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Sweet liking predicts liking and familiarity of some alcoholic beverages, but not alcohol intake: A population study using a split-sample approach

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A B S T R A C T

Sweetness has been proposed to be an important quality in the decision to consume alcohol, and strong preferences for sweet tastes have been associated with alcohol abuse. However, alcohol is characterized by a number of other sensory properties, including astringency and bitterness that may drive preference and consumption. Spinelli et al. (2021) classified individuals into three sweet-sensory liking clusters (High Sweet-Liking, Moderate Sweet-Liking, and Inverted-U) that differed in their sweetness optima and sensory-liking patterns (relationship between liking and sweetness, bitterness and astringency perception in a food model). The current paper replicates the sweet sensory-liking clusters in a new set of participants (n = 1976), and extends the predicted value of these clusters examining their relationship to wine and other types of alcoholic beverages by gender using a split-sample approach on a total of over 3000 adults. The sweet sensory-liking clusters had a predictive relationship for the familiarity and liking of some alcoholic beverages characterized by stronger tastes, but not weekly alcohol intake levels. Thus, although sweet sensory-liking clusters may be associated with the type of beverages and frequency with which a person will drink and enjoy a type of alcoholic beverage, they are poor predictors of the quantity of alcohol that a person ingests over the course of a week.

1. Introduction

Alcoholic beverages, historically and across cultures, are humanity's most enduring psychoactive substances. For example, more than 85% of US consumers over the age of 18 indicate that they have used alcohol at some point during their lives (SAMHSA - Center for Behavioral Health Statistics and Quality, 2019). In particular, wine has been an important drink for more than 6,000 years (McGovern et al., 2017). While wine is often associated with celebrations and pleasure (Ferrarini et al., 2010) and is a part of the social fabric of everyday life (Silva et al., 2017), it is also an essential component of the Mediterranean diet, where it represents more than one fourth of total consumption of alcoholic beverages in the World Health Organization European Region (29.8%). Wine consumption has increased over the last decade in Europe, with the highest level of intake in Italy (64.8%; WHO, 2018).

From the perspective of sensory properties, wines – like many other foods and beverages – are complex mixtures of odor volatiles, sweet, sour and bitter taste qualities, and other oral sensations such as astringency and pungency (e.g., the 'bite' of alcohol). Individual variations in both perception and preference for food and beverage sensory properties have been identified and it is likely that such variations translate to differences in intake (Liem & Mennella, 2002; Mennella, 2014). For example, preference for sweet tastes varies widely among individuals (Iatridi et al., 2019), even though sweetness *per se* is innately liked (Steiner, 1979). Such variations in sweet-liking may be mediated genetically (Keskitalo et al., 2007; Mennella et al., 2016), although at least one twin study has failed to corroborate such links (Greene et al., 1975). Gender differences have also been reported in sweet-liking, with men preferring higher levels of sweetness in food and beverages than women (Yeomans et al., 2007) but other results are not as conclusive (Tuorila et al., 2017). Instead, women have been found to consume more sweet and fat and sweet and sour foods, compared with men (Van Langeveld et al., 2018).

Typically on the basis of responses to sweet solutions, three clusters of preferences for the optimal sweetness of taste solutions have been identified (Armitage et al., 2021; Iatridi et al., 2019): high sweet-liking (increased liking as sweetness increases), low sweet-liking (liking decreases as sweetness increases), and an inverted U function (optimal

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liking at moderate sweetness concentrations). Similar clusters of individuals have been identified based on liking for the sweetness of foods (Kim et al., 2014), while a recent study identified individuals with different patterns of sweet liking for sweetness based on correlations between sensory and hedonic responses to a chocolate food model in which the sucrose content was varied (Spinelli et al., 2021). This study showed that the identified sweetness sensory-liking clusters were predictive of liking for phenol-rich beverages and foods, such as vegetables and chocolate, that differed in bitterness/sweetness. It is possible that these sensory-liking clusters might also shed light on the consumption of other foods and beverages, such as alcoholic beverages characterized by different level of sweetness and bitterness. Given the considerable biological evidence that alcohol and sweet preferences share neurological underpinnings (Fortuna, 2010; Lemon et al., 2004), it is important to examine the relationship between the two.

Patterns of sweet liking have been linked to alcohol use and consequently have been put forward as a candidate genetic endophenotype associated with both alcoholism and alcohol use disorder (AUD) recovery (e.g., Bouhlal et al., 2018; Garbutt et al., 2009; Kampov-Polevoy et al., 1999; Salvatore et al., 2015). Thus, alcoholic men are more likely to be sweet likers than sweet dislikers (Kampov-Polevoy et al., 1999), raising the possibility that sweet liking could be a predictor of alcohol use or potentially alcohol-related disorders. However, some studies did not confirm these results (Kranzler et al., 2001; Scinska et al., 2001; Tremblay et al., 2009). The few studies on the relationship between sweet liking status and alcohol preference in non-dependent individuals provide only limited support for a positive association (Lanier et al., 2005; Robb & Pickering, 2019) and suggest moreover that this may be specific to particular types of beverages. Furthermore, in one study, scotch intake was predicted by higher sweet and lower bitter intensity perception (Lanier et al., 2005), while other data indicate that greater perceived sweetness in ethanol was associated with increased drinking frequency of wine, but was negatively associated with intake of straight spirits (Nolden & Hayes, 2015).

Studies that have explored the relationship between sweet liking and alcohol intake in non-dependent subjects have typically used relatively small participant samples, consisting mainly of university students. This means that the range of alcohol types is necessarily limited, especially with regard to wine. Research with a wider, more diverse and larger participant sample is therefore a prerequisite to effectively demonstrating whether sweet liking could be a phenotypical marker of alcohol intake in the general population.

Being able to predict the sensory determinants of alcohol preferences or intake also means considering other sensory qualities besides sweetness. Indeed, alcohol elicits a number of oro-sensory properties, including bitterness and astringency (Nolden & Hayes, 2015), that may be related to alcohol intake. For example, people who perceive the bitterness of the most commonly used index of taste responsiveness, 6-n-propylthiouracil (PROP), most intensely experience greater bitterness from alcohol than do PROP nontasters (Bartoshuk, 1993), and this may be reflected in the fact that PROP tasters consume fewer alcoholic beverages overall than do non-tasters (Duffy et al., 2004; Nolden & Hayes, 2015; Pickering & Thibodeau, 2021; Snyder et al., 2010). It is likely that the ability to perceive sensory qualities in a complex flavor matrix interacts with other individual, environmental, and social factors to produce variations in alcohol consumption (Pereira & van der Bilt, 2016).

Individual differences in age, body mass index (BMI), and gender are additional factors that have been shown to affect alcohol intake levels (Colditz et al., 1991; Cummings et al., 2017; Kampov-Polevoy et al., 2004; Prescott et al., 1999). Daily alcohol consumption increases with age (Eurostat, 2022). Though heavy episodic drinking peaks in the age group of 20–24 years, AUD is generally less prevalent in older individuals (Johnson, 2000). In addition to age, other demographic variables play a role in alcohol consumption. Those with a higher BMI consume alcohol less frequently than those with a lower BMI (Colditz et al., 1991; Gearhardt & Corbin, 2009), a finding that has led to a hypothesis that food and alcohol may share reward pathways and thus engage in a caloric competition (Cummings et al., 2017). Men typically consume alcohol more frequently and in larger quantities than do women, and are also less likely to be abstinent (Hasin et al., 1990; Regier et al., 1990; Warner et al., 1995; Wilsnack et al., 2000), though there are some studies in which these patterns are not observed (Bratberg et al., 2016; Robb & Pickering, 2019). Such gender differences are certainly related to cultural aspects (Bloomfield et al., 2006; Gefou-Madianou, 1992) and it is well known that the gender difference in alcohol consumption is generally greater where there is greater gender inequality (Wilsnack et al., 2009). Furthermore, these differences could arise also due to the greater negative biological consequences that women tend to suffer from alcohol consumption as compared to men (Nolen-Hoeksema & Hilt, 2006), and they could also be related to the fact that there are gender differences in sweet preferences (Yeomans et al., 2007).

In order to understand preferences and intake of wine and other alcoholic beverages, there is a clear need to link them to preferences for tastes and other sensory qualities while simultaneously considering other individual factors that have been linked to alcohol intake. The present study provides a comprehensive examination of multiple factors potentially affecting alcohol consumption and preferences, including sensory perception and sweet liking, in a large cohort. This approach has the advantage of examining the relative contribution of a variety of factors in combination, rather than as separate factors. The present data are derived from the general population and thus differ from much other research in this area. The main question that we addressed was whether differences in sweet sensory-liking patterns (taking into account BMI, gender, and age) affect the consumption, familiarity, or liking of alcohol, particularly for the different types of wine. An additional objective was to determine if we could confirm the sweet sensory-liking clusters identified by Spinelli et al (2021) in a different sample of individuals.

2. Material and methods

2.1. Participants

The data analyzed in this paper were collected within the *Italian Taste* (IT) project, a nationally executed, large-scale study designed to explore the sensations, attitudes, and habits associated with food preferences and intake (Monteleone et al., 2017). The dataset included 3184 participants (1766 women) who ranged in age from 18 to 70 ($M = 38.53$, $SD = 12.9$) and BMI from 14.5 to 54.1, with an average BMI of 23.93 ($SD = 4.1$). Participants were recruited among individuals in the general population, 97.6% of whom self-reported their health as above 'fair', and 96.85% indicating that they had no present or past problems related to taste perception. Details of participant recruitment can be found in earlier publications of the *Italian Taste* study (Monteleone et al., 2017).

Participants were excluded from the study if they had lived in Italy for less than 20 years or if they were pregnant or breast-feeding at time of testing. All testing was in compliance with the Declaration of Helsinki, and was approved by the Ethics Committee of the University of Trieste (n. 64, 9.6.2015). Participants signed written informed consent documents in accordance with the Italian ethical requirements on research activities and personal data protection (Law Decree 30.6.03, 196).

2.2. Procedure

The information below represents a brief overview of the testing, as the complete details of the experimental procedure have already been published elsewhere (Cravero et al., 2020; Dinnella et al., 2018; Monteleone et al., 2017; Spinelli et al., 2021).

2.2.1. Sensory tests

Participants tasted four samples of chocolate pudding (CP) differing in sucrose concentration (38, 83, 119, 233 g/kg), presented in a

balanced order across respondents, over two different sessions. Participants rated their liking for the samples using the Labeled Affective Magnitude scale (LAM; Schutz et al., 2001) on one day, and used the General Labeled Magnitude Scale (gLMS; Bartoshuk, 2000) to rate the intensity of the sensory properties of the samples (sweetness, bitterness, astringency, overall flavor) on the subsequent day.

2.2.2. Familiarity and liking ratings for foods

The IT-Food Liking Questionnaire (IT-FLQ) and the IT-Food Familiarity Questionnaire (IT-FFQ) and were used to evaluate each participant's stated liking and familiarity with 184 randomly-presented food and beverage items. On the IT-FLQ, participants indicated their liking for these food and beverage items via a 9-point hedonic scale (1 = *extremely disliked, 5 = neither liked nor disliked,* 9 = *extremely liked,* Peryam & Pilgrim, 1957), with the option to report that they had never tasted the item (this option was treated as a missing value). On the IT-FFQ, the items were evaluated with a 5-point scale (1 = *I do not recognize it,* 2 = *I recognize it, but I have never tasted it,* 3 = *I have tasted it, but I do not drink it,* 4 = *I occasionally drink it,* 5 = *I regularly eat it*) which measure both familiarity with the item and frequency of consumption (4-–5) (Tuorila et al., 2001). Because the focus of the current paper involves alcohol and sweet taste, responses for 14 alcoholic beverages were selected that were either very high or very low in alcohol content. This includes blonde beer, dark beer, limoncello, grappa, amaro (digestif), whisky, alcoholic aperitif, non-alcoholic aperitif, and several wine varieties: dry and sweet spumante; red wine; white wine; white sparkling wine; sweet (dessert) wine. These products were selected among the most consumed alcoholic beverages among Italians in each category (ISTAT, 2014), to span the main sensory differences based on a preliminary study with consumers. Subjects (n = 188, 75.4% females; age range 19–68; mean age 40.1 SD 14.3) participated in a Check-All-That-Apply study to describe the sensory properties of these alcoholic beverages (presented as names, not tasted). The Correspondence Analysis on the data (Fig. 1) showed that the main differences between the samples were between white wine, sparkling white wine, sweet and dry spumante and light beer, characterized by milder flavors, and grappa, whisky, amaro, dark beer, red wine characterized by stronger flavors. Furthermore, some products were described by a more bitter flavor (dark beer, amari, whisky, grappa) compared to others characterized by sweeter flavors (limoncello, passito/sweet wine, sweet spumante, white wine).

2.2.3. Weekly intake of alcoholic beverages and added sugar in coffee

Participants self-reported through an online questionnaire information about their weekly intake of alcoholic beverages for beer (glasses/cans = 330 ml per week), wine (glasses = 125 ml per week), liquors/spirits (glasses = 40 ml per week), and aperitifs/cocktails (glasses = 100 ml per week). Participants also gave some indication of their level of sugar consumption by responding to the same online questionnaire as to the amount of sugar that they typically included in their coffee (spoons/sachets per cup).

2.2.4. Data analysis

In order to evaluate each hypothesis, the dataset was subject to a split-sample approach (Anderson & Magruder, 2017) in which participants were split into an exploratory sample [ES: 1208 participants (58.36% women, mean age = 35.50, SD = 12.86) analyzed in Spinelli et al. (2021)] and a confirmatory sample [CS: 1976 participants (58.69% women, mean age = 40.39, SD = 12.64)] so as to minimize Type I errors. All the analyses were repeated on data from both samples. The samples were observed to be different in a number of ways. Age class (18–29 years, 30–45 years, 46–60 years) distribution was statistically significantly different between the two samples [$\chi^2(2) = 110.19$, $p < .0001$], with the confirmatory sample on average older. Gender also differs between the two samples [$\chi^2(2) = 6.42$, $p = .011$]; though both samples included more women than men, the disparity was slightly greater for the ES. In addition, the average BMI was significantly higher in the CS [$t(2659) = 3.38$, $p < .001$].

Each participant's rating of the liking for the chocolate pudding samples was correlated with their ratings for the astringency, bitterness, sweetness, and overall flavor of the samples. K-means cluster analysis was performed on these correlation coefficients following the procedure described in Spinelli et al. (2021). Due to missing values (and in some cases no variability in ratings), data from 84 (ES) and 157 (CS)

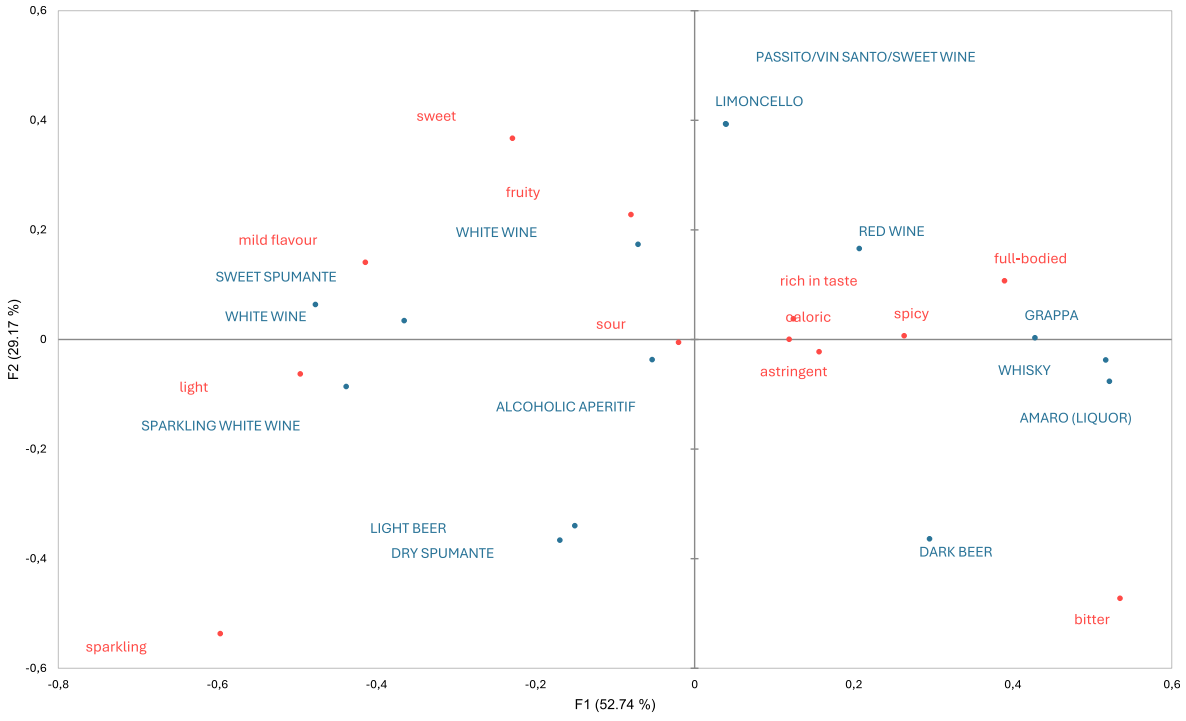

Fig. 1. Correspondence analysis biplot of the CATA results for the alcoholic beverages illustrating the sensory space of the samples evaluated.

participants were not considered in the cluster analysis. This number slightly differs from Spinelli et al (2021) in that the present analyses exclude 14 people who showed a lack of variability in their sweetness ratings.

Chi-square analysis was conducted to test for the effects of gender and age on the clusters, and a one-way ANOVA was used to determine if mean BMI was significantly different across sweet sensory-liking clusters. Because the key demographic variables of gender and age affected the sensory-liking clusters, we sought to control them in the examination of the relationship between the clusters and the other variables of interest. To account for gender, the sweet sensory-liking clusters were recalculated separately for each gender, and all further analyses were performed for each gender independently. Additionally, subsequent analyses included age and BMI as covariates. Though BMI was not significantly different by cluster, it was statistically significantly different across the two samples (ES and CS), and so was still included in all subsequent analyses.

Separate two-way analysis of variance (ANOVA) models were carried out for each gender that included BMI and age as factors to predict the amount of sugar (number of teaspoons) added to coffee by sweet sensory-liking cluster. When the ANOVAs showed a significant effect ($p < 0.05$), post-hoc comparisons were used with Bonferroni corrections to adjust for multiple comparisons.

The total amount of alcohol consumed was calculated by summing across the reported weekly alcohol intake (in number of servings) of the four types surveyed (Beer, Wine, Aperitifs, Spirits), an approach used in previous studies (see e.g. Lanier et al., 2005). This was done as the number of servings was reported in U.S. "standard" drinks that contains roughly 14 g of pure alcohol (NIAAA, 2022). People who did not consume alcohol [19.6% of the exploratory sample (71.6% female) and 21.4% of the confirmatory sample (75.2% female)] were not considered in this analysis, as our experimental questions concerned individuals who chose to consume alcohol in their lives. Using quartiles, the participants were categorized into low, moderate, or high frequency drinkers for each gender. Logistic regression was used to compare the high and low frequency drinkers across sweet sensory liking clusters, accounting for BMI and age. The analysis was repeated for wine intake only.

An ordinal regression was performed for each gender to assess the effect of sweet sensory-liking cluster on the familiarity score for each beverage, including BMI and age class as covariates. Non-parametric Kruskal-Wallis post-hoc tests with Bonferroni corrections were applied to further test significant differences.

ANCOVA models were conducted to test the effect of sweet sensory-liking clusters (with age class and BMI as covariates) on liking of alcoholic beverages for each gender. Tukey post-hoc tests were applied to further test significant differences.

3. Results

3.1. Validation and verification of sweet sensory-liking clusters

In an attempt to replicate published findings from the exploratory sample (ES; previously reported in Spinelli et al., 2021), the liking ratings for the chocolate pudding series were correlated with ratings of sweetness, bitterness, astringency and overall flavor in the confirmatory sample. A k-means cluster analysis based on correlation coefficients identified three clusters in the CS. Their mean values are shown in Table 1, which is annotated following the cluster naming convention delineated by Spinelli et al. (2021). In the high sweet-liking cluster (HSL; $n = 669$, 36.8%), liking was positively related to the intensity of sweetness and overall flavor, but inversely related to the intensity of bitterness and astringency. For the moderate sweet-liking cluster (MSL; $n = 703$, 38.6%), liking was positively related to only sweetness, and was negatively related to bitterness, astringency, and overall flavor. In contrast, the inverted u-shaped cluster (IU; $n = 447$, 24.6%) had liking ratings that were negatively weakly related to sweetness and to overall flavor (which differed from the ES slightly), but were positively related to bitterness, and astringency. Thus, the present results were similar in both the ES and CS in that three sweet sensory-liking (SSL) clusters were identified that differed in terms of optimum liking and pattern of sensory-liking that correspond to high sweet, moderate sweet, and inverted u-shaped patterns (see Table 1). This result therefore confirms the exploratory finding of sweet-sensory-liking clusters identified by Spinelli et al (2021) in a different sample of individuals.

3.1.1. Age, gender and body mass index in sweet sensory-liking clusters

The variables of age, gender, and BMI were explored in both the ES and the CS in separate analyses. Chi-square analyses demonstrated an association between gender and the sweet sensory-liking clusters in both the ES ($\chi^2(2) = 9.71$, $p = .007$) and the CS ($\chi^2(2) = 14.47$, $p = <0.001$). Women were more likely to be MSL in both the ES (44%) and the CS (41%), while men were more likely to be HSL in both the ES (44%) and the CS (41%). In addition to the differences in gender, age differences between the sweet sensory-liking clusters were also observed in one-way ANOVAs that were conducted for the ES [$F(2,1121) = 8.55$, $p < .001$] and the CS [$F(2,1121) = 3.98$, $p = .019$]. These ANOVAs demonstrated that people who were MSL tended to be younger than those who were HSL and IU in both the ES and CS. Thus, the sweet sensory-liking clusters were significantly affected by both of these demographic variables. One-way ANOVAs showed that mean BMI was not significantly different by sensory sweet-liking cluster in either the exploratory [$F(2, 1118) = 1.46$, $p = .23$] or confirmatory sample [$F(2, 1812) = 0.64$, $p = .53$].

3.1.2. Sweet sensory-liking clusters by gender

Having demonstrated that the sweet sensory liking clusters developed in Spinelli et al (2021) were replicated in the confirmatory sample, the data were re-analyzed for men and women separately. Fig. 2 below shows the similarities when examining mean liking score. While the patterns are very similar, some differences by gender emerged, with a lower liking for the sweetest sample for the Inverted U cluster in women, compared to men, and with a higher liking for this sample in the High Sweet likers in men. See Figure S1 (supplementary material) for a similar representation of sweetness, intensity of overall flavor, intensity of astringency, and intensity of bitterness of the four chocolate pudding samples.

The sweet sensory-liking clusters demonstrated relationships to sweet, astringency, and bitterness similarly to those found previously (Spinelli et al., 2021), despite using slightly different analyses than the earlier work. The separate repeated measure ANOVAs in the present

Table 1
Class centroids for each cluster in the exploratory sample (ES; similar to those previously published in Spinelli et al., 2021*) and confirmatory sample (CS**).

	Sweet		Bitter		Astringent		Flavor	
	ES	CS	ES	CS	ES	CS	ES	CS
High Sweet	0.766	0.719	−0.662	−0.592	−0.375	−0.284	0.580	0.563
Moderate Sweet	0.583	0.566	−0.711	−0.739	−0.487	−0.562	−0.571	−0.533
Inverted U-Shaped	−0.199	−0.310	0.335	0.370	0.324	0.241	0.123	−0.014

* 70 participants excluded for missing values and 14 participants excluded for a lack of response variability;
** 157 excluded for either missing values or no response variability.

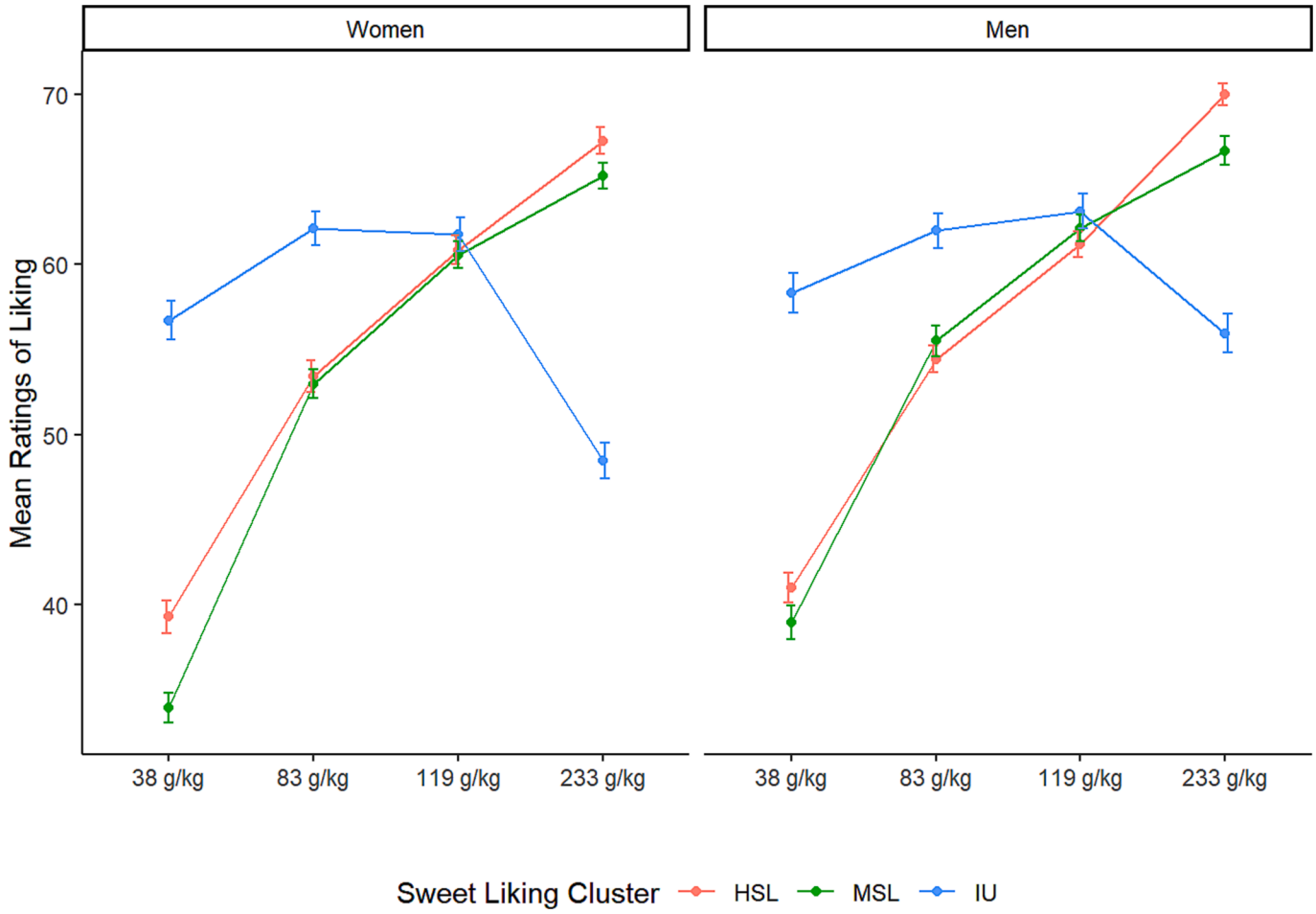

Fig. 2. Mean ratings of liking for the chocolate pudding samples with increasing sucrose concentrations across the sweet-sensory-liking clusters (HSL = High Sweet-Liking; MSL = Moderate Sweet-Liking; U = Inverted U-Shaped) and divided by gender in the exploratory sample (ES).

paper on the ratings of liking and sensory properties of the chocolate pudding samples (with age class and BMI included as covariates) revealed statistically significant differences by cluster over the pudding samples for both men and women in the exploratory sample. The strongest differences were for liking and overall flavor for both men and women, with the weakest differences by sweetness rating. All of these significant differences replicated in the confirmatory sample except for sweetness in women (see Table S1, supplementary material).

3.1.3. *Use of sugar by sweet sensory-liking clusters by gender*

We replicated the analyses on the self-reported amount of sugar in coffee that was performed by Spinelli et al. (2021) in the exploratory sample for both genders combined; as anticipated, the present results on the amount of sugar preferred in coffee by cluster match those already published (ES: $F = 13.385$, $p < .001$; CS: $F = 10.545$, $P < .001$). We then conducted separate analyses for both the men and the women in each sample with age class and BMI included as covariates, and this overall result was confirmed; significant differences were observed for the amount of sugar used in coffee consistently by gender and in both the ES and the CS sample, with High Sweet like that add more sugar than the Inverted-U shaped group (see Table S2, supplementary material).

3.2. *Sweet sensory-liking cluster relationships with weekly intake, liking, familiarity of alcohol with a focus on wine*

We examined the ability of the sweet sensory-liking clusters to predict three different variables (weekly intake, liking, and familiarity associated with alcohol beverages in the sections below. Each analysis of all alcoholic beverages is followed by an additional analysis that has a specific focus on wine.

3.2.1. *Sweet sensory-liking cluster relationships with weekly alcohol intake*

Among women 52,98% in the ES (51.46% in the CS) did not report to consume any beer, 43.32% any wine (40.85 in the CS), 77.27% (82.83% in the CS) any spirits, 53.63% (62.92 in the CS) any aperitif/fortified wines in a typical week. In men instead in a typical week only 28.14% in the ES (29.82% in the CS) did not report to consume any beer, 26.15% (23.03% in the CS) any wine, 59.48% (61.29% in the CS) any spirits, 55.49% (55.92% in the CS) in ES any aperitif/fortified wines. The total amount of alcohol consumed in a week was calculated by summing across the reported weekly alcohol intake of the four types surveyed (Beer, Wine, Aperitifs/fortified wines, Spirits). People who did not consume any alcoholic beverage [19.6% of the exploratory sample (71.6% female) and 21.4% of the confirmatory sample (75.2% female)] were removed from the samples for further analysis on weekly intake, given the focus of the study on participants' relationship with alcohol.

The quartiles for the exploratory sample (divided by gender) were used to determine the cutoffs for low, moderate and high drinkers. For women in the ES, the lower quartile was 2 and the upper quartile was 6, so those women who drank 2 or fewer drinks were notated as "low", and those women who drank 6 or more were categorized as "high" drinkers for both the ES and CS. For men, the exploratory sample had a lower quartile of 3 ("low") and an upper quartile of 10 ("high") and these cutoffs were used to designate the men in the CS as well. The distribution of alcohol intake groups for men and women in both the exploratory and confirmatory samples is shown in Table S3 (supplementary material).

The distribution of sweet sensory-liking clusters in both sample sets is presented separately for each gender in Table S4 (supplementary material), and is separated by alcohol intake groups. To examine the effect of sweet sensory-liking clusters on alcohol intake, a logistic regression was performed to predict the alcohol intake group (either low or high) by sweet sensory-liking cluster, with age class and BMI as covariates. To maximize potential differences, only the low consumption and high consumption groups were compared, leaving out the medium consumption group. While sweet sensory-liking cluster was a significant predictor of alcohol intake for men in the exploratory sample ($\chi^2(2) = 12.12$, $p = .002$), this did not hold for men in the confirmatory sample ($\chi^2(2) = 1.58$, $p = .455$). For women, sweet sensory-liking cluster was not a significant predictor of alcohol intake group for either sample (Exploratory: $\chi^2(2) = 3.07$, $p = .215$, Confirmatory: $\chi^2(2) = 2.34$, $p = .310$). This indicates that patterns of sweet sensory-liking are not related to alcohol intake when all of the types of alcohol were evaluated together. Neither BMI nor age was significant as a covariate for any sample or gender.

3.2.2. Sweet sensory-liking cluster relationships with weekly wine intake

The above analysis was repeated, this time restricting the data solely to wine intake. Those who did not drink wine were removed from the data set [36.4% of the exploratory sample (69.8% female) and 32.7% of the confirmatory sample (67.1% female)], then the ES was used to determine the cutoffs for low, moderate and high intake wine drinkers. For both the ES and CS sample for women, the lower quartile was 1 drink per week and the upper quartile was 3 drinks per week; so, those women who drank one or fewer glasses of wine per week were notated as "low" and those women who drank 3 or more were categorized as "high" drinkers for both samples. For men, the ES had a lower quartile of 2 ("low") and an upper quartile of 5 ("high"), which were also used as the cut-offs for the CS. The distribution of wine intake for men and women in both the exploratory and confirmatory samples is shown in Table S5 (supplementary material).

To examine the effect of sweet-liking cluster on wine intake, a logistic regression was again performed to predict either high or low intake of wine based on sweet sensory-liking cluster, age class, and BMI. Sweet sensory-liking cluster was not a significant predictor of weekly wine intake for either men or women in either sample (Table S6, supplementary material).

However, the covariate of age was significant for both samples for men (Exploratory: $\chi^2(2) = 9.21$, $p = .010$, Confirmatory: $\chi^2(2) = 39.51$, $p < .001$). In both samples, there is a higher proportion of older individuals classified as high intake wine drinkers than the other age classes. For the exploratory sample, 51.6% of high intake drinkers were in the oldest age class (46–60 years), versus only 32.9% of low intake wine drinkers; for the confirmatory sample, 72.3% and 42.9% were in the oldest age group for high intake and low wine intake drinkers respectively. For women, this effect only held in the confirmatory sample ($\chi^2(2) = 8.37$, $p = .015$) and not in the exploratory sample. The covariate of BMI did not vary significantly across sample or gender.

3.2.3. Sweet sensory-liking cluster relationships with familiarity of all alcoholic beverages

Each participant gave a familiarity score for each alcoholic beverage on a 5-point familiarity scale and an ordinal regression was performed that included BMI and age class as covariates (Table 2). SSL clusters had a significant effect on the familiarity scores for dark beer and for dessert wine for men in both the exploratory and confirmatory samples. Men SSL clusters in the exploratory sample also had significant effects on red wine, grappa, and whisky, but these effects did not hold in the confirmatory sample. For women, SSL clusters had a significant effect on the familiarity scores for dark beer, grappa, dessert wine, and whisky in both samples. In all cases, post hoc tests revealed that the familiarity scores of the IU sweet liking cluster were significantly higher than either the Moderate Sweet Likers, High Sweet Likers, or than both other groups. Age class was a replicated significant covariate for dessert wine, grappa and whisky for the women, and for grappa and dessert wine for the men, whereas BMI was only significant for grappa for men in both samples (with higher familiarity associated with a higher BMI), and was not significant for any of the beverages in Table 2 for the women.

3.2.4. Sweet sensory-liking cluster relationships with liking of all alcoholic beverages

ANCOVAs were conducted in order to explore whether sweet sensory-liking clusters predict ratings of liking of alcohol first in the ES and then the CS, in women and men separately (Tables 3 and 4). The IU sweet sensory-liking cluster reported a significantly higher liking for dark beer and grappa in women (Table 3), and for dry spumante, grappa (close to significance) and whisky in men (Table 4).

Liking was higher in the older men for dry spumante and grappa, but also for red and white wine while it was lower for sweet spumante in this age group (both in the ES and the CS). BMI was never significant in men, except for a positive correlation for liking of grappa and whisky in ES partially confirmed in CS (only a trend was observed in CS for grappa, but in the same direction of the ES).

For women we did not observe any effect of BMI on liking both the ES and CS, while we found an effect of age on sweet spumante and alcoholic aperitif confirmed in ES and CS, with young women that expressed a higher liking for these two products compared to older women.

Table 2
Ordinal regression to predict familiarity of alcoholic beverages in both the exploratory (ES) and the confirmatory (CS) sample by gender. The effect of sweet sensory-liking cluster (χ^2 test statistic and p-value) is reported, with age class and BMI included as covariates.

	Women				Men			
	ES		CS		ES		CS	
Beverage	χ^2	*p*-value	χ^2	*p*-value	χ^2	*p*-value	χ^2	*p*-value
Light Beer	0.65	0.722	11.22	**0.004**	3.53	0.172	2.24	0.326
Dark Beer	6.65	**0.036**[a]	7.41	**0.025**[b]	8.47	**0.014**[a]	10.32	**0.006**[a]
Dry Spumante	0.16	0.922	1.54	0.463	1.41	0.495	3.28	0.194
Sweet Spumante	3.06	0.217	1.38	0.501	1.67	0.434	4.10	0.129
Red Wine	1.23	0.542	1.65	0.438	6.63	**0.036**	3.00	0.224
White Wine	0.55	0.761	2.06	0.358	3.82	0.148	4.09	0.129
White Sparkling Wine	0.37	0.832	0.41	0.815	0.28	0.869	4.05	0.132
Limoncello	1.00	0.606	4.14	0.126	0.64	0.725	0.95	0.623
Grappa	8.14	**0.017**[a]	7.25	**0.027**[ab]	11.50	**0.003**[**a]	2.58	0.276
Amaro Digestif	0.25	0.884	1.85	0.397	2.74	0.254	1.32	0.516
Dessert Wine	10.96	**0.004**[ab]	8.48	**0.014**[a]	6.40	**0.041**[a]	17.90	**<0.001**[ab]
Whisky	7.47	**0.024**[a]	15.96	**<0.001**[ab]	18.59	**<0.001**[ab]	3.73	0.155
Alcoholic Aperitif	3.97	0.137	2.22	0.329	1.36	0.506	1.59	0.451

[a]Group IU significantly higher than group MSL in the post hoc test. [b] Group IU significantly higher than HSL in the post hoc test.

Table 3
Sweet sensory-liking cluster relationships with liking of all alcoholic beverages, including wine, for women in the exploratory (ES) and the confirmatory samples (CS). Table shows results (*F, p*) of ANCOVA, as well as the means for Sweet Sensory-Liking clusters for that test. Significant results are shown in bold.

	Exploratory Sample					Confirmatory Sample				
	F	*p*	HSL	IU	MSL	*F*	*p*	HSL	IU	MSL
Light Beer	0.12	0.888	6.260	6.306	6.202	**2.99**	**0.051**	**6.168^{a}**	**6.614^{a}**	**6.158^{a}**
Dark Beer	**3.38**	**0.035**	**5.370^{ab}**	**5.931^{a}**	**5.298^{b}**	**4.40**	**0.012**	**5.244^{b}**	**5.866^{a}**	**5.353^{ab}**
Dry Spumante	1.15	0.316	5.546	5.886	5.536	0.50	0.605	5.629	5.800	5.618
Sweet Spumante	2.74	0.065	6.279	5.791	5.839	**3.34**	**0.036**	**5.773^{ab}**	**5.397^{b}**	**5.935^{a}**
Red Wine	0.21	0.808	6.528	6.432	6.454	0.39	0.677	6.484	6.508	6.357
White Wine	0.42	0.658	6.119	6.259	6.033	0.03	0.970	6.111	6.123	6.152
White Sparkling Wine	0.82	0.443	6.311	6.223	6.060	0.97	0.381	6.139	5.970	6.262
Limoncello	0.29	0.748	5.683	5.479	5.594	0.75	0.473	5.718	5.711	5.546
Grappa	**3.59**	**0.028**	**3.220^{ab}**	**3.725^{a}**	**2.982^{b}**	**4.44**	**0.012**	**3.573^{ab}**	**3.916^{a}**	**3.301^{b}**
Amaro Digestif	0.65	0.523	4.411	4.606	4.340	1.10	0.332	4.527	4.610	4.329
Dessert Wine	0.99	0.371	6.196	6.151	5.878	0.57	0.563	5.982	6.202	6.018
Whisky	**4.75**	**0.009**	**3.141^{ab}**	**3.594^{a}**	**2.873^{b}**	2.08	0.126	3.179	3.493	3.104
Alcoholic Aperitif	0.34	0.709	5.906	5.854	6.171	**6.43**	**0.002**	**6.021^{b}**	**6.610^{a}**	**6.503^{a}**

^{ab} Different letters indicate a significant difference in Tuckey post hoc test ($p < 0.05$).

Table 4
Sweet sensory-liking cluster relationships with liking of all alcoholic beverages, including wine, for men in the exploratory (ES) and the confirmatory samples (CS). Table shows results (*F, p*) of ANCOVA, as well as the means for Sweet Sensory-Liking clusters for that test. Significant results are shown in bold.

	Exploratory Sample					Confirmatory Sample				
	F	*p*	HSL	IU	MSL	*F*	*p*	HSL	IU	MSL
Light Beer	**4.58**	**0.011**	**7.317^{ab}**	**7.523^{a}**	**6.907^{b}**	1.42	0.241	7.065	7.307	7.183
Dark Beer	4.75	0.009	6.465	6.966	6.200	2.41	0.091	6.335	6.595	6.169
Dry Spumante	**10.40**	**<0.001**	**6.051^{b}**	**7.195^{a}**	**6.115^{b}**	**3.37**	**0.035**	**6.260^{ab}**	**6.658^{a}**	**6.151^{b}**
Sweet Spumante	0.78	0.461	6.116 a	6.000 a	5.920 a	1.64	0.194	5.914 a	5.652	6.030
Red Wine	**4.04**	**0.018**	**7.382^{b}**	**7.932^{a}**	**7.195^{b}**	1.82	0.162	7.284	7.572	7.215
White Wine	2.34	0.097	6.772	7.047	6.497	4.80	**0.008**	**6.625^{b}**	**7.080^{a}**	**6.545^{b}**
White Sparkling Wine	0.01	0.992	6.374	6.398	6.425	0.07	0.930	6.388	6.421	6.350
Limoncello	0.94	0.390	6.442	6.455	6.218	0.45	0.638	6.302	6.328	6.188
Grappa	**4.32**	**0.014**	**5.144^{b}**	**5.897^{a}**	**4.860^{b}**	**2.97**	**0.052**	**5.216^{a}**	**5.712^{a}**	**5.344^{a}**
Amaro Digestif	1.84	0.160	6.020	6.184	5.757	1.15	0.318	5.874	6.070	5.798
Dessert Wine	2.39	0.093	6.800	7.193	6.622	1.84	0.160	6.647	6.731	6.354
Whisky	**8.76**	**0.0002**	**4.909^{b}**	**5.816^{a}**	**4.609^{b}**	**6.11**	**0.002**	**4.840^{b}**	**5.457^{a}**	**4.736^{b}**
Alcoholic Aperitif	1.26	0.285	6.601	6.466	6.387	1.57	0.208	6.154	5.874	6.129

^{ab} Different letters indicate a significant difference in Tuckey post hoc test ($p < 0.05$).

4. Discussion

While there is a body of literature that predicts an inverse relationship between the amount of alcohol and the amount of sweet high-fat food consumed (Cummings et al., 2017) and many studies that do not report any significant relationship between alcohol consumption and sweet liking (Kranzler et al., 2001; Scinska et al., 2001; Tremblay et al., 2009), other work predicts a positive relationship between alcohol consumption and sweet foods, due to the impaired eating control associated with alcohol (Kampov-Polevoy et al., 2003, 2006). The present study examined the related question of the relationship between the well-established trait of sweet liking and the weekly intake, consumption/familiarity of, and liking for, different types of alcohol in a non-clinical adult population. Thus, this sample differs considerably from other research in this area that mainly focused on those with alcohol dependence. A major strength of the study was the use of two separate participant samples, one exploratory and one confirmatory. For both samples, three previously established (Spinelli et al., 2021) sweet sensory liking clusters (SSL) – Moderate Sweet Likers (MSL), High Sweet Likers (HSL), and Inverted U-shaped (IU) liking – were confirmed, as were their characteristic sensory responses to sweet, bitter and astringent qualities. Furthermore, the present study confirmed the association of these SSL clusters with variations in added sugar to coffee, thus indicating that although defined based on a chocolate food model they are indicative of more general habits related to the consumption of sugar.

Despite the large sample sizes involved, the present data do not provide any real evidence in either direction for a relationship between sweet liking and alcohol weekly intake in general, nor wine in particular. The situation is somewhat different, however, when considering alcohol familiarity and liking. Familiarity suggests a willingness to sample, even if liking and regular consumption do not necessarily follow, and may therefore be indicative of greater openness to new flavors, even those that might be considered aversive (bitterness, pungency, etc.). Higher familiarity was evident in both samples for the IU cluster for several mostly strongly flavored alcoholic beverages (dark beer, which is typically bitter; grappa and whisky, both highly pungent spirits; dessert wines, which are intensely sweet). These effects are consistent across samples for women, but for men the effects on grappa and whisky only held for the ES. It should also be noted that the familiarity scale that was used has the two highest items that measures frequency of consumption (4 = occasional and 5 = regular consumption), so higher familiarity also reflects roughly a higher frequency of consumption of these alcoholic beverages in the IU cluster.

Interestingly, as with familiarity, the effects for liking were not observed on all the alcoholic beverages that were examined, but instead seem to affect only those with more intense, bitter or irritating tastes. Measures of liking reflected the same trends for the IU group showing significantly higher liking of this cluster for dark beer and grappa in women, and for dry spumante, grappa and whisky in men. These findings for the IU cluster are consistent with the characteristics of this group, namely that their liking for the test food (chocolate pudding) is negatively weakly related to sweetness, but positively related to bitterness, and astringency. Also evident are distinct group previously

identified differences in personality characteristics; thus, particularly when compared to the Moderate Sweet Liker group, the IU cluster tends to be less sensitive to punishment (Spinelli et al., 2021). One indication of such a characteristic is lower negative responsiveness to bitterness and other 'aversive' characteristics, as indicated by the fact that they add less sugar to coffee than other sweet liker groups. This group also shows lower disgust sensitivity, and they also tend to rate tastes and oral sensations (PROP, bitter, umami, pungency) as less intense (Spinelli et al., 2021).

These results therefore suggest that it is not sweetness liking alone that may drive alcohol liking but also bitterness and other often hedonically-negative qualities that have previously been labeled as warning sensations because of their potential links to toxicity (Laureati et al., 2018; Thibodeau & Pickering, 2019). This reflects the fact that our SSL clusters were built on correlations between liking and all the target sensations, not only sweetness, and is in contrast to more commonly used methods to define sweet liker phenotypes (Iatridi et al., 2019). Thus, our clusters also differ in their perception of the chocolate samples, particularly the most bitter sample, which is perceived as more bitter and astringent by the MSL compared to the other two clusters, while the IU group reports higher sweetness intensity for the samples.

These findings are therefore consistent with the hypothesis proposed by Lanier et al. (2005) that suggests a role of both bitterness and sweetness sensitivity in alcohol consumption. As a corollary, these data imply that for a majority of alcoholic beverages that are not highly pungent or noticeably bitter, factors other than sensory characteristics are more relevant for the development of liking. For example, it is well known that context and social aspects play an important role in alcohol consumption (Pavis et al., 1997). This may also explain why we are not observing an effect on total alcohol consumption. If sweet liking affects liking and consumption of certain type of beverages, but not others, based on sensory properties, a sweet liker may prefer less bitter and alcoholic beverages to grappa and whisky, or dark beer, but still consume beer and spirits with a milder taste in a similar amount compared to an IU individual. The functional role of taste is well known (Forde & de Graaf, 2023) and there is evidence that mechanisms of flavour-consequence learning may promote liking for alcoholic beverages based on their postingestive reinforcement through the positive effects associated with alcohol (Yeomans, 2006). However, while this has been largely shown in rats (Ackroff et al., 2004; Ackroff & Sclafani, 2002), studies on humans are elusive, probably also for the role that the individual differences in taste responsiveness may have impacting on the effectiveness of the mechanisms.

More generally, as noted by Parr and colleagues in relation to wine consumption (Parr & Rodrigues, 2019; Rodrigues & Parr, 2019), culture is the strongest determinant of food and beverage choices (Rozin & Fallon, 1986; Rozin & Vollmecke, 1986). It is perhaps not surprising therefore that we do not observe associations between sweet sensory-liking phenotypes and wine liking or consumption in this Italian sample. While sensory aspects may guide preferences *within* the wine category (Bruwer et al., 2011) not explored here, other motivational factors guide consumption and liking of wine as a product (Parr & Rodrigues, 2019; Urdapilleta et al., 2021), especially in a country such as Italy where it is so deeply part of the food identity and where wine is the 64.8% of the recorded alcohol consumption (WHO, 2018).

With such large, independent samples, it is worth considering the role of demographic factors such as age and gender. Cultural factors also explain the age effects noted in these data sets. The fact that the data set was able to identify an expected positive association between wine consumption and age does suggest that this data set as a whole was sensitive to variations in consumption patterns that occur with age (see also Cravero et al., 2020). For example, evidence of traditional patterns of liking was evident for the older men in their greater appreciation of dry spumante and grappa, and for red and white wine, while liking for sweet spumante was lower in this age group (both in the ES and the CS). An age effect was also evident with a consistent finding across both data sets that young women are more likely than their older counterparts to like sweet spumante and alcoholic aperitif drinks. These may indicate either a generational change in drinking habits, or the fact that sweeter wines may be a "stepping stone" to drier or more robustly flavoured styles.

In line with reports of WHO and Eurostat (Eurostat, 2022; WHO, 2018), we observed quite large differences in alcohol intake between men and women, with abstinence rates in a typical week at 12% and 25%, respectively. Men also showed higher percentages of moderate and high intake. The lower intake in women should also be considered in the light of the fact that we classified intake based on the quartiles calculated by gender. Thus, to be classified as a high drinker, a man had to consume 10 or more drinks per week, in contrast to 6 drinks per week for women. These cut-offs are much lower than the cut-off values used by the US National Institute on Alcohol Abuse and Alcoholism (NIIIA) to classify heavy drinkers (with 15 or more and 8 or more drinks per week in men and women, respectively), indicating once again that the Italian Taste sample is very different from previous samples focused on individuals with a history of heavy alcohol use. However, although the differences in alcohol consumption by gender are wide, we did not observe large gender differences in the way in which sweet liking affected familiarity and liking of alcoholic beverages. For both women and men, SSL patterns were associated with familiarity and liking with beverages stronger in tastes.

5. Conclusions

This study examines the relationship between sweet sensory-liking patterns and alcohol intake, consumption, familiarity and liking in an exploratory and in a confirmatory sample of non-clinical adult population. The sweet sensory-liking clusters were able to predict the familiarity and liking of some alcoholic beverage, but not weekly intake levels neither in men or in women. Individuals characterized by an inverted-U shape pattern (that like moderate levels of sweetness) are more familiar, consume more and like more some alcoholic beverages characterized by a stronger bitter and astringent taste, compared to sweet likers. Although sweet sensory-liking clusters may be associated with the type of beverages and frequency with which a person will drink and enjoy a type of alcoholic beverage, they are poor predictors of the quantity of alcohol that a person ingests over the course of a week.

CRediT authorship contribution statement

S. Spinelli: Conceptualization, Methodology, Formal Analysis, Visualization, Writing - Original draft. **C. Cunningham:** Formal Analysis, Methodology, Visualization, Validation, Writing - Original draft. **J. Prescott:** Writing – review & editing. **E. Monteleone:** Writing – review & editing, Project administration, Methodology, Conceptualization. **C. Dinnella:** Writing – review & editing, Investigation. **C. Proserpio:** Writing – review & editing, Investigation. **T.L. White:** Conceptualization, Methodology, Visualization, Writing – original draft.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Data availability

Data will be made available on request.

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Ethics Declaration

All procedures were in accordance with the ethical standards of the responsible committee on human experimentation (institutional and national) and with the Helsinki Declaration of 1975, as revised in 2008. Informed consent was obtained from all participants included in the study. The study was approved by the Ethics Committee of the University of Trieste (n. 64, 9.6.2015).

Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.foodres.2024.114155.

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