

RESEARCH

Open Access



The perceptual categorisation of blended and single malt Scotch whiskies

Barry C. Smith^{1*}, Carole Sester², Jordi Ballester³ and Ophelia Deroy¹ 

Abstract

Background: Although most Scotch whisky is blended from different casks, a firm distinction exists in the minds of consumers and in the marketing of Scotch between single malts and blended whiskies. Consumers are offered cultural, geographical and production reasons to treat Scotch whiskies as falling into the categories of blends and single malts. There are differences in the composition, method of distillation and origin of the two kinds of bottled spirits. But does this category distinction correspond to a perceptual difference detectable by whisky drinkers? Do experts and novices show differences in their perceptual sensitivities to the distinction between blends and single malts?

To test the sensory basis of this distinction, we conducted a series of blind tasting experiments in three countries with different levels of familiarity with the blends versus single malts distinction (the UK, the USA and France). In each country, expert and novice participants had to perform a free sorting task on nine whiskies (four blends, four single malts, one single grain, plus one repeat) first by olfaction, then by tasting.

Results: Overall, no reliable perceptual distinction was revealed in the tasting condition between blends and single malts by experts or novices when asked to group whiskies according to their similarities and differences. There was nonetheless a clear effect of expertise, with experts showing a more reliable classification of the repeat sample. French experts came closest to a making a distinction between blends and single malts in the olfactory condition, which might be explained by a lack of familiarity with blends. Interestingly, the similarity between the blends and some of their ingredient single malts explained more of participants' groupings than the dichotomy between blends and single malts.

Conclusions: The firmly established making and marketing distinction between blends and single malts corresponds to no broad perceptually salient difference for whisky tasters, whether experts or novices. The present study indicates that successfully blended whiskies have their own distinctive and recognizable profiles, taking their place in a common similarity space, with groupings that can reflect their component parts.

Background

The distinction between single malt and blended Scotch whisky is well-established throughout the world—in drinks magazines, retail outlets and in people's reported preferences. Blended whiskies represent around 90% of the market for Scotch, although most whisky writers focus exclusively on the 300 or so single malts, produced by distilleries in Scotland [7]. The distinction is often accompanied by an implicit hierarchy—with single malts being regarded as having a more distinctive and

authentic flavour while blends are regarded as having more homogeneous, commercial flavours. It is not uncommon to read statements contrasting the two types of scotch: "a blended whisky, however famous its brand name, is only a recipe. It has no provenance, and little heritage, other than the originator's name or brand" while "the delicious feature of single malt whiskies is that their flavours are so diverse" ([15], p. 22). Perhaps it is these beliefs that lead creators of whisky flavour maps to classify the characteristics of single malts without including blends. Many scientific papers have also implicitly accepted the distinction and tested the flavour characteristics of blended whiskies [5, 9] independently of those of single malts [8, 15].

* Correspondence: Barry.Smith@sas.ac.uk

¹Centre for the Study of the Senses, School of Advanced Study, University of London, Malet Street, Senate House, WC1E 7HU London, UK
Full list of author information is available at the end of the article

In chemistry, optical spectroscopy can be reliably used to discriminate the compounds in single malts and blended whiskies [10]. Other chemical markers are detectable by gas chromatography/mass spectrometry or simple chemical analysis. (e.g. [2]; see [16] for a review). None of this guarantees, however, that the distinction between single malts and blended scotch is perceptually salient and readily detectable by whisky drinkers.

There are *prima facie* reasons to posit the existence of a clear sensory distinction between blends and malts. Blended Scotch whiskies use anywhere between 4 and 50 single malts [3] in a blend and sometimes even highlight one of them as their signature component: for example, Strathisla is the “heart” of Chivas Regal; Glenrothes of Cutty Sark and Mortlach of Johnnie Walker. Single malts can also be ‘blends’ in the more restricted, technical sense of the term, as they can result from mixing liquids from different casks from the same distillery. A perceptual distinction between single malts and blends might need to reflect ‘single distillery’ vs ‘mixed origins’. A more plausible difference would be in terms of the number and variety of components that make up the flavour profiles of each Scotch. Hypothetically, we might expect tasters to perceive blended whiskies to have more complexity and layers than single malts (pace [15]). However, the goal of blending is to start with casks of single malts in different condition each year and achieve a unified and distinctive flavour, so information about the composition may be lost.

An even more likely sensory difference between single malts and blends could be the distinctive presence in the latter of grain whisky. Grain whisky is made from wheat or maize, not barley. It is produced by continuous distillation in a column still and is aged for at least three years in oak barrels. Grain whisky’s flavour is usually described as simpler than the flavour of single malts and blenders will often speak of grain whisky as being necessary to create cohesion between the malts that enter into the composition of the blended whisky (although some blends do not use it). The selection of malt whiskies and grain whiskies are said to have a significant impact on the flavour of the resulting blend [11]. As grain whisky often represents a significant proportion of the blended scotch (between 40 and 60%), it is expected to introduce a perceived difference in the flavour of the liquid, notably to reduce heavy malt whisky flavour characters [9] and/or to introduce smooth characters [14]. Whether the presence of grain whisky means that blends stand out as globally different from single malts, however, is an important question. Since grain whisky is often cheaper to produce than single malts and less often consumed on its own, its presence might at least be partly responsible for the frequent difference in reputation between single malts and blended whiskies.

The closest published study to have looked into the perceptual basis of the difference between single malts and blends comes from a rather unusual report published in 1983 in the *British Medical Journal* by two fellows of the Royal College of Surgeons. Drs. Chadwick and Dudley were worried by the cost of single malt whiskies at their social gatherings. To put the sensory distinction to the test they blindfolded eight colleagues of their surgical unit in St Mary’s Ward hospital, ‘after their evening ward’ and presented them with six glasses of whisky, of which they knew that three would be blends and three would be single malts of different regions. Each whisky was presented 6 times, leading to 36 responses per participant. This improvised method led to the conclusion that people were unable to discriminate blends from single malts and that the small advantage of more experienced drinkers only came from answering blends more often than ‘I don’t know’. The authors conclude “the inexpert drinker should choose his whisky to suit his taste and pocket and not his self image” ([4], p. 1913). The paper has many experimental flaws, notably the limited number of participants, the background information and the rather strenuous tasting regime. Interestingly though, the only response it led to in the pages of the distinguished *British Medical Journal* was that of a colleague who recommended that the BMJ did not “include this article in any copies of your journal destined for Scotland or indeed for any part of the world where there are truly discriminating drinkers of whisky” ([4], p. 1913). The role of expertise and cultural differences are obviously factors that need to be taken into account when testing for a perceptual distinction between single malts and blends.

The present experimental design was intended to assess whether the difference between single malts and blended whisky was perceptually salient. The question is all the more interesting since recent results show that people are not good at perceiving blends as blends, at least those that are crafted to produce unified flavours. For instance, Harrar et al. [6] showed that neither experts nor novices could tell the proportion of white grapes present in a Champagne—even when the proportion was 0 or 100%.

A first hypothesis to consider is that either the blending of many different single malts with grain whisky or just the presence of grain whisky in blends, makes them perceptually distinct from single malts. A second possibility is that blends enjoy characteristic flavour profiles, with each as distinctive as any single malt, and do not fall into an undifferentiated category; something which could then be explained by the fact that they retain some similarities with the key single malts that feature as ingredients. To test which of these hypotheses was more likely, we conducted a series of blind tasting

experiments in three countries known for their different familiarities with, and attitudes towards, blends and single malts: the United Kingdom (UK), the United States (US) and France. While consumers will be familiar with blends in both the UK and the US, France remains a market dominated by single malts. French and British consumers will share an implicit or explicit hierarchy between blends and single malts, while the American consumers, being also exposed to Bourbon, might have a less dichotomous view of the whisky world. In each country, experts and novice participants were tested.

Methods

Participants

Overall, 92 participants took part in the study. The study was conducted in three countries. Experts were recruited through whisky tasting clubs or as professionals (writers, those serving in specialised whisky shops and whisky buyers for generalist shops). There were 3:2 male to female participants. The mean age was 37.7 years (range = 18–56 years). No specific familiarity with whisky or spirit was required from novices, and a questionnaire was used to assess familiarity, along with age, gender and weekly alcohol consumption (see Table 1).

Whiskies

Commercially available whiskies were selected to provide a range of characteristic flavours, and these included four single malts, four blended Scotches and one single grain whisky (Table 2). These whiskies were chosen because they are well-established brands in the UK, sell in large quantities and cover a range of sensory characteristics [4]. The blends were selected among the most popular on the global market, and the single malts came from distilleries whose malts are also components in one of the blends (i.e. Cardhu and Mortlach for Johnnie Walker blends; Glenlivet for Chivas Regal). The exact proportions used in the blends are protected information and cannot be displayed.

The whiskies were selected as being good representatives of blends and malts (age, location, brands, quality/prices), having been judged as such by two consulted

whisky experts. In a pilot study with seven samples (three single malts, three blends and one grain whisky), the findings revealed that experts participants treated a single malt with a heavy peaty character as an outlier, distinguishing it from the other single malts and blends, so very peaty single malts were removed from the main study. Two further samples were added and a repeat sample to assess reliability. Table 2 shows that the whiskies ranged in alcohol level from 40 to 46%. All bottles were purchased in the country of the tasting, except for Johnnie Walker Platinum in France and Mortlach and Cameron Brigg in the USA, which are not commercially available there.

Sample preparation

All whiskies were stored and served at ambient temperature, in coded glasses in which was poured 30 ml of Scotch to which 10 ml of bottled mineral water was added in order to lower the alcohol content to approximately 23%. The addition of water released certain volatile compounds and hence increased the aroma of the samples, while moderating the effect of the high alcohol content on the mouths of participants.

Samples presentation and set up

For each participant, the 10 glasses included the 9 coded for whiskies in Table 1, as well as a repeat glass of Johnny Walker Black Label, given a different code. The sample whiskies were presented in random order, each in similar transparent tasting glasses. There were no significant differences between blends and malts regarding their colour. The three-digit codes were different for each participant, so that the glasses could not be matched with other participants. A spittoon and water were made available to each participant.

Design and procedure

The study was composed of three blocks in each country. Each block was composed of one session for novices, and one for experts. The sessions took place in quiet, well-ventilated locations (Paris, New York, London). In all cases, the environment was well-lit, and

Table 1 Participant demographics from the three countries where the test was conducted

	Male	Female	Age	Knowledge of whisky					Frequency of whisky consumption					
				None	Minimal	Moderate	Large	Expert	<2	2–5	6–10	11–15	>16	
UK expert	5		35,8		1			4			1	4		
UK non-expert	19	2	32,3		17	4				2	4	6	6	2
French expert	6	2	47,7		3	1	4			1	4	3		
French non-expert	14	6	36,4	3	10	6				2	4	6	5	1
US expert	3	2	40,0				3	2			1	1	3	
US non-expert	15	18	33,9	4	17	12				4	12	12	4	1

Table 2 List of the nine whiskies presented blind to the participants (one, Johnnie Walker Black Label, was repeated)

Designation	Type	Age	Origin	Alcohol content	Approx. retail price (£)
Cardhu	Single malt	12	Speyside	40%	35
Mortlach	Single malt	16	Speyside	43%	95
Glenlivet	Single malt	18	Speyside	43%	60
Glenmorangie	Single malt	12	Highlands	46%	50
Cameron Brig	Grain whisky	6	N.A.	40%	20
Chivas Gold	Blend	18	N.A.	40%	50
Ballantine's	Blend	17	N.A.	43%	50
Johnnie Walker Black Label	Blend	12	N.A.	40%	30
Johnnie Walker Platinum	Blend	18	N.A.	40%	65

NA not available

the experiments took part during daytime. Before the session, participants were informed that the purpose of the experiment was to examine the perception of whisky, and that there were no right or wrong answers. They signed the informed consent forms and were told that spitting out of whisky was recommended. Each session lasted 1 h and included two sorting tasks (one orthonasal only; a full tasting task which included orthonasal, retronasal and palate judgement) and one identification task. The tasks were conducted in this order, for all groups, and participants could not go back to the previous task and change their answers (Fig. 1).

Free sorting task

Each participant had ten glasses containing nine different whiskies, and one repeat (Johnnie Walker Black Label). In both sorting tasks, participants were asked: "Please sort the samples into groups. The groups can be based on anything that makes a meaningful classification for you. There is no limit on the number of groups you can make, and they can range from 1 (if they all seem the same to you) to 10 (if they all seem different) and anything in between". They were given a table

containing ten rows (non-numbered) and were asked to report the code numbers of the glasses they grouped together in separate rows. In the first task, they were instructed to proceed by sniffing alone (orthonasal, task 1); once this sorting task was completed, and they had made their groupings, the glasses were reshuffled by the experimenter, and participants were asked to proceed to the full tasting sorting task (full tasting, task 2).

Once the full tasting sorting task had been completed, participants were asked to provide flavour descriptors for each of their groups from a list of descriptors provided (see Table 3). They were told there was no limit to the number of descriptors they could use, but the minimum was one. The flavour descriptors corresponded to the descriptors that were most used in a pilot study (15 tasters, including 4 experts). This vocabulary was developed from earlier versions [12, 13] and substituted non-specialist terms such as fruity, floral, smoky for certain chemical terms (e.g. estery, phenolic) ([9]a).¹

After the completion of the full tasting sorting task, the participants were given a table with the list of nine whiskies, similar to Table 1. They were told "The whiskies that you have tasted today are all in this list. If you

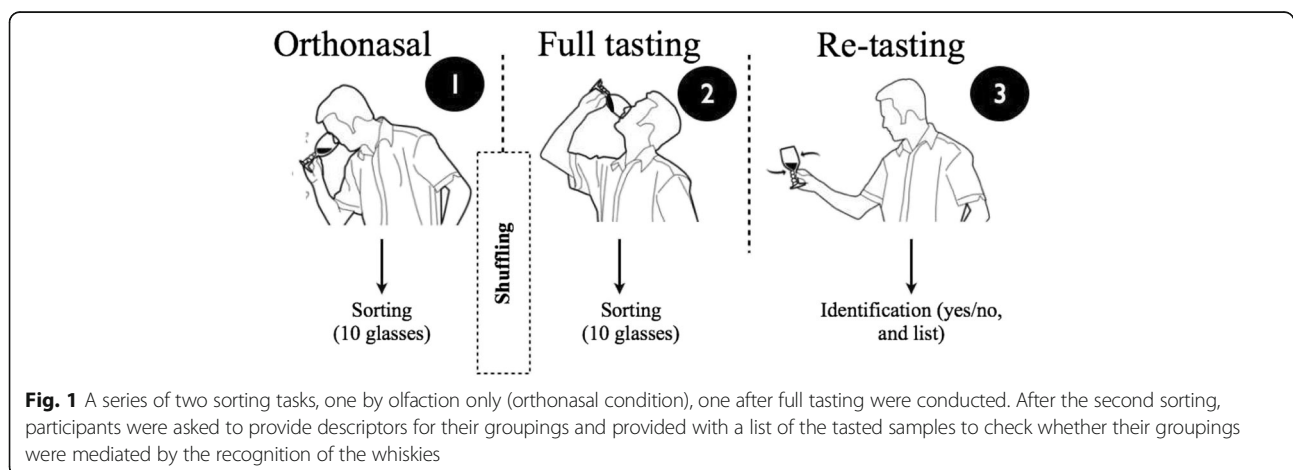


Fig. 1 A series of two sorting tasks, one by olfaction only (orthonasal condition), one after full tasting were conducted. After the second sorting, participants were asked to provide descriptors for their groupings and provided with a list of the tasted samples to check whether their groupings were mediated by the recognition of the whiskies

Table 3 List of the descriptors provided to participants in the UK and US (English) and France (French). The selection from the list established by [12] resulted from a preliminary pilot study.

Descriptors (English)	Descriptors (French)
Woody	Boisé
Herbal	Herbacé
Harsh	Dur
Soft	Doux
Butter	Beurre
Malty	Malté
Nutty	Noix
Cereal	Cereale
Supple	Souple
Dry	Sec
Sweet	Sucré
Complex	Complexe
Simple	Simple
Rich	Riche
Austere	Austere
Thick	Epais
Balanced	Equilibré
Citrus	Agrume
Peppery	Poivré
Smoky	Fumé
Spicy	Epicé
Salty	Salin
Peaty	Tourbé

think you recognised one or some of them, please write down the code number of the corresponding glass beside the name; if you did not recognize any, leave the table blank". Interested participants were offered debriefing after the session.

Data analysis

For each assessor, results of the free sorting tasks were encoded in individual distance matrices where the rows and the columns are the whiskies. For each individual distance matrix, a value of 1 between a row and a column indicates that the assessor put the two whiskies together, whereas a value of 0 indicates that the whiskies were not put together. For each group of assessors (i.e. French, UK, US, experts and non-experts) and each condition (orthonasal and full tasting conditions), the individual distance matrices obtained from the sorting data were computed in a global similarity matrices. These global similarity matrices were then submitted to non-metric multidimensional scaling (MDS). In addition, hierarchical ascending classifications (HAC)

were performed on each MDS coordinate to identify groups of whiskies.

The analysis of the descriptors associated to the full tasting condition started by the construction of a contingency matrix with descriptors in columns and whiskies in rows. Pearson correlations were calculated between each descriptor (i.e. frequencies for each whiskies) and each dimension of the MDS. These correlations constitute the coordinates of the descriptors in the MDS configuration.

Results and discussion

Results

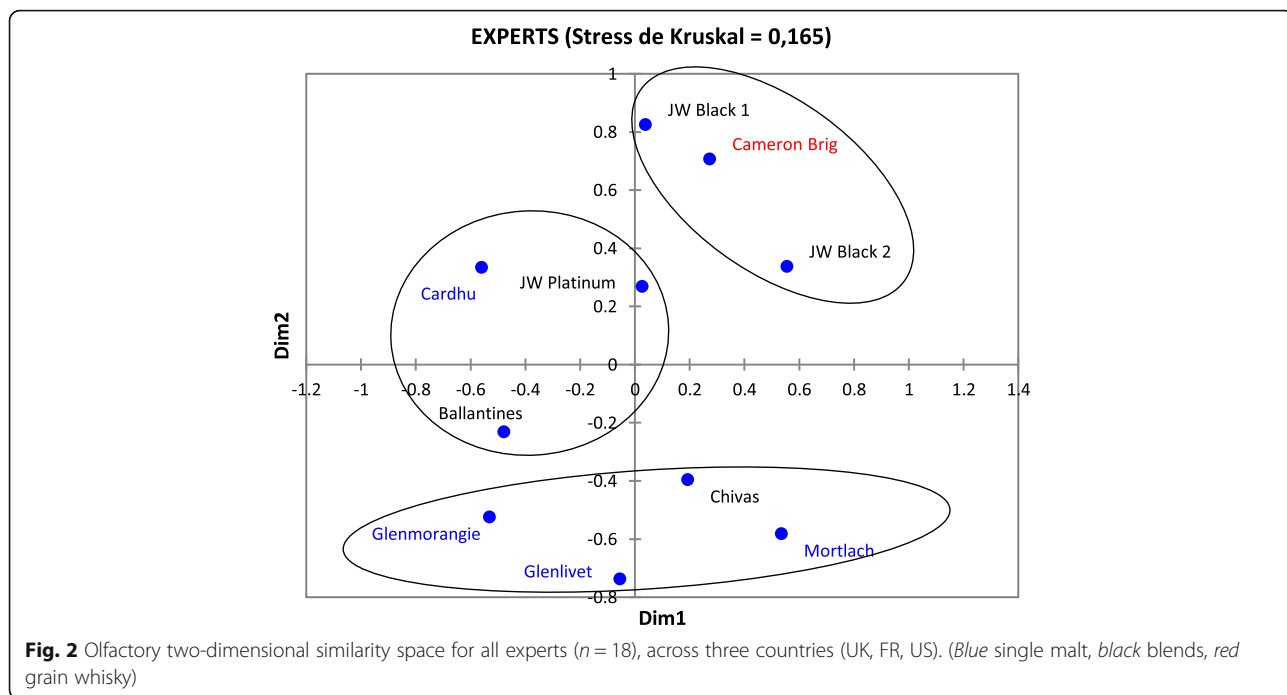
Olfactory sorting task

MDS statistical analysis provided two-dimensional solutions for both the six olfactory free sorting tasks (three countries and two expertise levels) with normalised raw stress values ranging from 0.156 to 0.233. Figure 2 shows the collective MDS plots for all experts; Fig. 3 shows the collective MDS plots for non-experts. Cluster analysis was used to group samples, as circled in each figure. According to the dendograms, three-cluster partitions seemed reasonable for the MDS. This was also true for all plots country by country, as shown in the Supplementary Materials. Only in the case of the US non-experts did two clusters seemed more appropriate.

In the olfactory sorting tasks, neither experts or non-experts made a clear separation between blends vs. single malts. Moreover, grain whisky was not systematically clustered with blends as expected. Experts' performance on repeatability of a sample was visibly better than non-experts, as for all experts' panels, the two instances of Johnnie Walker Black Label (JW) were systematically clustered together.

Looking country by country, as shown in Additional file 1: Figure S6, Additional file 2: Figure S7, Additional file 3: Figure S8, Additional file 4: Figure S9, Additional file 5: Figure S10 and Additional file 6: Figure S11 (MDS plots for UK experts, UK non-experts, FR experts, FR non-experts, US experts and US non-experts, respectively), commonalities were found between experts' configurations. For instance US experts Dim2 coordinates were significantly correlated to FR and UK Dim2 coordinates ($r = 0.87$; $p < 0.05$ and $r = 0.66$; $p < 0.05$ respectively). This dimension tends roughly to oppose for each panel of experts the grain whisky and the three Johnnie Walker samples on one extreme, to the Glenmorangie and Glenlivet on the other extreme. FR and US experts also consistently categorise together the grain whisky with the two Johnnie Walker samples.

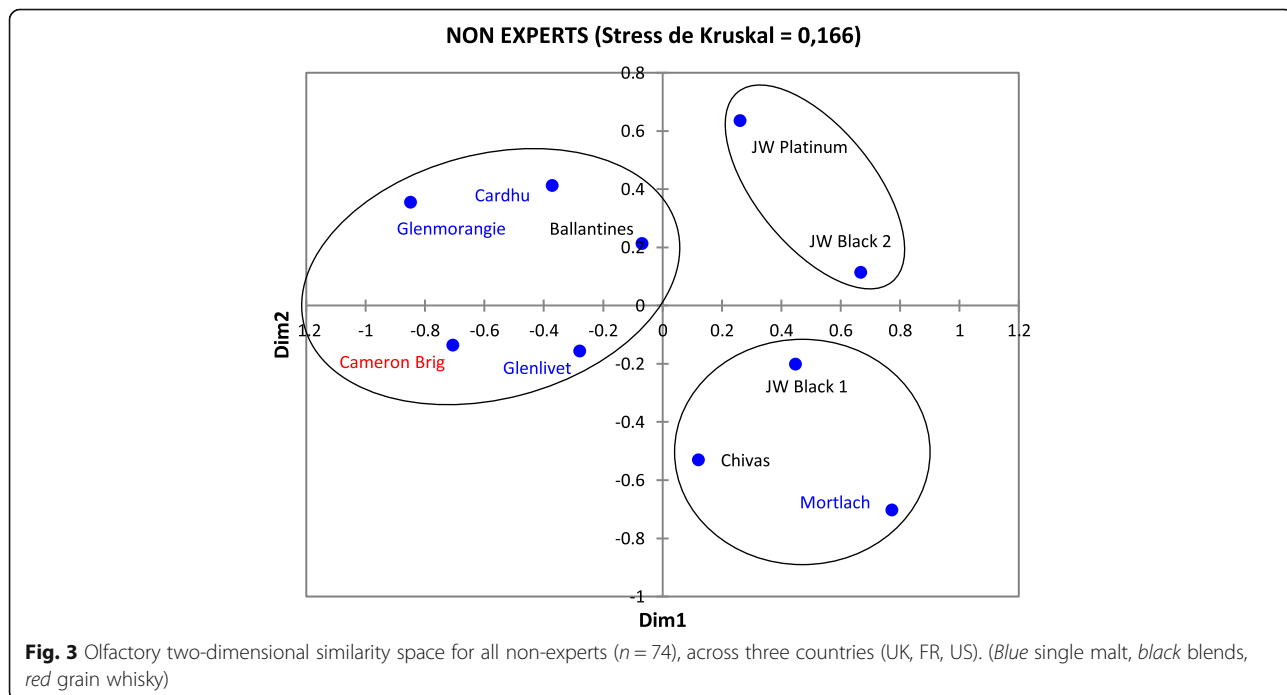
Non-experts' results were less structured and only one significant correlation was found, in particular between US non-experts Dim2 and UK non-experts Dim1 ($r = 0.71$; $p < 0.05$).

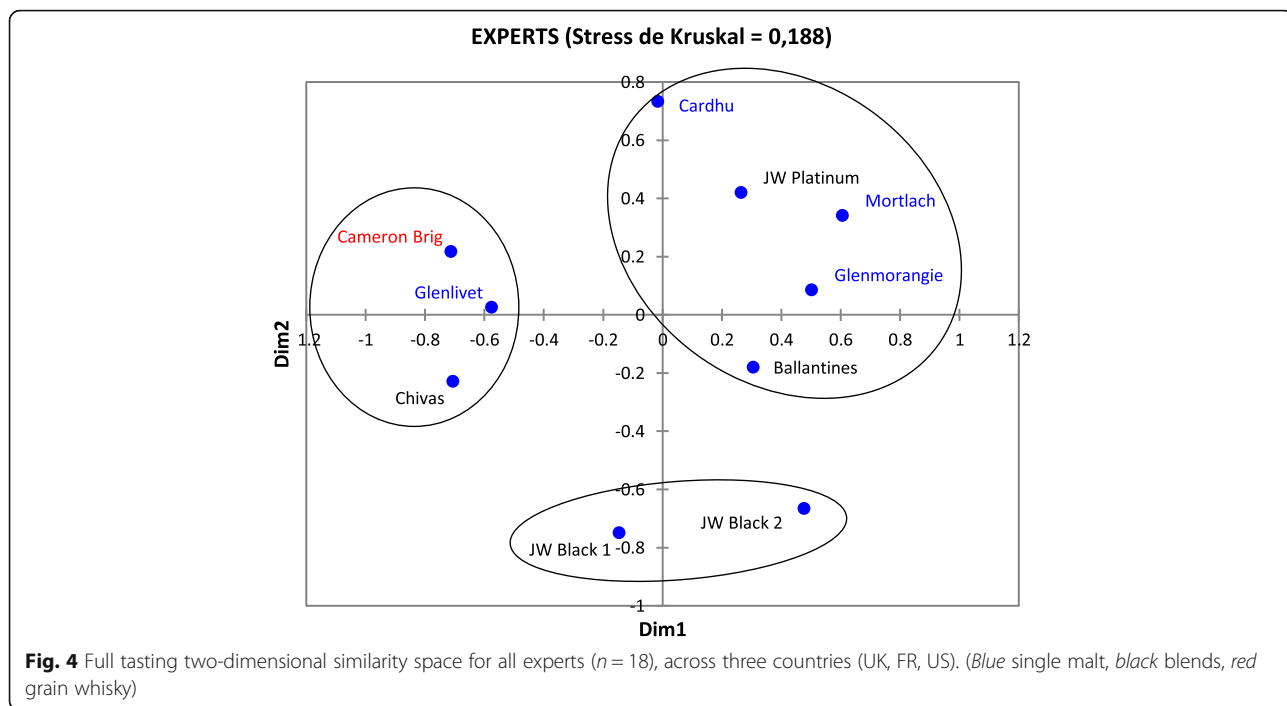


This pattern of results strongly indicates that all participants, experts in particular, were sensitive to sensory differences between the whiskies, but that the difference between single malts and blends, or indeed the presence of grain whisky, was not a salient dimension.

Full tasting sorting task

MDS statistical analysis provided two-dimensional solutions for all experts and non-experts (as well as for the six full tasting free sorting tasks in three countries with two expertise levels) with normalised raw stress values ranging from 0.148 to 0.223. Figures 4 and 5 show the



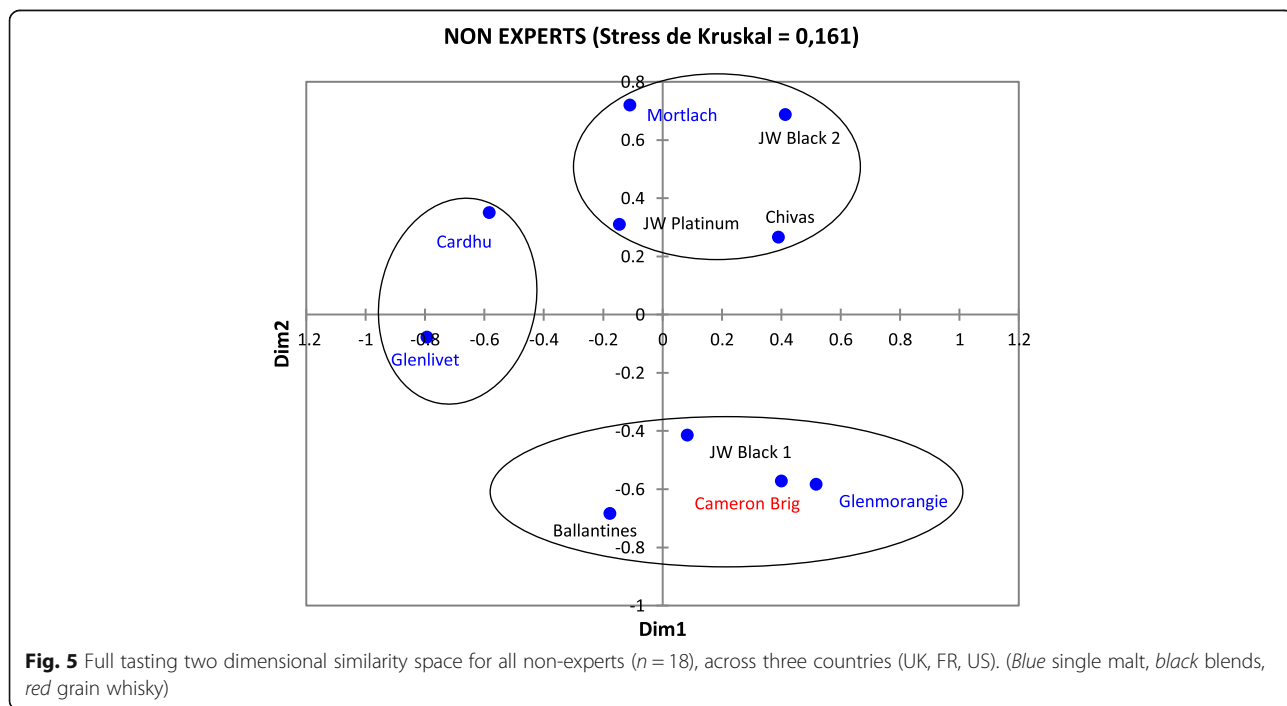


MDS plots for experts and non-experts. Cluster analysis performed on MDS coordinates were used to group the samples, as circled in each figure. The descriptors generated by the panellists were projected onto the results.

The results of the sorting task in the full tasting condition confirm the main results obtained in the olfactory condition. Whether non-expert or expert, there was no

salient perceptual distinction between blends and single malts.

Looking in detail, country by country as shown in Additional file 7: Figure S12, Additional file 8: Figure S13, Additional file 9: Figure S14, Additional file 10: Figure S15, Additional file 11: Figure S16 and Additional file 12: Figure S17 (UK experts, UK non-experts, FR



experts, FR non-experts, US experts and US non-experts, respectively) US and UK experts showed a good repeatability also in the full taste condition. FR experts, despite their good repeatability on the olfactory condition did not show such good performance in the full taste condition. Similarities were found between expert panels. UK experts Dim1 was significantly correlated to FR experts Dim1 ($r = 0.69$; $p < 0.05$) and the Dim2 was correlated to US experts Dim1 ($r = -0.71$; $p < 0.05$). It is interesting to note that UK experts succeeded in grouping in the upper part of Additional file 7: Figure S12, all the single malts in a single cluster together with Ballantines and Johnnie Walker Platinum. Moreover, they grouped together Chivas Regal and the grain whisky. This is the closest result to a hypothetical distinction in the tasting condition, but still by no means the expected dichotomy.

Description

Whiskies and their descriptions are plotted on Additional file 1: Figure S6 and Additional file 2: Figure S7. The figures support the idea that all whiskies, blends and single malts alike, presented distinctive flavour characteristics. The expert descriptions were congruent with some pre-established descriptions provided for the whiskies, adding to the claim that there was a benefit of expertise in the task. Besides Cardhu being described as 'salty', there was however little agreement between experts and non-experts regarding the characteristics of the whiskies.

Identification

Participants were instructed to match the tasted samples to the list of the whiskies presented in Table 2, or to leave the column blank if they did not know these whiskies or did not recognise them. Most participants did not provide answers, and none of the participants managed to identify the samples above chance, ruling out the hypothesis that the groupings provided before were mediated by background knowledge of the whiskies and their origins.

Conclusions

The present study shows that the distinction between blends and single malts, which is central to the production, presentation and marketing of Scotch whisky, does not correspond to a clear cut perceptual distinction for tasters. The olfactory (orthonasal) and full tasting (flavour) profiles of the nine whiskies tested blind in this experiment give rise to perceptual similarities for novices and experts across the single malts and blends boundary.

Importantly, the study shows a real effect of expertise, with experts' classifications being more structured and with repeated samples being identified more reliably by experts than by non-experts. The lack of a perceived

distinction between blends and single malts by experts, does not show a lack of reliability or consistency in experts' use of perceptual categories (a result consistent with other studies on flavour expertise, see Ballester et al 2008, Schlich et al 2015). In the country by country analysis, French experts (in the orthonasal task) and UK experts (in the full tasting condition) were the closest to grouping single malts together, but they also grouped blends along with them. In no condition was a clear perceptual distinction found between single malts and blends.

Endnotes

¹For more information about the methodology of free sorting tasks, see [1].

Additional files

Additional file 1: Figure S6. Olfactory two-dimensional similarity space for UK experts. (Blue single malt, black blends, red grain whisky). (DOCX 113 kb)

Additional file 2: Figure S7. Olfactory two-dimensional similarity space for UK non-experts. (Blue single malt, black blends, red grain whisky). (DOCX 24 kb)

Additional file 3: Figure S8. Olfactory two-dimensional similarity space for FR experts. (Blue single malt, black blends, red grain whisky). (DOCX 136 kb)

Additional file 4: Figure S9. Olfactory two-dimensional similarity space for FR non-experts. (Blue single malt, black blends, red grain whisky). (DOCX 13 kb)

Additional file 5: Figure S10. Olfactory two-dimensional similarity space for US experts. (Blue single malt, black blends, red grain whisky). (DOCX 21 kb)

Additional file 6: Figure S11. Olfactory two-dimensional similarity space for US non-experts. (Blue single malt, black blends, red grain whisky). (DOCX 21 kb)

Additional file 7: Figure S12. Full tasting two-dimensional similarity space for UK experts. (Blue single malt, black blends, red grain whisky). (DOCX 21 kb)

Additional file 8: Figure S13. Full tasting two-dimensional similarity space for UK non-experts. (Blue single malt, black blends, red grain whisky). (DOCX 20 kb)

Additional file 9: Figure S14. Full tasting two-dimensional similarity space for FR experts. (Blue single malt, black blends, red grain whisky). (DOCX 17 kb)

Additional file 10: Figure S15. Full tasting two-dimensional similarity space for FR non-experts. (Blue single malt, black blends, red grain whisky). (DOCX 75 kb)

Additional file 11: Figure S16. Full tasting two-dimensional similarity space for US experts. (Blue single malt, black blends, red grain whisky). (DOCX 91 kb)

Additional file 12: Figure S17. Full tasting two-dimensional similarity space for US non-experts. (Blue single malt, black blends, red grain whisky). (DOCX 102 kb)

Abbreviations

HAC: Hierarchical ascendant classifications; JW: Johnnie Walker; MDS: Non-metric multidimensional scaling; UK: United Kingdom; US: United States

Acknowledgements

The authors would like to thank Diageo for supplying the samples, arranging the logistics for their delivery and for providing access to, and information

from, their blending team. Gillian Arnold for the GPA, Maggie Sheen for consumer testing advice and to the assessors who took part in the tastings. Thanks to Dr Sarah Garfinkel for helpful comments on the data analysis.

Availability of data and materials

The data sets supporting the results of this article are included within the article and its additional files.

Authors' contributions

BCS and OD designed the experimental protocol and coordinated the study. OD and BCS drafted the manuscript. BCS, OD carried out the data collection. CS and JB carried out the data analysis. All authors read and approved the final manuscript.

Competing interests

The authors declare that they have no competing interests.

Ethics approval and consent to participate

All experimental procedures within the lab were approved by SAS research ethics committee and applying these procedures to the current population was consistent with ethical approval SASREC_1617-64-R.

Author details

¹Centre for the Study of the Senses, School of Advanced Study, University of London, Malet Street, Senate House, WC1E 7HU London, UK. ²ISIPCA, Versailles, France. ³Centre des Sciences du Goût et de l'Alimentation, CNRS, INRA, Université de Bourgogne Franche-Comté, 21000 Dijon, France.

Received: 22 September 2016 Accepted: 25 February 2017

Published online: 16 March 2017

References

1. Abdi H, Valentin D, Chollet S, Chrea C. Analysing assessors and products in sorting tasks: DISTATIS, theory and applications. *Food Qual Prefer.* 2007;18:627–40.
2. Adam T, Duthie E, Feldmann J. Investigations into the use of copper and other metals as indicators for the authenticity of Scotch whiskies. *J Inst Brew.* 2002;108:459–64.
3. Booth M, Shaw W, Morhalo L. Blending and bottling. In: Piggott JR, Sharp R, Duncan REB, editors. *The science and technology of whiskies.* Essex: Longman; 1989. p. 295–326.
4. Chadwick SJ, Dudley HA. Can malt whisky be discriminated from blended whisky? The proof. A modification of Sir Ronald Fisher's hypothetical tea tasting experiment. *Br Med J.* 1983;287:1912–5.
5. Guy C, Piggott JR, Marie S. Consumer profiling of Scotch whisky. *Food Qual Prefer.* 1989;1:69–73.
6. Harrar V, Smith B, Deroy O, Spence C. Grape expectations: how the proportion of white grape in Champagne affects the ratings of experts and social drinkers in a blind tasting. *Flavour.* 2013;2:1–11.
7. Jackson M. *The world guide to whisky.* London: Dorling Kindersley; 1987.
8. Lapointe FJ, Legendre P. A classification of pure malt Scotch whiskies. *Appl Stat.* 1994;43:237–57.
9. Lee KYM, Paterson A, Piggott JR, Richardson GD. Sensory discrimination of blended Scotch whiskies of different product categories. *Food Qual Prefer.* 2001;12:109–17.
10. Mignani AG, Ciaccheri L, Mencaglia AA, Gordillo B, Gonzalez-Miret ML, Heredia FJ, Culshaw B. Optical spectroscopy and pattern recognition techniques for discriminating and classifying Scotch whiskies. In: *Proceedings of IEEE Conference Date of Conference: 28–31 Oct. 2011.* In: *Sensors, IEEE;* 2011. pp. 1946–1949. <http://ieeexplore.ieee.org/abstract/document/6126980/>.
11. Murray J. *Classic blended scotch.* London: Prison Books Ltd.; 1999.
12. Piggott JR. Selection of terms for descriptive analysis. In: Lawless HT, Klein BP, editors. *Sensory science theory and applications in foods.* New York: Marcel Dekker Inc.; 1991. p. 339–51.
13. Piggott JR, Canaway PR. Finding the word for it : methods and uses of descriptive sensory analysis. In: Schreier P, editor. *Flavour* '81. Berlin: New York Walter de Gruyter & Co; 1981. p. 33–46.
14. Schoeneman RL, Dyer RH. Analytical profile of Scotch whiskies. *J AOAC.* 1973;56:1–10.
15. Wishart D. The flavour of whisky. *Significance.* 2009;6:20–6.
16. Wiśniewska P, Dymerski T, Wardencki W, Namieśnik J. Chemical composition analysis and authentication of whisky. *J Sci Food Agric.* 2015;95:2159–66.

Submit your next manuscript to BioMed Central and we will help you at every step:

- We accept pre-submission inquiries
- Our selector tool helps you to find the most relevant journal
- We provide round the clock customer support
- Convenient online submission
- Thorough peer review
- Inclusion in PubMed and all major indexing services
- Maximum visibility for your research

Submit your manuscript at
www.biomedcentral.com/submit

