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Perceptions of drinking water quality and risk and its effect on behaviour: A cross-national study ☆

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ABSTRACT

There is a growing effort to provide drinking water that has the trust of consumers, but the processes underlying the perception of drinking water quality and risks are still not fully understood. This paper intends to explore the factors involved in public perception of the quality and risks of drinking water. This purpose was addressed with a cross-national mixed-method approach, based on quantitative (survey) and qualitative (focus groups) data collected in the UK and Portugal. The data were analysed using several methods, including structural equation models and generalised linear models. Results suggest that perceptions of water quality and risk result from a complex interaction of diverse factors. The estimation of water quality is mostly influenced by satisfaction with organoleptic properties (especially flavour), risk perception, contextual cues, and perceptions of chemicals (lead, chlorine, and hardness). Risk perception is influenced by organoleptics, perceived water chemicals, external information, past health problems, and trust in water suppliers, among other factors. The use of tap and bottled water to drink was relatively well explained by regression analysis. Several cross-national differences were found and the implications are discussed. Suggestions for future research are provided.

1. Introduction

There is a growing focus on consumers' satisfaction with tap water and an increasing effort to supply drinking water that has the trust of consumers (e.g. IWA's 2004 Bonn Charter for Safe Drinking Water). This effort requires a multidisciplinary approach, in order to combine technical perspectives focusing on supply reliability and safety with consumers' perceptions. For this purpose, a good understanding of the processes involved in public perception of water quality is needed in order to maintain or improve consumer satisfaction and trust.

Previous research has identified several factors influencing public perception of drinking water quality (e.g. Doria et al., 2005; Jardine et al., 1999; Jones et al., 2007; Levallois et al., 1999). Such factors include organoleptic properties (especially flavour), risk perception, previous experience (e.g. familiarity with a specific drinking water), contextual cues provided by the supply system, perceptions of chemicals, trust in water companies and other groups, impersonal and interpersonal information (e.g. from the mass-media and family members), and demographic variables (for a discussion see Doria, in press). It has been suggested that dissatisfaction with tap water may lead to the search of alternatives.

In spite of the work developed in this area, it is not fully understood how different factors interact to influence perceptions and the potential role of variables such as perceptions of water chemicals is largely understudied. Published research on this area has focused on several countries (e.g. C.I.Eau, 2000; Jones et al., 2007; Syme and Williams, 1993), but the use of different research instruments makes cross-national comparisons difficult and it is unclear how the role of different factors varies from one country to another. Moreover, while the consumption of bottled water has been growing worldwide, factors such as convenience are also involved and it is not clear to what extent it is being used as an alternative to tap water (e.g. Anadu and Harding, 2000; Doria, 2006; Levallois et al., 1999).

This study starts by comparing perceptions and water uses in the UK and Portugal. The validity of a model previously developed with convenience data (Doria et al., 2005) was verified and the model was improved with additional variables. Particular focus was placed on perceptions of hardness, chlorine and lead. Quantitative results are complemented with focus groups. A general discussion and suggestions for further research are provided.

☆ This paper was prepared when the author was based at the University of East Anglia, Norwich, UK. The views presented in this paper are not necessarily those of UNESCO and do not commit the Organization in any way.

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2. Research design

This research is based on a mixed-methods approach with quantitative and qualitative methods, a procedure that improves the validity of the findings through the triangulation of complementary data sets (Fern, 2001; Creswell, 2003; Bryman, 2006). Following a theory development technique proposed for non-experimental settings (e.g. Saris and Stronkhorst, 1984), a testable causal hypothesis on the perceptions of tap water quality and risks was developed and formulated as an hypothetical model (see Doria et al., 2005). This model is tested here with empirical data (see model A) and extended to include additional variables (models B and C). Ideally, a single structural model would include all water-related variables. However, due to the large number of latent variables involved, such a model would be too large to expose significant relationships, even with a realistically large sample. Thus, the approach used in this study was to test a simplified model for behaviours (model D). The validity of the models is further improved by undertaking a variable-oriented cross-national study. In parallel to the structural models, cross-national differences in tap water consumption were analysed with generalised linear models. Finally, a closer look was given to the role of some water characteristics and chemicals (hardness, lead and chlorine). The qualitative approach used for the triangulation largely corresponds to what Fern (2001) classified as 'experiential focus groups', and it intends to unveil personal experiences that converge or diverge from the quantitative models.

2.1. Quantitative methods

The sampling procedure intended to provide data that are representative of the UK and Portuguese populations within calculable margins of error, and that allow an acceptable cross-national comparison. Using a confidence interval approach (see Sapsford, 1999), the sample size needed for a confidence level of 95% with a margin of error ± 0.35 (i.e., 5% of the 7-point scale) was estimated to be 500 in each country, assuming a response rate of about 30%, and a maximum standard deviation of 2.2 (with this value based on the data used for Doria et al., 2005). The sample used for this study was randomly selected from phone directories. A mail survey with telephone follow-up approach was used for the data collection, in order to minimise non-response bias. A first version of the survey, which intended to pre-test the instruments selected from Doria et al (2005), was sent by post in January 2004 to 100 people in each country. A second version, with very small improvements, was sent later in March 2004 to the remaining 400 people of each country. The telephone backup was performed between 3 weeks and 4 months after the mail survey. The response rate was approximately 41% in both countries ($n=203$ in the UK and $n=204$ in Portugal). Incomplete replies (<80% of questionnaire items answered) and non-contacts were regarded as non-responses.

The UK sample is composed of 52.8% women and 47.2% men; the Portuguese sample is composed of 53.0% women and 47.0% men. These samples do not differ significantly in relation to gender ($\chi^2=.001$, $p=.972$) and closely follow the gender distribution described in the 2001 National Census. The mean age is 52 ± 19 yrs in the UK sample and 46 ± 18 yrs in the Portuguese sample. The age difference between the samples is significant ($t=3.301$; $p=.001$), and does not reflect true population differences. Therefore, the data used for the descriptive analysis and cross-national comparison were weighted for age, following the method described in Sapsford (1999). The practical consequences of the weighting are extremely small.

The survey instruments consisted of a questionnaire about water-related perceptions and behaviours. The measurement of respondents' perceptions, attitudes, and behaviours is based on the agreement with several statements (see Table 1 for examples). Respondents' agreement was measured using a Likert-type scale from "completely disagree" (1) to "completely agree" (7). Between 2 and 4 questionnaire items, measuring manifest variables, were used to estimate each latent variable. The items were selected from Doria et al. (2005) on the basis of their reliability. The questionnaire was back-translated from Portuguese into English, and cross-checked by a bilingual colleague. The reliability of the manifest variables is very good (α>.90) or satisfactory (α>.70); with the exception of hardness in Portugal, whose reliability is very low (α<.35). For this reason, the survey items focusing on hardness were considered separately in the analysis and are presented as 'hardness 1' (for the survey item mentioning limescale) and 'hardness 2' (for the survey item mentioning hardness).

Table 1
Main study variables, with examples of the survey items used for their measurement.

Latent variables	Manifest variables (examples of survey items)
Quality	My tap water is usually of high quality
Risk	There are health risks associated with drinking tap water in my home
Flavour	I am happy with the taste of my tap water
Colour	I am happy with the colour of my tap water
Odour	I am happy with the odour of my tap water
Context	The water pipes and taps of my home are clean and well maintained
Information—Friends	Some friends and/or family told me negative comments regarding tap water
Memorabiliy	Tap water has caused health problems to me or to someone in my family
Trust	I trust my tap water company
Familiarity	I am used to my tap water
Pressure	I am satisfied with the water pressure in my home
Lead	My tap water is contaminated with lead
Chlorine	My tap water has too much chlorine
Hardness	(1) My tap water has too much limescale (2) My tap water is too hard
Tap water use	I always drink tap water at home
Bottled water use	I often use bottled water at home

UK and Portuguese data were compared using independent samples t-test for equality of means, adjusted for unequal variances when appropriate. A $p<.01$ significance level criterion was adopted to account for multiple comparisons (see Perneger, 1998). Due to non-normal distribution, tap water uses were compared with the Wilcoxon Mann-Whitney Z for independent samples. The variables that explain cross-national differences were identified using a univariate generalised linear model (GLM) approach (McCullagh and Nelder, 1989). The models tested for this purpose had water uses as dependent variables, country as independent variable (fixed factor), and water-related perceptions as covariates (both as main effects and as interactions with country). GLM is robust to accommodate non-normality.

Regarding the structural equation models (SEM), the procedure adopted in this study is identical to the one detailed in Doria et al. (2005). The estimator used for the analysis was Robust ML due to non-normal multivariate distributions. The goodness of fit indexes adopted for this research are based on the proposal of Hu and Bentler (1999), who suggested a combination of relative fit indexes to minimise type I and type II errors. The indexes that will be used are the comparative fit index (CFI), the non-normed fit index (NNFI), and the root mean square error of approximation (RMSEA). The cut-off values proposed for these indexes are NNFI>.95, CFI>.95, and RMSEA<.06, which indicate good fit (Hu and Bentler, 1999). Different models are presented in this paper and it should be noted that fit indexes tend to worsen when the number of latent variables in a model is increased (Kenny and McCoach, 2003).

2.2. Qualitative methods

Three focus group sessions were organised in each country in January 2005. Participants were recruited in Norwich (UK) and Lisbon (PT) using street adverts and leaflets, being subsequently selected and

Table 2
Means of survey variables measured in a 7-point scale and mean difference between the UK ($n=203$) and Portugal ($n=204$), 95% lower and upper confidence intervals of the difference, *t*-test statistic and significance level.

Variable	UK mean	PT mean	UK SD	PT SD	Difference (UK-PT)	CI lower	CI upper	*t*	*p*
Quality	5.61	5.27	1.47	1.84	.34	−.04	.72	1.760	.079
Risk	2.20	2.24	1.31	1.53	−.04	−.37	.28	−.267	.790
Flavour	5.33	5.40	1.72	1.94	−.07	−.49	.35	−.322	.748
Colour*	6.22	5.74	1.43	1.59	.48	.13	.82	2.729	.007
Odour	5.78	5.88	1.05	1.87	−.10	−.45	.24	−.585	.559
Context*	5.18	5.98	1.63	1.58	−.80	−1.17	−.44	−4.315	<.001
Information — friends *	3.21	2.35	1.96	2.00	.86	.41	1.31	3.743	<.001
Memorability	1.67	1.41	1.20	1.10	.26	−.01	.52	1.911	.057
Trust	5.27	5.26	1.38	1.61	.00	−.34	.35	.024	.981
Familiarity*	5.48	4.43	1.22	1.45	1.05	.74	1.35	6.703	<.001
Pressure*	5.42	6.21	1.98	1.68	−.79	−1.21	−.37	−3.677	<.001
Lead	1.98	2.26	1.45	1.66	−.28	−.74	.18	−1.184	.238
Chlorine	3.75	3.18	2.08	2.25	.57	.00	1.13	1.968	.050
Hardness 1	3.83	3.23	2.27	2.05	.60	.10	1.09	2.375	.018
Hardness 2	3.85	3.62	2.21	1.69	.23	−.37	.83	.766	.445

Variables that differ at the $p<.01$ level are marked with an asterisk.

assigned to specific groups on the basis of age, gender, and occupation. Eight people were invited to attend each session and the five to eight people that attended each session completed a form consenting to participate in this research. The decision for local (rather than national) focus groups was due to practical limitations.

The moderator input was largely restricted to the introduction of discussion items (e.g. "What do you understand by water quality?"), which were derived from the survey items. The moderator adopted a non-judgmental style, providing only minimal responses during the discussions. The analytical style adopted for the focus groups corresponds to what Gibbs (2002: 157–159) calls "pattern matching" — i.e., focus group results were analysed for patterns that support, contradict, or extend the theoretical patterns described by the quantitative models.

3. Results

3.1. National perspectives and differences

On average, tap water is perceived as having high quality (mean = 5.61 in the UK and 5.27 in Portugal — see Table 2). In both countries, all positive aspects (i.e., satisfaction with flavour, odour, colour, trust, context, familiarity, water pressure) are above the mid-point of the scale (i.e. 4), and all negative aspects (i.e., risk, memorability, negative information from friends and family, excess of hardness, chlorine, lead) are below it.

Regarding cross-national differences, the data provided by UK and Portuguese respondents do not significantly differ in relation to most variables, including perceived quality and risk. However, there are some differences between these two countries. Satisfaction with colour and familiarity with tap water are higher in the UK; satisfaction with contextual indicators and with tap water pressure is higher in Portugal. The number of respondents who claimed to have heard negative information from friends and family is higher in the UK than in Portugal.

Frequencies for tap and bottled water consumption are presented in Table 3. The large majority (80%) of UK respondents and about half of the Portuguese respondents (46%) use tap water as their main source of drinking water at home (i.e. scale points 5 and above). Only 6% of the UK respondents seem to rarely drink tap water, but this proportion was much higher (24%) in Portugal. About one third (34%) of UK respondents and about half of the Portuguese respondents (53%) use bottled water as the main source of drinking water at home (i.e. scale points 5 and above).

Tap and bottled water consumptions were compared. Tap water consumption is much more frequent than bottled water consumption in the UK (Wilcoxon $Z=-8.040$; $p<.001$), but no significant difference was found in Portugal (Wilcoxon $Z=-1.271$; $p=.204$). In relation to cross-national differences, it was found that UK respondents reported to rely more on tap water to drink (mean rank UK = 203.19, PT = 139.76; Wilcoxon-Mann-Whitney $Z=-5.973$, $p<.001$) and less on bottled

Table 3
Tap and bottled water consumption in the UK and Portugal (adjusted for age).

Consumption	Tap water % UK	% PT	Bottled water % UK	% PT
(Very high) 7	43.05	21.09	12.44	39.35
6	25.87	18.40	9.72	5.00
5	11.51	6.40	12.10	8.58
(Medium) 4	8.33	16.01	9.98	12.03
3	1.79	3.43	9.48	5.86
2	3.92	10.92	13.04	4.51
(Very low) 1	5.53	23.74	33.26	24.67

The labels presented for consumption are illustrative and correspond to the percentage of respondents completely agreeing (7) or completely disagreeing (1) that they always drink tap or bottled water at home. The values presented are based on the average of two manifest variables, rounded to the mid point of the scale.

Table 4
GLM tests of between subjects effects for tap and bottled water use.

Source	Tap use Mean Sq.	F	*p*	Bottle use Mean Sq.	F	*p*
Corrected model	28.761	11.701	<.001	35.012	13.137	<.001
Intercept	20.002	8.138	.005	187.943	70.521	<.001
Country	8.002	3.255	.072	3.635	1.364	.244
Country*flavour	.084	.034	.853	1.134	3.803	.052
Country*colour	.217	.088	.766	7.801	2.927	.088
Country*odour	.695	.283	.595	.019	.007	.932
Country*context	.091	.037	.847	.121	.045	.831
Country*risk	.286	.117	.733	1.589	.596	.441
Country*info .— friends	.015	.006	.937	16.899	6.341	.012
Country*memorability	4.452	1.811	.179	7.085	2.658	.104
Country*trust	1.013	.412	.521	8.409	3.155	.076
Country*pressure	1.960	.797	.372	.003	.001	.973
Country*tap use	–	–	–	.071	.027	.870
Flavour	48.327	19.662	<.001	.001	.001	.982
Colour	.898	.365	.546	12.530	4.701	.031
Context	.258	.105	.746	.020	.008	.931
Risk	13.914	5.661	.018	1.186	3.822	.051
Information — friends	2.481	1.009	.316	3.167	1.188	.276
Memorability	7.448	3.030	.083	.573	.215	.643
Trust	12.377	5.035	.025	3.345	1.255	.263
Odour	.032	.013	.909	22.984	8.624	.004
Pressure	5.516	2.244	.135	.462	.173	.677
Tapuse	–	–	–	283.310	106.305	<.001
Error	2.458			2.665		

Mean squares, *F*-statistics and significance levels are presented. Tap use $R^2_{adj}=.336$; Bottle use $R^2_{adj}=.389$.

water (mean rank UK = 138.91, PT = 176.75; Wilcoxon-Mann-Whitney $Z = -3.610$, $p < .001$) than Portuguese respondents.

3.2. Understanding cross-national differences in consumption

Univariate GLMs were developed to seek for variables that explain the consumption of tap and bottled water, including national differences (Table 4). GL models included the main effects of single dependent variables and their interactions with country. Both tap and bottled water models moderately explain water uses (tap use $R^2_{adj} = .336$; bottle use $R^2_{adj} = .389$). Tap water use is explained by flavour, risk, and trust in water companies. Bottled water use is explained by tap water use (included here to test the use of bottled water as an alternative rather than a complement to tap water), colour, odour, and the interaction between country and negative information from friends. However, negative information from friends is higher in the UK than in Portugal and therefore does not well explain the cross-national differences found in water consumption.

3.3. Structural models

All factor loadings of the factor-analytic models were relatively high (>.7 for all items but one risk item in the UK, which was >.6), and the observed variables were considered to be good indicators of the constructs they intended to measure.

3.3.1. Basic model

A basic model (A), which was found to fit convenience data (NNFI = 0.964; CFI = 0.967; RMSEA = 0.046) in a previous study (Doria et al., 2005), was tested with the UK and Portuguese samples. Standardised solutions and coefficients of determination (R^2) for latent variables are presented on Fig. 1. The fit indexes are presented in Table 5 and indicate that the model fits the data of both countries in an acceptable manner.

With the exception of the association between flavour and colour, which is weaker in the UK than in Portugal, the relationships between organoleptic variables are very similar in both countries. Perceived quality is very well explained by the model, risk is moderately well explained, and context is poorly explained. There are some clear national differences in relation to the predictors of quality and risk. In the UK, quality is strongly influenced by flavour, moderately influenced by context and poorly influenced by risk perception; in Portugal, quality is strongly influenced by flavour, moderately influenced by risk perception, and poorly influenced by context. In the UK, perceived risk is moderately influenced by colour and flavour, and weakly influenced by context; in Portugal, risk is strongly influenced by flavour, and weakly influenced by colour and context.

Table 5
Fit indexes for models (A) to (D).

Model		NNFI	CFI	RMSEA
(A)	UK	.952	.963	.051
	PT	.953	.964	.056
(B)	UK	.864	.881	.069
	PT	.839	.859	.074
(C)	UK (with InfoF)	.926	.937	.054
	(without InfoF)	.950	.957	.046
	PT (with InfoF)	.914	.926	.057
	(without InfoF)	.929	.940	.054
(D)	UK (quality)	.945	.955	.051
	(Flavour)	.953	.962	.047
	PT (Quality)	.950	.959	.056
	(Flavour)	.952	.961	.054

Indexes for model (C) with and without the variable 'negative information from friends and family' ("InfoF"); indexes for model (D) with either quality or flavour as a predictor of tap water use.

3.3.2. Extended models

An extended model (B) was tested using UK and Portuguese data. This model includes the variables of the basic model, plus trust in water companies, satisfaction with tap water pressure, homeownership, memorability, and negative information from friends and family. The standardised solutions for this model are presented in Fig. 2. Trust in water companies has a moderate influence on context, and memorability has a moderate influence on risk perception, but the relevance of the additional variables seems to be weak. Furthermore, this model does not satisfactorily fit the data of either country (see

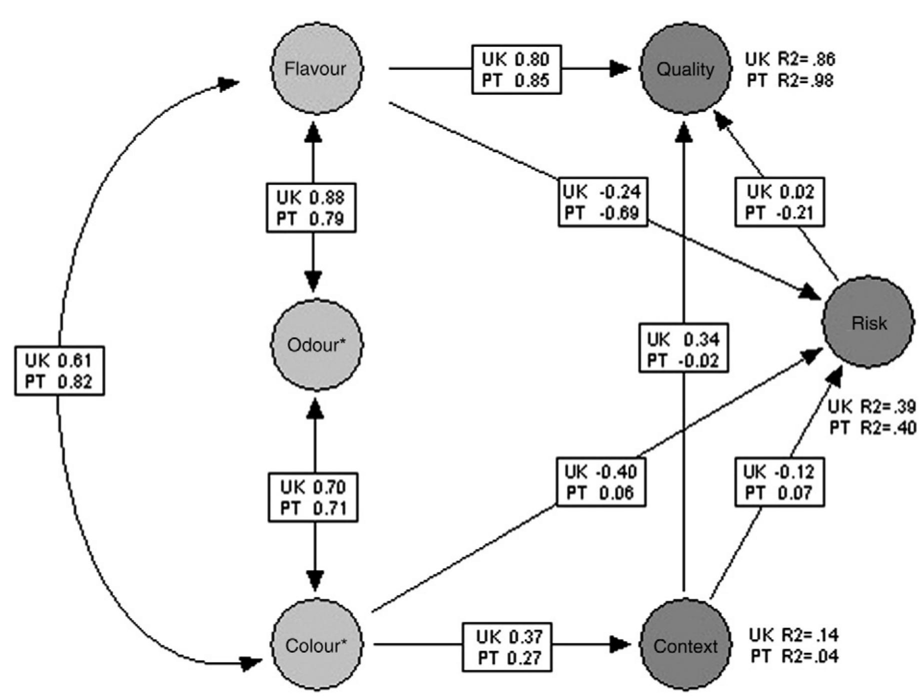

Fig. 1. SEM standardised solutions and R^2 of latent variables of model (A). Disturbances UK: quality = .378; risk = .780; context = .929. Disturbances PT: quality = .074; risk = .771; context = .980.

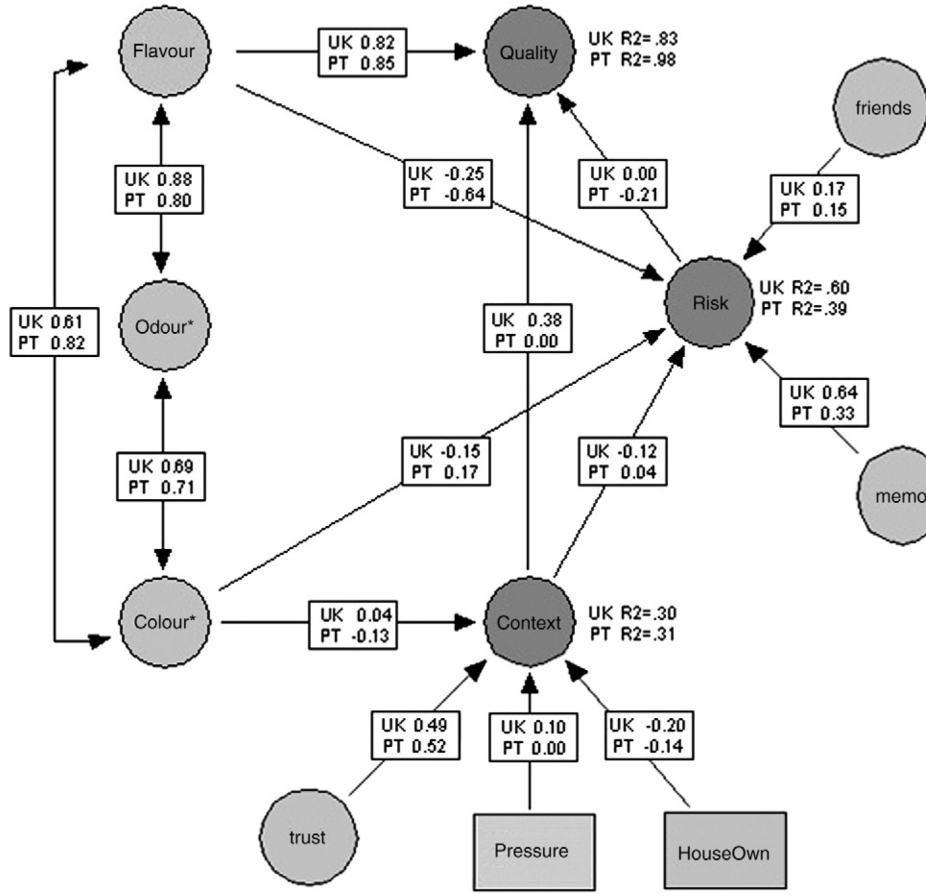

Fig. 2. SEM standardised solutions and R^2 of latent variables of the extended model (B). Disturbances UK: quality = .406; risk = .633; context = .838. Disturbances PT: quality = .110; risk = .780; context = .830.

Table 5). The model has a large number of variables, several of them are only weakly related to the other variables of the model, and the sample size may not be big enough to provide an acceptable fit.

The extended model (B) was improved using Wald test and Lagrange multipliers in conjunction with theoretical considerations, to develop a new model (C). The relationships between (a) colour and risk, (b) colour and context, (c) water pressure and context, (d) homeownership and context, and (e) risk and quality were excluded based on modification indexes. Several new relationships, all predicting trust in water companies, were established using flavour, colour, memorability and negative information from friends. Model (C) has a much better fit (see Table 5) and is presented in Fig. 3. Although the fit of this improved model is still non-acceptable according to the criteria presented on the research design, the lack of fit is likely to be due to the size of the model. To support this hypothesis, it can be pointed out that the model would fit UK data if the variable 'information from friends' is excluded (Table 5). Nonetheless, the model does not fit the Portuguese data satisfactorily according to the fit indexes criteria adopted for this research, and no acceptable alternative model was found for Portugal.

3.3.3. Modelling water use

Tap water use was incorporated in model (A) and connected with bottled water use. Two alternative models were tested, one using perceived quality as a predictor of tap water use, and the other using flavour as a predictor of tap water use. Both models included risk perception as an additional predictor of tap water use. Bottled water consumption at home was also included in the model and was considered to be an alternative to tap water. Although both models satisfactorily fit the data (see Table 5), the model that considered flavour as a predictor of tap water use has the best fit; this model (D) is presented in Fig. 4.

Tap water consumption is moderately well explained in both countries. Tap water consumption is moderately influenced by satisfaction with flavour, and weakly influenced by risk perception. Bottled water consumption is strongly and inversely affected by tap water use. Lagrange multipliers did not suggest any good additional predictors of tap or bottled water use.

3.4. Perceptions of hardness, chlorine and lead

The relationships of perceived hardness, lead, and chlorine with other water-related variables are presented in Table 6. Perceptions of excessive hardness, lead, and chlorine are usually directly interrelated. Consistent with the reliability analysis, the variables hardness 1 and 2 are strongly related in the UK but weakly related in Portugal. This suggests that Portuguese respondents do not associate limescale with the concept of hardness. Hardness, lead, and chlorine are inversely related with all positive indicators (quality, flavour, odour, colour, context, familiarity, and trust) and directly related with all negative indicators (risk, negative information from friends, and memorability). Although this pattern is evident in both countries, these relationships are usually stronger in the UK sample than in the Portuguese sample. The strongest relationships found with water hardness are with flavour, odour and trust in water companies. Lead is mostly related to risk perception, colour and trust. Chlorine is particularly related to odour, perceived quality and flavour.

It should be noted here that the survey items with most missing data refer to specific chemical aspects: lead (25% of the UK and 48% of the Portuguese participants have not provided data for it), chlorine

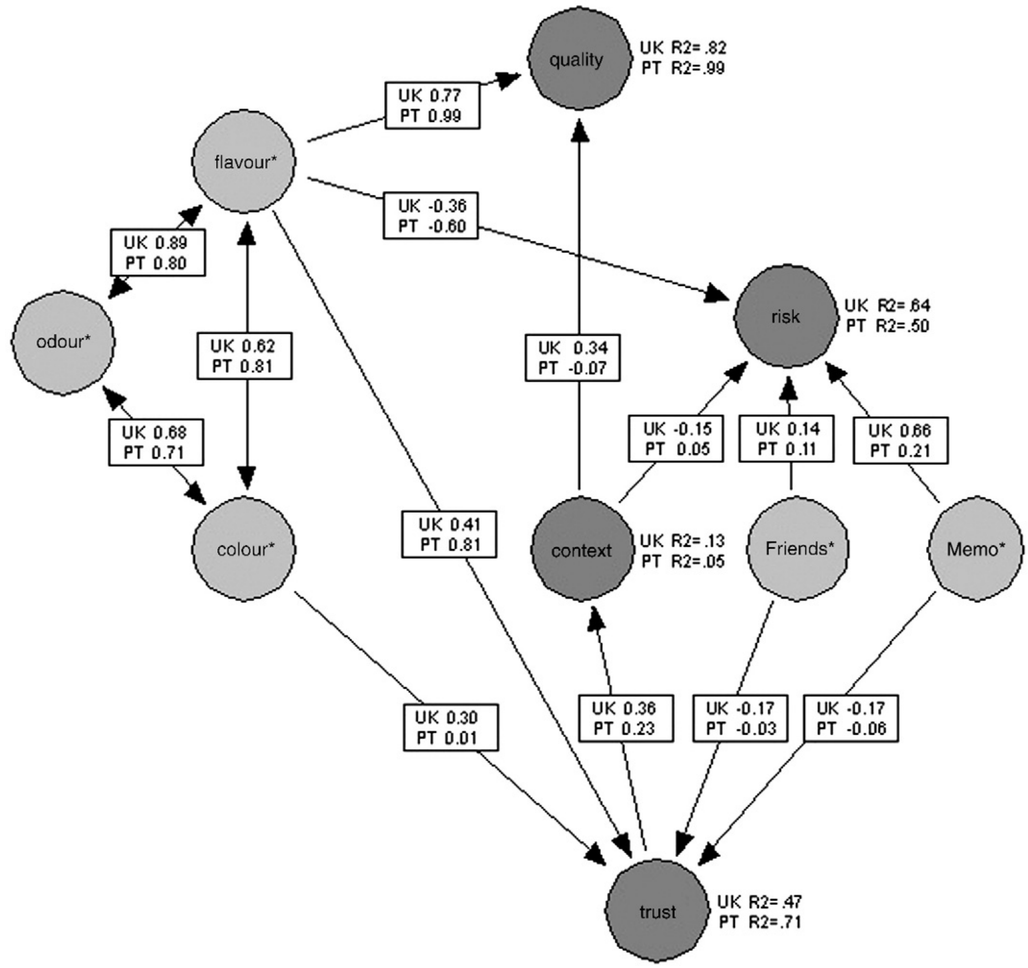

Fig. 3. SEM standardised solutions and R^2 of latent variables of the extended model (C). Disturbances UK: quality = .424; risk = .596; context = .932; trust = .731. Disturbances PT: quality = .001; risk = .702; context = .972; trust = .534.

(13% of the UK and 30% of the Portuguese data is missing), and hardness (10% in the UK and 39% in Portugal). As lead in drinking water is often related to leaded pipes in households, it could be hypothesised that homeowners were better informed about it than tenants. However, there is no significant difference between the number of owners and of tenants that did not reply to the item about lead (UK chi-square = .100, $p = .752$; PT chi-square = 1.553, $p = .213$).

3.5. Focus groups

The focus group results largely converged with the quantitative results, confirming many of the relationships described in the structural models. The results presented in the following paragraphs summarise the main points that were raised by the participants and the main differences identified.

The relevance of organoleptics, risk and contextual indicators was clear during the focus group discussions. However, the convergence between quantitative studies and focus groups data was not perfect and several details should be noted. While the role of flavour was prominent in the relationship between organoleptics and water quality, participants also mentioned colour and odour. In addition, although there was widespread consensus on the importance of organoleptics for water quality, very few participants were able to justify their views. On most occasions, the relevance of organoleptics was presented as self-evident, requiring no further explanation. For some participants, good water flavour was regarded as essential, because people need to drink and it should not be an unpleasant experience. When asked about the meaning of good drink water, some participants would just say something like "you can taste it" or "the water that tastes OK". Some participants tried to relate organoleptics with risk, but this relationship was not consensual. Others said they consider 'good water' to be a water with 'good organoleptics' because they were taught it — and although they did not clarify where they have learned it, one participant who demonstrates during school trips even said she teaches it that way. When speaking about water quality and health issues, participants mentioned not only risks but also the potential aesthetical and health benefits of water. Regarding contextual indicators, the role of the water source (e.g. mountain spring, river, boreholes) and of the geographical place where the water is consumed (e.g. at home, in a restaurant) was raised. There were also mentions of variables that were not included in the structural models, such as water treatments and unspecified drinking water chemicals. The importance of water treatments for water quality emerged during discussions in both countries, but its role substantially differed between UK and Portuguese groups. Several UK participants attributed a largely negative connotation to water treatments, regarding it as an artificial operation with potential for chemical contamination, both in the case of tap and bottled water. Trust in those who perform or supervise the treatments was also raised, as a guarantee that water is safe or that a treatment should to be performed. The position of Portuguese participants in relation to water treatments is in stark contrast. For Portuguese participants, water treatments — including chemical treatments — are good and needed to 'purify' the water.

In relation to the way risks are perceived, the relevance of flavour and colour was raised but questioned by several participants, who considered that the relationship of organoleptics and health risks was

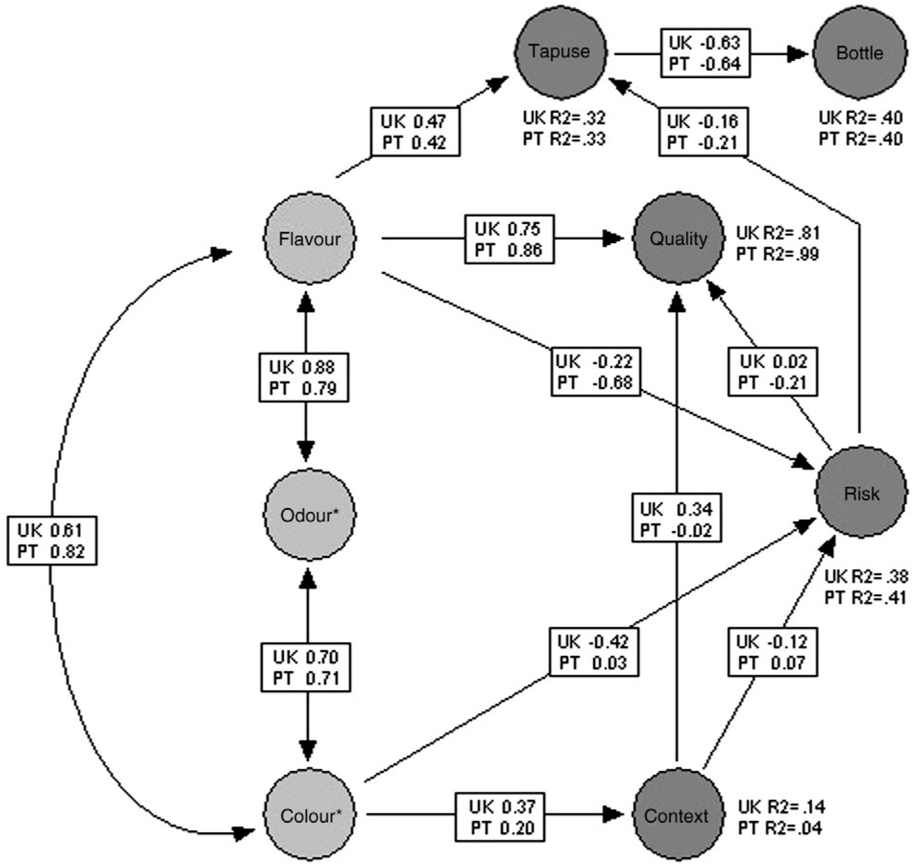

Fig. 4. SEM standardised solutions and R^2 of latent variables of model (D) (using flavour as a predictor of tap water consumption). Disturbances UK: quality = .432; risk = .786; context = .928; tap use = .825; bottle use = .774. Disturbances PT: quality = .002; risk = .769; context = .980; tap use = .821; bottle use = .781.

not straightforward. Context was mentioned, but it sometimes included references to the wider context. Memorability emerged as an important factor, with participants referring to both past illnesses attributed to drinking water and the absence of such events to estimate risk. There were some references to external information about risk, particularly from the media, work colleagues, and doctors, but not from friends and family. Such information was presented as having an impact on the way people think about water quality, influencing trust and behaviour.

Organoleptics emerged during the discussions as an extremely relevant factor for the perceptions of water risks and quality. The way organoleptics were perceived seems to be strongly influenced by familiarity — people seem to become accustomed to the characteristics of a specific water that will serve as a reference standard. However, the number of qualitative terms used to describe flavours, odours, and colours was very limited, and often restricted to the use of general qualitative terms (e.g. 'very good'). Several Portuguese participants shared their concerns about a 'white colour', which is usually caused by air bubbles, but was attributed by a few of the participants to chlorine.

Attitudes towards water chemicals in the UK and Portugal differed markedly. UK participants are more concerned about chemicals and seem to be more informed about them. Several UK participants understood the advantages and disadvantages of adding fluoride to water but were confused by the debate and the dilemma posed by the way risks and benefits are distributed depending on consumers' age.

Table 6
Relationships between perceptions of hardness, lead, and chlorine and other water-related variables.

	Hardness1 UK	PT	Hardness2 UK	PT	Lead UK	PT	Chlorine UK	PT
Hardness2	.777**	.213*						
Lead	.189*	.433**	.247*	.157				
Chlorine	.397**	.410**	.463**	.094	.302**	.411**		
Quality	−.208*	−.153*	−.087	−.150	−.384**	−.171	−.415**	−.236*
Flavour	−.252**	−.207*	−.210*	−.169*	−.297**	−.217*	−.396**	−.272**
Odour	−.299**	−.266**	−.286**	−.260**	−.350**	−.238*	−.496**	−.270**
Colour	−.084	−.189*	−.145	−.138	−.484**	−.228*	−.169*	−.171*
Context	−.182*	−.085	−.056	−.055	−.340**	−.196*	−.272**	−.082
Familiarity	−.167*	−.134	−.185*	−.131	−.333**	−.034	−.414**	−.148
Trust	−.320**	−.136	−.288**	−.122	−.438**	−.281*	−.362**	−.183*
Risk	.123	.163*	.163	.089	.529**	.330**	.348**	.233*
Info. friends	.133	.097	.024	.059	.159*	.290*	.247**	.372**
Memorability	.097	.061	.120	.025	.342**	.136	.267**	.220*

Correlation coefficients are provided for the UK and Portugal.
* $p < .05$, ** $p < .001$.

In spite of concerns, some UK participants noted that they were in favour of adding chemicals such as chlorine and fluoride to drinking water. Although this position may seem contradictory, it may just represent a more informed attitude to risks and benefits. It can be argued that more naive views focus exclusively on either risks or benefits, regarding them as mutually exclusive. However, participants seem to be very conscious that risks and benefits of drinking water chemicals are relative and coexist.

Although the quantitative analyses only focused on one kind of contextual indicators (i.e. the distribution system), group participants mentioned several kinds of indicators, referring not only to the condition of water pipes and taps, but also to the water source and the characteristics of the geographic place where the water is consumed. The relationship of contextual indicators with risk and trust was confirmed, but the association with organoleptics, house ownership and water pressure was not evident during group discussions. The way people choose a tap (e.g. toilet or kitchen water tap) to take as drinking water is highly influenced by the context. However, participants' decisions to use a particular tap are only partially due to inferences about water quality from the context, and largely affected by practical considerations, such as the location of glasses (which are usually in the kitchen) and the possibility of using a tap to fill a kettle (which depends on the size of the sink).

Focusing on water suppliers, participants closely associate water companies with water bills. This association seems to be largely due to the very little contact consumers have with water treatment works, distribution system maintenance, water source management, and other stages of the water supply process, only hearing about their water company when they have to pay for the service. To some extent, participants seem to assume that the natural position towards water companies is one of distrust, perhaps because they are companies and these are often assumed to be untrustworthy by the general public (e.g. EORG, 2002). While positively-phrased comments such as 'I trust them because the water is good and safe' were rare during group discussions, negatively-phrased comments such as 'I have no reason to distrust them as I never had problems' were frequent.

The final behavioural outcome of drinking or rejecting water seems to be largely influenced by organoleptics and risk perception. Familiarity is doubtless an important factor, but it is both the cause and consequence of water use, being hard to differentiate from the water use itself. The use of tap water alternatives like bottled water seems to be moderated by several other factors, such as price, convenience, status quo considerations, and environmental concerns.

4. Discussion

4.1. Perception of water quality

Perceptions of water quality are well explained by the factors considered for this study. Water flavour has a strong influence on perceived quality. Perceptions of risk and context also influence perceived quality, but the strength of these relationships depends on the country. Perceived quality also seems to be directly influenced by trust in water companies. In the UK, lead is also associated with the perception of water quality, but this relationship was not verified in Portugal. It was hypothesised in model B that the influence of some of these variables would be indirect, via perceived risk and context. This extended model was tested and was partially supported with the data.

One of the main conclusions is that many factors interact to influence perceptions of water quality. This conclusion has precedents in the literature, but this research presents the dynamics involved. Such interactions clarify why most factors are interrelated (see for example Syme and Williams, 1993) and suggest that people seek an overall consistency for their evaluations by relating different factors. Consequently, perceptions may be considerably stable — and while there is no data available over a long period to validate this hypothesis, the results of annual surveys from 1996 to 2000 presented in C.I.Eau (2000), with global satisfaction with water quality fluctuating from 6.6 to 6.7 on a 10-point scale, suggests so. As several factors are involved, changes in one factor are likely to be counterbalanced by the stability of other factors. This also helps to understand why, for example, media coverage of potential problems often only has a small impact on perception, especially when the problems reported seem to contradict the information of direct experience.

The main factor influencing perceptions is flavour, which has a strong impact on the perception of water quality and other variables (see also Jardine et al., 1999; Mackey et al., 2004; McGuire, 1995). It might be thought surprising that so much relevance is given to something that is purely aesthetic. However, flavour is one of the few indicators that are directly experienced, and it may be preferred over second-hand or ambiguous information. Furthermore, drinking water may be increasingly regarded as a commodity that must be enjoyed, as argued by some focus groups participants. This is consistent with research of food preferences that has shown that taste is more important than most other food characteristics (e.g. Moskowitz and Krieger, 1995). Additionally, from a Maslownian-hierarchical perspective, flavour may be simply emphasised after the more basic needs of water quantity and safety have been achieved. Notwithstanding, it is unclear why flavour prevails over colour and odour, particularly when they are strongly interrelated and many of the considerations that may justify the relevance of flavour are also valid for the other organoleptics. Drinking water flavours are typically more noticeable than odours (Young et al., 1996), and this can explain its prevalence over odour. However, western countries are predominantly visual (e.g. Levin, 1993), and reported problems with colour seem to be slightly more frequent than those with flavour (e.g. DWI, 2003). Whatever reasons justify the relevance of taste, its importance is clear and stresses the usefulness of addressing this parameter via panels and other methods.

4.2. Risk perception

The perception of risks associated with tap water is moderately explained by flavour, memorability, context, and negative information from friends. Similar to water quality, flavour seems to be particularly relevant for risk perception. Colour also seems to be a relevant factor, but — particularly in Portugal — its role seems to be indirect, via its association with flavour and trust. However, while the influence of flavour and other organoleptic variables was evident in quantitative research, this relationship was disputed during the focus groups. Such scepticism about the potential of organoleptics to detect hazardous substances seems to resonate with the theoretical notion of a 'risk society' (see Beck, 1992). Unlike the old concepts of danger and peril, modern risks are often regarded as invisible and their scope is much broader. Nonetheless, some ambiguity was evident during the focus groups, and the fact that this relationship was frequently mentioned on the discussions reveals its relevance. Such ambiguity may also suggest a transition phase, where both beliefs are present at different levels. Possibly, the association between organoleptics and risk is intuitively used and may be questioned when people have time to think about it.

Apart from organoleptics, risk perception also seems to be influenced by other factors, such as memorability, contextual indicators, and interpersonal impersonal information. The influence of these variables is weak, but they may have clear consequences within large populations.

In addition to organoleptics, other inconsistencies between the quantitative and qualitative results must be pointed out. The direct association of chlorine with risks, which emerged in the quantitative research, was challenged during the focus groups, with some participants pointing out that chlorine taste and/or odour reveal water safety. Likewise, in the survey results lead has a significant effect on risk perception, but this influence was not evident during the focus groups. Although lead was recognised as a potential problem, most focus group participants did not think their drinking water had any significant level of lead and therefore did not consider it an actual risk. In this case, the discrepancy between quantitative and qualitative studies may be due to the much larger sample size used in the survey.

Regarding trust in water suppliers, contrarily to model B, its relationship with risk perception does not seem to be restricted to an indirect influence via contextual indicators (i.e., the supply system) or even to a direct influence of trust on risk perception. As presented in model C, trust seems to be largely influenced by the same factors that influence risk perception, namely by water flavour, colour, memorability, and interpersonal information from friends and family. This finding supports research suggesting that trust variations may sometimes be a consequence rather than a cause of risk perception (Poortinga and Pidgeon, 2005). In addition, this is consistent with focus group results, which suggest that trust in water companies is characterised by the absence of aesthetic, health, and supply problems. Quantitative research revealed a considerably high level (>5 on the 7-point scale) of trust in water companies, and the ambivalence with the positions raised during focus groups seems to correspond to what Walls et al. (2004) designate as 'critical trust', which refers to the capacity of people to voice criticisms towards organizations that they nonetheless support and have to rely upon for managing their safety.

4.3. Behaviours

Flavour emerged as the most relevant variable and more adequately explains consumption than perceived water quality. Water quality, even when measured as overall satisfaction, may be too abstract to have a direct impact on behaviour. Flavour and risk moderately explain tap water consumption, which in its turn moderately explains the consumption of bottled water. Additionally, from the GLM models, tap water consumption also seems to be influenced by trust in water companies. Familiarity may have an important role to play, and was initially included in the analysis. However, it became clear that familiarity is a cause as much as a consequence of behaviour, also presenting collinearity problems, and this variable was omitted from the models.

It should be noted that this study is based on statements about behaviour and not on behaviours themselves. The relevance of the perception factors to actual behaviours is just suggested by this model, and needs to be validated by external criteria, but the consistency of the results with large market surveys (Mintel, 2003) and bottled water sales data (INETI, 2004; Euromonitor, 2004) provides at least some corroboration. In addition, the main factors presented in this study as affecting bottled water consumption largely correspond to those identified in other countries, such as Canada, France and the US (e.g. Anadu and Harding, 2000; IFEN, 2000; Jones et al., 2007; Levallois et al., 1999).

Finally, as the use of tap water is influenced by organoleptics, the link between illness cases and water quality may be somewhat minimised during contamination episodes that impact organoleptics. This can potentially influence the findings of epidemiological research that focus exclusively on the number of cases during contamination events, not taking into consideration potential behavioural changes and the use of alternative water sources (Hunter and Syed, 2001; Jones et al., 2006).

4.4. Cross-national comparison

Several similarities and differences were found in the way tap water quality and risks are perceived in Portugal and the UK. The main differences encompass the magnitude of perceived contextual indicators, colour, pressure, interpersonal information, familiarity, and tap/bottled water consumption. No significant differences at the $p < .001$ level were found in relation to the magnitude of perceived water quality, risk, flavour, odour, trust in water companies, hardness, lead, chlorine, and memorability. Focus group results confirmed these findings and pointed out some additional cross-national disparities, especially in relation to chemicals. UK participants seemed to be more critical about chemicals in drinking water than Portuguese participants, and such difference is reflected in the views participants have about drinking water treatments.

The differences found in relation to the use of bottled water could be expected from data on bottled water consumption. Although water consumption is moderately explained by the variables included in this study, it was not possible to provide a full explanation of the national differences. Cross-national differences in water consumption may result from other variables, which were not considered here. In addition, consumption changes may be a cumulative process over time, resulting in differences that are hard to explain with cross-sectional surveys.

Differences were also found regarding the influence of different variables on perceptions of quality and risk. The influence of flavour on risk perception is much stronger in Portugal than in the UK. Moreover, in the UK, the main influence of contextual indicators is on quality. In Portugal, contextual indicators have the greater influence on perceived risk. The influence of risk on perceived quality is only noticeable in Portugal, and seems to be irrelevant in the UK. Overall, these differences suggest that while the structure of the models is somewhat stable, the causal paths that are active can change across countries. This finding is consistent with the results of other authors that studied intra-national regional differences in water perception (Anadu and Harding, 2000; Syme and Williams, 1993). Moreover, it can be hypothesised that the strength of different paths also changes over time. Historical overviews of the issues that have been highlighted in water management seem to support this hypothesis, showing for example that the main concerns at the beginning of the 20th century were related with bacteriological contamination, changing to organic chemicals and metals in the 1940s, and to hazardous waste and groundwater contamination in the 1970s and 1980s (Tarr and Jacobson, 1987). Some relationships may be quiescent and do not manifest themselves until some event triggers them, such as the media amplification which can accompany a major risk alert, and new variables may emerge in the future.

4.5. Chemicals

On average, UK and Portuguese respondents do not consider concentrations of tap water chlorine and lead to be excessive and do not regard their water as too hard. Both quantitative and qualitative results reveal a certain degree of chemophobia, both in the UK and in Portugal. Nonetheless, the incidence of concerns with chemicals seems to be much stronger and widespread in the UK. Possible explanations for this cross-national difference include a higher industrialisation in the UK, with a consequent rise of perceived exposure to chemical risks, and a larger mobilisation of public opinion towards an environment free from anthropogenic chemicals. Nonetheless, while in quantitative studies chlorine, lead, and water hardness were invariably associated with poor water quality and with risks, the qualitative study revealed a larger spectrum of opinions. Moreover, the associations between chemicals and poor quality or risk perception are often moderate or weak, suggesting that several respondents have neutral or positive views about their influence on water quality.

5. Conclusions

Results suggest that perceptions of water quality result from a complex interaction of diverse factors. The estimation of water quality and risks is mostly influenced by satisfaction with organoleptic properties, but several other factors are involved. Although these factors are often common to both the UK and Portugal, their relative importance varies. This suggests that, even if the paths of the structural equation model are valid for different countries, the strength of particular relationships may change according to the place. While perceptions of water quality and risk seem to be very similar across the countries studied, differences were found in relation to several variables, including colour, pressure, interpersonal information, and tap/bottled water consumption. In addition, focus groups analyses suggested that UK participants are more critical about chemicals in drinking water than Portuguese participants. Such differences may result from cultural attitudes towards drinking water, and may have implications for the public acceptability of European-wide standards for drinking water.

Further research in this area may attempt to extend the structural models with additional variables (e.g. attitudes towards water treatments, water reuse, in-home water treatments, the perceived health benefits of tap water) and/or test them with different samples. In addition, it would be interesting to relate perceptions of water quality and behavioural variables with consumer complaints and enquiries to water suppliers and regulators. Further research may also try to relate specific organoleptic characteristics, using instruments such as flavour profiles and flavour wheels, with perceptions of quality and risk. Finally, it is likely that the models developed for the perception of drinking water quality and risk can have a wider application and be easily adapted to the wider perception of environmental quality.

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References

Anadu E, Harding A. Risk perception and bottled water use. Journal of the American Water Works Association 2000;92(11):82–92.

Beck U. Risk society. London: Sage; 1992.

Bryman A. Integrating quantitative and qualitative research: how is it done? Qualitative Research 2006;6:97-113.

Eau CI. Les Français et l'Eau: 5 Ans d'Opinions et d'Etudes 1995–2000. Paris: Centre d'Information sur l'Eau. In: Clesceri LS, Greenberg AE, Eaton AD, editors. 2001) Standard methods for the examination of water and wastewater. American Public Health Association, American Water Works Association and Water Environment Federation; 2000.

Creswell JW. Research design: qualitative, quantitative and mixed methods approaches. Thousand Oaks: Sage; 2003.

Doria MF. Bottled water versus tap water: understanding consumers' preferences. Journal of Water and Health 2006;4:271–6.

Doria MF. (in press) Factors influencing public perception of drinking water quality. *Water Policy*.

Doria MF, Pidgeon N, Hunter PR. Perception of tap water risks and quality: a structural equation model approach. Water Science & Technology 2005;52(8):143–9.

DWI (Drinking Water Inspectorate). Drinking water for England 2002: a report by the Chief Inspector. London: The Stationery Office; 2003.

EORG (The European Opinion Research Group). The attitudes of Europeans towards the environment. *Eurobarometer* 58.0. Brussels; 2002.

Euromonitor. Euromonitor soft drinks reports. Cit in the Australian soft drinks association website news (http://www.softdrink.org.au, PageID—5003 — accessed 17-07-04.); 2004.

Fern EF. Advanced focus group research. London: Sage; 2001.

Gibbs GR. Qualitative Data Analysis - Explorations with Nvivo. Buckingham: Open University Press, 2002.

Hu L, Bentler PM. Cutoff criteria for fit indexes in covariance structural analysis: conventional criteria versus new alternatives. Structural Equation Modeling 1999;6:1-55.

Hunter PR, Syed Q. Community surveys of self-reported diarrhoea can dramatically overestimate the size of outbreaks of waterborne cryptosporidiosis. Water Science and Technology 2001;43:27–30.

IFEN (Institut Français de L'Environnement). La préoccupation des français pour la qualité de l'eau. Les Données de L'Environnement 2000;57:1–4.

INETI (Instituto Nacional de Engenharia, Tecnologia e Inovação). Consumo per Capita de Água Engarrafada (http://www.igm.ineti.pt/estatisticas/aguas/engarrafadas/cons_pc.htm — accessed 27-10-04); 2004.

Jardine C, Gibson N, Hrudey SE. Detection of odour and health risk perception of drinking water. Water Science and Technology 1999;40(6):91–8.

Jones AQ, Dewey CE, Dore K, Majowicz SE, McEwen SA, Waltner-Toews D. Exposure assessment in investigations of waterborne illness: a quantitative estimate of measurement error. Epidemiologic Perspectives & Innovations 2006;3:6.

Jones AQ, Dewey CE, Doré K, Majowicz SE, McEwen SA, Waltner-Toews D, Henson SJ, Mathews E. A qualitative exploration of the public perception of municipal drinking water. Water Policy 2007;9:425–38.

Kenny DA, McCoach DB. Effect of the number of variables on measures of fit in structural equation modeling. Structural Equation Modeling 2003;10(3):333–51.

Levallois P, Grondin J, Gingras S. Evaluation of consumer attitudes on taste and tap water alternatives in Quebec. Water Science and Technology 1999;40(6):135–9.

Levin DM. Modernity and the hegemony of vision. Berkeley: University of California Press; 1993.

Mackey ED, Baribeau H, Crozes GF, Suffet IH, Piriou P. Public thresholds for chlorinous flavors in U.S. tap water. Water Science and Technology 2004;49:335–40.

McCullagh P, Nelder JA. Generalized linear models. London: Chapman and Hall; 1989.

McGuire MJ. Off-flavor as the consumer's measure of drinking water safety. Water Science and Technology 1995;31:1–8.

Mintel. Bottled water report. *Cit. in* FoodNavigator. Bottled water growth shows no sign of slowing (available at http://www.foodnavigator.com/news/news.asp?id-8018; accessed 2005-01-20); 2003.

Moskowitz H, Krieger B. The contribution of sensory liking to overall liking: an analysis of six food categories. Food Quality and Preference 1995;6:83–90.

Perneger TV. What's wrong with Bonferroni adjustments? British Medical Journal 1998;316:1236–8.

Poortinga W, Pidgeon NF. Trust in risk regulation: cause or consequence of the acceptability of GM food? Risk Analysis 2005;25(1):199–209.

Sapsford R. Survey research. London: Sage Publications; 1999.

Saris W, Stronkhorst H. Causal modelling in non-experimental research. Amsterdam: Sociometric Research Foundation; 1984.

Syme GJ, Williams KD. The psychology of drinking water quality: an exploratory study. Water Resources Research 1993;29(12):4003–10.

Tarr JA, Jacobson C. Environmental risk in historical perspective. In: Johnson BB, Covello VT, editors. The social and cultural construction of risk. Dordrecht: Reidel Publishing Company; 1987. p. 317–44.

Walls J, Pidgeon N, Weyman A, Horlick-Jones T. Critical trust: understanding lay perceptions of health and safety risk regulation. Health, Risk and Society 2004;6 (2):133–50.

Young WF, Horth H, Crane R, Ogden T, Arnott M. Taste and odour threshold concentrations of potential potable water contaminants. Water Research 1996;30:331–40.