchers (i.e., Bende & Nordin, 1997; Parr, Heatherbell, & White, 2002; Parr et al., 2004) is overly strong given the evidence. Although it would be unwise to claim a lack

of effect, we would suggest that Chollet and Valentin (2006) provide no evidence of a difference given the data they present, and thus no evidence of perceptual learning in the beer category.

Valentin, Chollet, Beal, and Patris (2007) provided 19 people with 44 hours of training in describing commercial beers, detecting and identifying added flavours and off-flavours, and evaluating the intensity of the characteristics of beer. Novices received no such training. The aim was to assess whether training affected people's ability to identify, recognise, and discriminate beers. In the identification task, participants smelled and tasted eight beers and chose descriptors from a list that best represented the beer's aroma. The recognition memory task consisted of a learning stage and a recognition stage. During the learning stage, participants tasted eight beers, or smelled 10 odours, and memorised them. A week later, and during the recognition stage, participants tasted 16 beers (the eight from the learning stage and eight new beers), or 20 odours (the 10 from the learning stage and 10 new odours), and were asked if they had tasted, or smelled, the stimuli during the learning stage. In the discrimination task, participants tasted and smelled 14 pairs of beers and decided whether or not the beers were the same (seven pairs were identical, while the other seven were not). Here, participants wore opaque glasses, and thus could not base their decisions on visual cues.

Valentin et al. (2007) found that trained participants performed significantly better than novices in the identification and recognition memory tasks, but only for familiar beers and aromas (i.e., stimuli they had been exposed to during training). This finding is consistent with several others in this field (e.g., Chollet et al., 2005; Chollet & Valentin, 2006). Trained individuals were, however, not significantly better than novices at discriminating beers. Valentin et al. (2007) suggest that this result provides evidence that "the experts' advantage in recognition memory is likely to have its source in more efficient coding and retrieval in long-term memory, rather than in better perceptual ability" (p. 776). This finding suggests that the potential benefits of training may be limited to those cognitive processes that are associated with recognising beers to which one has previously been exposed, rather than enhancing perceptual processes; a conclusion similar to those that emerge from research investigating the multisensory flavour perception of wine (see Spence & Wang, 2019, for a review). Training might improve the capacity to label one's perceptions, rather than necessarily influencing perception itself (i.e., training may not lower a person's detection threshold for specific flavours).

Patris, Gufoni, Chollet, and Valentin (2007) provided "more than 50 hours" (p. 19) of training in describing commercial beers, detecting and identifying added aromas, and evaluating the intensity of the characteristics of beer (i.e., alcohol, astringency, bitterness, fizziness, hops, malt, persistence,

and sweetness) to a group of 10 participants. Ten novices received no such training. The aim of the study was to assess whether training influenced the strategies that people use to sort beers into groups. Patris et al. had trained and untrained assessors sort eight beers into groups in a blind condition (i.e., the participants could smell and taste the beer, but the beer's colour was masked). The participants were free to sort the beers into as many groups as they deemed appropriate, and were free to put as many beers into each group as they felt necessary. The participants were then asked to watch a video of themselves sorting the beers and provide information regarding their thought processes. The main finding from this study was that trained assessors consistently grouped (a) the four lager beers, (b) the two amber beers, and (c) the two beers without alcohol together, while novices could only consistently group the amber beers. Given Patris and colleagues' method, they were able to determine that the ability of trained assessors was likely a product of trained assessors completing the task faster than novices[4] (which likely reduced memory load), or smelling the beers significantly more often than novices. The enhanced performance of experts might also have been some combination of these factors. Whatever the mechanism, this does not bode well for the usefulness of training. If the benefit of training is knowing that a task needs to be completed quickly (which might explain the experts' use of orthonasal aroma in decision-making at the expense of taste/flavour) then, as the Patris et al. acknowledge, "we could ask novices to do the task faster…[and/or] make more use of olfaction" (p. 27).

Previous studies assessing expertise in wine tasting suggest that training or experience may influence the ways in which people categorise wine (see Ballester, Patris, Symoneaux, & Valentin, 2008; Solomon, 1997). In a study intended to assess whether the findings related to wine could be generalised to beer, Lelièvre, Chollet, Abdi, and Valentin (2008) had trained and untrained assessors sort nine samples of beer: three types of beers (i.e., blonde, amber, and dark) from three different breweries (i.e., Pelforth, Chti, and Leffe). Trained assessors received one hour of formal training per week in evaluating beers (e.g., flavour and off-flavour identification) for an average of 3.4 years, whereas untrained assessors did not. In their study, Lelièvre et al. had trained and untrained assessors taste and sort beers into groups in a blind condition (i.e., the participants could smell and taste the beer, but the beer's colour was masked by red light). Participants were free to sort the beers into as many groups as they deemed appropriate, and were free to put as many beers into each group as they felt necessary. Assessors were then asked to provide terms describing each group in two ways: (a) using their own words, and (b) selecting no more than five terms from a

[4] Interestingly, Tempere, Hamtat, de Revel, and Sicard (2016) found that wine experts took significantly longer to complete tasks than did novices.

list of 44 terms developed by Meilgaard, Dalgliesh, and Clapperton (1979). Later, assessors were asked to match the nine beers to the sets of descriptors they had provided previously. Here, participants were unaware that the beers were the same as those they had consumed earlier.

Consistent with the findings reported by Chollet and Valentin (2001), Lelièvre et al. (2008) found that both trained and untrained assessors sorted beers similarly. Without a list of terms, untrained assessors (relative to trained assessors) used more terms to describe the beers[5], but displayed a lack of consensus in the terms that they used. This lack of consensus mirrors Chollet and Valentin's (2001) finding that untrained participants used descriptors that were less consensual and less precise than those used by trained participants, and is consistent with findings in the wine category (e.g., Croijmans & Majid, 2016; Zucco et al., 2011). Lelièvre et al. (2008) also found that when selecting terms from a list, trained and untrained assessors selected a similar number of descriptors, with several terms being common to both groups. Lastly, there was no difference in the ability of trained and untrained assessors to match beers to descriptors, either with a list or without.

Lelièvre, Chollet, Abdi, and Valentin (2009) also had trained and untrained assessors sort three types of beer (i.e., blonde, amber, and dark) from three different breweries (i.e., Pelforth, Chti, and Leffe). In this case, the trained assessors had received one hour of formal training per week for an average of 3.5 years in evaluating the flavours of, and off-flavours added to, beers. The untrained assessors received no training. A difference between their 2008 and 2009 studies is that in the latter study, Lelièvre et al. had trained and untrained assessors taste and sort beers into groups in both visual (i.e., participants could smell, taste, and see the beer) and blind (i.e., participants could smell and taste the beer, but the beer's colour was masked with red light) conditions. In the blind condition, Lelièvre et al. (2009) found that both trained and untrained assessors grouped beers according to their brewery of origin. According to the authors, this indicates that there are more similarities in the taste and smell attributes of different beers from the same brewery than there are in the same types (or styles) of beers (e.g., blonde) from different breweries. Interestingly, and consistent with Lelièvre et al. (2009), Solomon (1997) found that wine experts group wines by region of origin. However, and in contrast with Lelièvre et al. (2009), Solomon (1997) also found that novices grouped wines according to their sensory characteristics (e.g., fruitiness).

In the visual condition, trained assessors claimed that they based their judgments on the chemosensory properties (i.e., taste, aroma) of the beer. Lelièvre et al. (2009) found, however, that both trained and untrained assessors used colour to sort the beers into groups. This finding

[5] An earlier study by Solomon (1990) showed that, in contrast to the findings of Lelièvre et al. (2008), wine experts used more descriptors than did novices.

resonates with studies assessing the influence of colour on the perception of wine (e.g., Morrot, Brochet, & Dubourdieu, 2001; Wang & Spence, submitted). As both trained and untrained assessors seemed to rely on visual cues rather than chemosensory information when visual information was available, the authors concluded that "sensory training does not seem to have an effect on the criteria used to organize beer perceptions" (Lelièvre et al., 2009, p. 143). Lelièvre et al. suggested that the dominance of visual cues was such that other information (e.g., taste and smell) was 'tuned out', even by those who had been trained to use these sources of information (see Nikolova, Gabrovam, Boyadzhiev, Pisanova, Ruseva, & Yanakiev, 2017, for a discussion of how participants use beer colour to classify different types of beer; Spence, 2010a, 2010b, for discussion of the role of colour in the world of wine expertise; Spence, 2019, for a brief discussion relating to how experts can be distracted by irrelevant cues).

Lelièvre-Desmas, Chollet, Abdi, and Valentin (2015) built on their earlier work in an attempt to determine if 19 non-experts could be trained, via repeated exposure with feedback, to categorise beers as top-fermented or bottom-fermented. The training took place as part of a 70-hour long course on brewing techniques. Participants were exposed to information regarding the sensory aspects of beer, and technical information relevant to brewing. Lelièvre-Desmas et al. found that "participants learned to identify the category membership [e.g., top-fermented] of beers to which they had been exposed but were not able to generalize their learning to other beers" (p. 101), a finding consistent with several other studies (e.g., Chollet et al., 2005; Chollet & Valentin, 2006).

This finding relates to a suggestion made by Valentin et al. (2007) that beer training influences recognition memory, rather than necessarily enhancing perceptual processes, and may explain why participants commonly fail to generalise their learning to new beers. This contrasts with some research demonstrating that wine training dramatically improves people's ability to detect grape varieties (see Solomon, 1997), but is consistent with other findings in this field showing that training has little influence on taste and olfactory abilities (Wang, Prešern, Fermandes, & Fjældstad, 2019; Wang, & Prešern, 2018). The evidence presented here suggests that training allows people to recognise beers, but does not allow them to be able to generalise sufficiently to categorise them. It may be that training in wines enhances conceptual knowledge associated with the specific flavour profiles of particular, identifiable grape varieties (Spence, 2019). For example, grape varieties may be more distinct than beer styles, and/or there may be more variability within a given style of beer. Thus, training may not fine-tune conceptual knowledge in beer in the same way it does in wine.

Lelièvre-Desmas et al.'s (2015) study raises the issue of cross-sectional and longitudinal designs in this field. Specifically, and as alluded to earlier, an issue with cross-sectional studies is that, without

a clear definition of a 'novice' or 'non-expert', possible individual differences tend to be ignored (see Spence & Wang, 2019, for a similar argument in relation to cross-sectional studies of wine expertise). Spence (2019) identified another problem with cross-sectional studies comparing experts with novices. Specifically, supertasters (i.e., those individuals experiencing taste sensations at greater than average intensity) may be more likely to be employed in the tasting industry (see Hayes & Pickering, 2012, for a similar argument). As such, longitudinal studies can potentially overcome these limitations by having participants act as their own controls (e.g., baseline measure).

Consistent with earlier studies (Lelièvre et al., 2008; Patris et al., 2007), Giacalone, Ribeiro, and Frøst (2016) had participants (here, novices, enthusiasts, and experts[6]) sort beers into groups. Once again, they could create as many groups as they deemed appropriate, and were free to put as many beers into each group as they felt necessary. Here though, the method that participants used to sort beers differed from those of earlier studies in that Napping® was used (see Pagès, 2005). Specifically, eight beers were presented to participants simultaneously, and they were instructed to evaluate the perceived (dis)similarities between the beers. If beers were deemed to be similar, they were positioned close together on a blank sheet of paper, while those deemed to be different were placed some distance apart from one another. Participants also provided descriptors for each sample (e.g., caramel, hoppy). Giacalone et al. (2016) found that the expert and novice assessors sorted beers similarly. This finding, in conjunction with those of earlier studies (e.g., Chollet & Valentin, 2001; Lelièvre et al., 2008), provides reasonably compelling evidence suggesting that expertise/training does little to benefit people's ability to sort beers into categories. Another finding similar to those of Chollet and Valentin (2001) and Lelièvre et al. (2008) is that the expert group used more specific terminology (e.g., 'sulphuric') when describing the beers. That said, when equivalent lay terms were identified (i.e., yeasty), group differences disappeared. As Giacalone et al. (2016) indicate, the "results do not point at a large effect of product expertise on verbal ability" (p. 9).

Finally, Spearot (2016) assessed whether past experience influenced people's perception of the flavour of beer. Spearot divided participants into experts and novices based on their liking of beer, and their consumption habits. Specifically, participants were considered beer experts if they indicated that they drank beer at least once a week *and* rated that they liked beer 'slightly' or more (i.e., scores of six or higher on a 9-point Likert-type scale with the anchors 'Dislike extremely' and

[6] People were grouped together as novices or enthusiasts based on their scores on a beer knowledge questionnaire (e.g., "I know a lot about beer" [Giacalone et al., 2016, p. 4]). The experts were master brewers or members of a sensory panel.

'Like extremely'). Of note, individuals meeting the 'expert' criteria of Spearot would most likely be classified as novices in some other studies, considering they received no formal perceptual training. Spearot documented a statistically significant main effect of experience on the perceived saltiness (p = .018), bitterness (p = .019), and liking (p = .007) of beer. Experts liked beer significantly more than did the novices. Novices rated the beers as being more salty than did the experts, which Spearot argued was "a self-perception effect, with experts being more aware and paying more attention to scale use" (p. 59). Finally, the novices' rated the beer as tasting more bitter than did the experts.

Spearot (2016) claimed that when separated into groups based on the colour of the beer (i.e., light vs. dark), novices rated light beers as more bitter than did the experts. If one inspects Figure 16 in Spearot's thesis, one can appreciate how he came to this conclusion - colour does not seem to influence experts' ratings of bitterness, but there seems to be an effect for novices where light beers were rated as being more bitter than dark beers. However, the interaction term in Spearot's analysis was non-significant (i.e., p = .223), and thus the significant main effects should have been interpreted (i.e., the claim regarding simple effects should be avoided because the non-significant interaction suggests that the effects of expertise were not different at the different levels of colour). The main effect shows that novices rated the beers as tasting more bitter than did the experts, and this suggests that experience can influence the perceived taste of beer. Spearot argues that "past experience with beer plays a large role in how its flavors are perceived by consumers" (p. 59). Thus, perhaps it is not training *per se* that is crucial, but experience with beer that leads to differing perceptual abilities (cf. Hughson & Boakes, 2009).

The training methods or designs (i.e., cross-sectional vs. longitudinal) used in previous studies might have contributed to the many non-significant results, particularly in relation to perceptual abilities. For example, studies of perceptual learning in vision commonly involve thousands, or tens of thousands, of practice trials (e.g., Sowden, Rose, & Davies, 2002), which contrasts with the often short training periods seen in beer research. However, other factors might play a role in explaining the above differences. The culture surrounding beer, and knowledge of beers, differs across countries, and these factors may influence the effectiveness of training. France is often touted as a destination of choice for wine connoisseurs, while Germany is known for its beers (Aizenman & Brooks, 2008). In France, the culture of wine is older and more communicated than is the culture of beer (see Demossier, 2001, for a discussion of wine culture in France). As an example, there is a deeply embedded tradition of pairing foods with wines in France (Eschevins, 2018). One could argue that the reverse is true in Germany, a country that has had 'purity laws' preventing anything other than malted grains, hops, water, and yeast from being used in the making

of beer for the past 500 years (BBC, 2016). Although these two countries share a border, cultural factors may influence conceptual knowledge, and thus the benefits and efficacy of beer training programs. More work is needed in this area.

Conclusions

This review was performed with the aim of appraising the available research concerning the influence of training and experience on the multisensory perception of the taste/flavour of beer. To recap, and in agreement with Chollet and Valentin (2006) "it seems that only in some cases, experts tend to discriminate better than novices the stimuli for which they have been trained" (p. 189). However, and as noted above, it might be experience rather than training that contributes to differing perceptual abilities in novices and experts. Seven of the 12 papers reviewed here showed that training, under certain circumstances, improved people's abilities to (a) match beers, (b) discriminate between beers, (c) discriminate between the attributes of beers, or (d) identify beers (see Table 1). However, when significance was achieved, improvements were consistently seen only in those beers that the participants had been exposed to during training. If the benefits of training do not generalise to novel beers, alternatives (e.g., instrumental testing) might need to be considered. That said, quality control does not normally involve 'novel' beers but, rather, is about ensuring the quality of known beers.

Two studies showed no differences in the abilities of trained and untrained participants, with several other statistically non-significant results amongst statistically significant findings. The findings of these two studies should, however, be interpreted with caution because each of them is likely underpowered. Lelièvre et al. (2008), for example, had only 13 trained participants and two groups of untrained participants (n = 19 and 18), whereas Lelièvre et al. (2009) had 17 trained participants and 21 untrained participants. Power analyses suggest that a more adequate sample would include approximately 50 trained and 50 untrained participants. At the same time, however, it should also be acknowledged that it may be difficult to find a sufficient number of beer 'experts', for reasons not limited to the lack of clarity surrounding expertise (e.g., how many hours of training are required to become an expert?).

On the weight of the evidence, training/experience seems to improve people's ability to describe beers (i.e., the terms they use become more precise), but the evidence for an improvement in perceptual abilities is weaker. We raised a similar point earlier: Does training improve people's perceptual abilities? Or can we only hope to improve their (a) semantic or recognition memory, or

(b) ability to describe perception? Problematically, statistical and methodological concerns limit confidence in the findings of past studies. We would therefore like to suggest that considerable efforts are still needed in order to demonstrate that people's perceptual abilities, as they relate to beer, can be influenced by training. By way of a suggestion, we would advise researchers to (a) consider methods to limit individual differences, possibly through the implementation of longitudinal designs, and (b) settle on definitions of what constitute novices, trained participants, and experts. Two groups of actual novices (i.e., no experience with beer whatsoever) could be given equivalent amounts of training in one of two areas (e.g., aroma identification or identification of off-flavours) and compared. Or, potential experts might benefit from training that focuses on the identification of isolated compounds (see Tempere, Cuzange, Bougeant, de Revel, & Sicard, 2012, for an example), perhaps focusing on single modalities (e.g., taste in the absence of vision), to ensure that training is not overly complicated (or cognitive resources are not overly taxed).

Table 1. Summary of studies that have assessed the influence of training on people's perception of beer.

Study	Sample size	How was training manipulated?	DVs	Main findings
Clapperton & Piggott (1979)	103	Four panels with varying knowledge of brewing & experience in beer flavour assessment.	Assess the odour, flavour, and after-taste of four beers.	Knowledge & experience increased people's ability to discriminate between beers, as well as increasing the number of terms used to describe beers.
Peron & Allen (1988)	40	Non-discriminating novices allocated to one of four 'training' conditions: (1) perceptual training (5 mins), (2) verbal training (13 mins), (3) perceptual+verbal training (13 mins), & (4) no training.	Ability to match, identify, and describe different beers.	Perceptual training improved novices' sensitivity to, and ability to detect, beer flavours identical to those they had learned (i.e., they were able to match beers), but neither verbal training nor verbal+taste training improved performance. The taste group also improved their performance on triangle tests.
Chollet & Valentin (2001)	22 trained; 18 untrained	The trained group received one hr of training per week for 11 weeks, whereas the untrained group did not.	Participants (a) tasted all the beers & sorted them into groups, (b) matched six beers to another participant's verbal description of those beers, & (c)	Untrained participants sorted beers in a manner similar to trained participants. Untrained participants were also able to match commercial beers to verbal descriptions as

			selected 2-5 terms from a list that they felt best described each beer.	well as trained participants, but they used different descriptors to do so.
Chollet et al. (2005)	19 trained; 20 novices	Participants received one hr of training per week for two years, while novices did not.	Ability to discriminate between beer aromas.	Training improved participant's ability (relative to novices) to discriminate between the aromas of familiar beers, but not unfamiliar beers.
Chollet & Valentin (2006)	Unspecified	Duration of training manipulated (i.e., 11, 44, 61, or 72 hrs). People were trained to detect & identify flavours added to beer, & evaluate the intensity of characteristic beer attributes (e.g., bitterness). Novices (i.e., beer consumers who had no formal training) also recruited.	Perception of beers' flavour & aroma.	People acquire a lexicon of beer descriptors & the capacity to describe different beers to others early on in training, but perceptual abilities are acquired later (i.e., after 44 hours of training).
Patris et al. (2007)	10 trained; 10 novices	Experts had "more than 50 hours of training" (p. 19). Novices received no training.	Participants (a) tasted eight beers & sorted them into groups, & (b) provided a verbal description of their decision-making process.	Experts more accurately (e.g., lagers grouped together) and consistently (i.e., across individuals) sorted beers into groups. Novices took longer to sort beers (adding to cognitive load) and relied upon taste (whereas experts relied heavily on aroma).
Valentin et al. (2007)	19 trained; 2 groups of novices (n = 24 & 22)	Experts had 44 hours of training, while novices received no training.	Accuracy index (hits/false alarms) for ability to (a) identify beer tastes/aromas, (b) discriminate between beers, & (c) recognise beers from memory (e.g., beers experienced during training)	Experts outperformed novices in both identification & recognition memory tasks, but only for those beers that they had been exposed to during training. Experts were no better than the novices on the discrimination task.

Lelièvre et al. (2008)	13 trained; 2 groups of untrained (n = 19 & 18)	Trained assessors received one hour of formal training per week for an average of 3.4 years in evaluating beers (e.g., flavour identification), whereas untrained assessors did not.	Beers were sorted into groups in a blind condition. Assessors then provided terms to describe each group in two ways: (a) using their own words, & (b) selecting no more than five terms from a list of 44 terms. Assessors then matched the nine beers to the sets of descriptors that they had provided previously.	Trained & untrained assessors sorted beers similarly. Untrained assessors (relative to trained assessors) displayed a lack of consensus in the terms used. When selecting terms from a list, trained and untrained assessors selected a similar number of descriptors, with several terms being common to both groups. There was no difference in the ability of trained & untrained assessors to match beers to descriptors.
Lelièvre et al. (2009)	17 trained; 21 untrained	Trained assessors received one hour of formal training per week for an average of 3.5 years in evaluating beers (e.g., flavour identification), whereas untrained assessors did not.	Trained & untrained assessors sorted beers into groups in both sighted & blind conditions.	In the blind condition, both trained & untrained assessors grouped beers according to brewery of origin. In the sighted condition, both trained & untrained assessors used colour to sort beers into groups instead.
Lelièvre-Desmas et al. (2015)	19 non-experts	Participants took part in a 70-hour long training course	Ability to categorise beers as top-fermented or bottom-fermented.	Training improved people's ability to identify familiar beers as being either top- or bottom-fermented, but people were not able to generalize their learning to novel beers.
Giacalone et al. (2016)	14 novices; 26 enthusiasts; 15 experts	3 groups: novices, enthusiasts, and experts. Novices and enthusiasts were assigned based on their scores on a questionnaire. Experts was drawn from a sensory panel and a group of master brewers.	The DVs were the degree to which (a) participants in each group agreed with respect to the configurational arrangement of beers, and (b) the three panels used similar descriptors.	Untrained participants sorted beers in a manner similar to trained participants. Trained assessors used more specific terminology than did novices.
Spearot (2016)	51 experts; 34 novices	2 groups: Experts were those who consumed beer once a week or more & who rated their liking of beer as 6 or higher on a 9-point Likert scale. Novices were everyone else.	Participants rated several beer-relevant attributes (e.g., bitterness) using 15-point Likert scales. They also rated their liking of each beer.	Experts liked beer significantly more than did the novices. Novices rated the beers as being more salty and more bitter than did the experts.

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