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Pour Guess: The effect of glass shape and an ice substitute on alcohol pouring and estimation.

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**Abstract**

Background: Research suggests that people are poor at estimating the amount of alcohol they have served themselves. Glass shape, the presence of ice, and alcohol consumption may influence the amount of alcohol people pour and estimate they have poured. The aim of these studies was to examine whether these factors would affect pouring behaviour, in the laboratory and in real world environments.

Methods: Across four studies, one laboratory study and three conducted during public engagement events, we tested the effect of glass shape (straight sided highball and tumbler glasses) and, using an ice substitute (whiskey stones), the effect of ice on pouring and estimating a self-defined typical drink. We also assessed the association between alcohol consumption and pouring accuracy.

Results: Overall, participants consistently overestimated their typical serving of alcohol, and poured more than one UK unit when pouring into an empty glass. Findings demonstrate no credible effect of glass shape or ice substitute on alcohol unit estimation or the amount of a typical serving. However, while alcohol consumption was not related to accuracy, presence of an ice substitute improved accuracy when pouring a single UK unit.

Conclusions: Given that participants overestimated the amount of alcohol in their typical alcoholic drink, self-report measures of alcohol consumption may be overstating the amount of alcohol individuals consume. Additionally, the presence of ice may improve accuracy when pouring standard servings (UK Units) of alcohol. Therefore, self-report measures may be improved if the presence of ice is considered.

Key Words: Alcohol Pouring, Alcohol units, Alcohol estimation, Self-report measures, accuracy

**Introduction**

Many countries have developed alcohol guidelines to ensure standardised monitoring of alcohol consumption (Kalinowski and Humphreys, 2016). Within the UK, these guidelines are communicated as alcohol ‘units’ with one UK alcohol unit equating to 8g of pure alcohol (Department of Health, , 1995). Currently, UK guidelines propose that both men and women should not exceed 14 alcohol units per week (Department of Health, , 2016). Recent research suggests over 80% of drinking occasion include at least some alcohol consumption at home (Ally et al., 2016), therefore, to adhere to such guidelines, people must be able to accurately assess how much alcohol they have served themselves. However, people often serve themselves more than a unit or a standard drink when asked to pour their usual serving or when asked to pour a standard drink (for reviews see; Boniface et al., 2013, Schultz et al., 2017). Moreover, individuals are poor at estimating how much alcohol they have served themselves; with one study suggesting that people tend to underestimate the number of units they have poured (Wilkinson et al., 2011) and another, from the UK, reporting a tendency to overestimate the number of alcohol units poured (Boniface et al., 2013).

Perceptual factors may also affect people’s ability to monitor their alcohol use. For example, glass shape may affect how much alcohol people pour and estimate that they have poured. Indeed, participants have been shown to pour more liquid into tall thin ‘highball’ glasses than short wide ‘tumbler’ glasses when attempting to pour a ‘shot’ of alcoholic spirit and when pouring soft drinks (Caljouw and van Wijck, 2014, Wansink and van Ittersum, 2003, 2005).

The effect of glass shape on pouring is argued to be the result of perceptual biases akin to Piaget’s classic findings (Piaget, 1969) in that the height of a glass and the liquid are used in order to judge its volume (Raghubir and Krishna, 1999), with taller glasses, and higher levels of liquid, being associated again with greater perceived volume. People may therefore use the height of the liquid in a glass as an indication as to when to stop pouring. Consequently, factors which affect the height of the liquid may reduce the amount which is poured and affect alcohol unit estimations. The perceived fullness of a glass may also concurrently affect the amount of liquid individuals pour (Pechey et al., 2015). For example, highball glasses would appear relatively fuller than tumbler glasses when containing the same amount of liquid. The presence of ice in a glass will also increase both the height of the liquid and the relative fullness of a glass, perhaps leading to a reduction in the amount of alcohol poured and increased error in alcohol unit estimation.

Another factor which may influence an individual’s ability to effectively monitor their alcohol consumption is prior alcohol consumption. To our knowledge only one study has investigated the effect of alcohol consumption on estimation of liquid (Bertrand and Standing, 2008) and found no effect on individual’s ability to estimate volumes of water. Critically, the effect of alcohol consumption on the amount people pour has not been investigated, but there is reason to believe that self-pouring will be increased. For example, consuming alcohol has been shown to increase craving and consumption of alcohol (Christiansen et al., 2013, Fernie et al., 2012) and this increased motivation to drink may increase self-serving. Intoxicated individuals may also be less able to control behaviour (e.g. de Wit et al., 2000) and so may also over pour when attempting to pour a standard amount (i.e. a single UK unit).

The aim of this series of studies was to examine whether perceptual features of a drinking vessel i.e. the shape of the glass and contents, as well as alcohol consumption influence individuals pouring behaviours. Study 1 was conducted in a laboratory while studies 2-4 were conducted during a series of large-scale public engagement events.

**Study 1: Effect of glass shape and ice on amount of alcohol poured and estimated in a typical serving**

Study 1 was a laboratory-based study which examined the effect of ice substitute and glass shape (highball/tumbler) on the amount of liquid people poured when asked to pour their usual serving of spirt (e.g. vodka, gin, rum, whiskey). We hypothesised that more liquid would be poured into tumbler glasses than highball and alcohol unit estimates would be greater when pouring into highball glasses, resulting in increased error. It was also expected that people would pour less into glasses containing an ice substitute. In order to be confident in our findings this study was conducted twice, the original is presented here and the replication is presented as supporting information.

***Participants***

An opportunistic sample was used to test as many participants as possible during the timeframe of the study. Overall, a sample of one hundred and twenty-six students, aged 18-29 were recruited. Participants were recruited as part of a student research project. A post-hoc power analysis using the acquired sample size, and an α level of .05 revealed there to be 80% power to detect a between-subject effect (of glass shape) and 94% power to detect a within-subject effect (of ice substitute) on volume poured. Participants were required to be fluent English speakers, who typically drink alcohol (at least one occasion per week), and were excluded from participation if they had ever received treatment for an alcohol problem or were currently seeking treatment. All studies received ethical approval from the University of Liverpool Research Ethics Committee.

***Design***

A mixed design was used with glass shape (highball/tumbler) as a between-subject factor and presence of stones (stones/empty) as a within-subject factor.

***Materials***

*Whiskey stones*

As an ice substitute 3 whiskey stones were used in all four studies. Whiskey stones are granite cubes which are used to cool a drink without adding water. Each cube was 18mm x 18mmx 18mm and three stones were used in every instance throughout all studies. These were preferred over actual ice as they are a standard size and would not melt during testing which would confound measurement of liquid in the glasses.

*Glasses*

This study used a highball and tumbler glass of identical volume (300ml). Studies 2-4 used the tumbler glass only.

**Insert Figure 1 about here**

*Alcohol unit awareness*

The alcohol unit awareness questionnaire was adapted from the Health Survey for England (HSE; 2007) and was previously used by Boniface et al (2013). Participants were asked whether or not they were aware of alcohol units before and were then asked to estimate how many units are contained within a small glass of wine, a pint of normal strength beer and a single pub measure of spirits. Alternatively they could indicate that they do not know.

*Alcohol use disorders identification test (AUDIT)*

The AUDIT (Saunders et al., 1993) assesses hazardous drinking; it is comprised of 10 items (scored up to 40). Scores of 8+ suggest hazardous or harmful patterns of drinking (for this study; α=.65).

*Leeds dependence questionnaire (LDQ)*

The LDQ (Raistrick et al., 1994) assesses severity of substance dependency; it contains 10 items each scored 1(never) to 4(always). Higher scores suggest greater dependency (α=.83).

*Time line follow back (TLFB)*

The TLFB (Sobell and Sobell, 1992) is a self-report measure of alcohol consumption, participants are required to retrospectively record the number of UK alcohol units they have consumed over the previous two weeks. Participants were provided with information regarding the alcohol unit content of a number of drinks to aid completion.

*Awareness*

Participants were presented with the open-ended question ‘*What do you believe the purpose of the study to be?’* and recorded their response via paper and pencil.

***Procedure***

Participants provided informed consent before completing demographic information (age and sex) and completing the alcohol unit awareness measure. They were then presented with a glass (either highball or tumbler, order counterbalanced) and provided with a vodka bottle which had been filled with water and were asked to pour their usual serving of spirit *(‘Please pour as if you were pouring yourself your typical amount of spirit…’*). Participants poured twice, once into an empty glass and once with whiskey stones present (counterbalanced). Following each pour they were asked to estimate and record how many alcohol units they think they have poured. Following the first pour the AUDIT and LDQ were completed to allow some time to pass between pours. Participants then completed the second pour. Finally, the TLFB and awareness measure were completed before participants were debriefed. Overall, the procedure lasted for approximately 15 minutes. The amount of liquid poured was subsequently measured (in this and all other studies) by the experimenter using a syringe with 1 millimetre accuracy.

**Data reduction and analysis**

The number of alcohol ‘units’ participants had poured was calculated (volume of drink x alcohol by volume [ABV]/1000). Units were calculated using an ABV of 40% consistent with the ABV of many spirits (gin, whiskey, rum etc.). Error margins were also calculated by subtracting the actual number of units from the estimated number of units poured. Participants with error margins above or below 3 SD’s of the condition mean were removed from analyses in all studies. Throughout all studies non-parametric tests are reported when appropriate. Effect sizes for non-parametric tests calculated according to (Grissom and Kim, 2012).

**Results**

Although no participant correctly identified the study as assessing the effect of glass shape, 16 participants did state the study to be about the effect of ice on pouring alcohol. The pattern of the results remains the same when these participants are removed so we include them here. Analysis of order effects did not alter our findings, therefore is not presented here. We also directly replicated the findings of this study (see supporting information). A series of between-subject t-tests revealed no significant differences (p’s≥.07) between conditions on participant characteristics (see table 1).

***Volume***

Data from one participant was removed due to outlying estimations[[1]](#footnote-1) . An additional participant did not estimate how many units they had poured and so were also removed. Participants poured significantly more liquid into glasses which were empty (52.56 ± 17.00 ml) relative to those which contained whiskey stones (47.77 ± 17.30 ml), *F* (1, 122) = 12.58, *p*=.001, ηp2= .093, 95% CI 2.15, 7.57 (see fig 2). The presence of whiskey stones therefore led to a reduction in the amount of liquid which was poured. However, contrary to our hypotheses the amount of alcohol poured into highball and tumbler glasses did not differ, *F* (1, 122) = 0.10, *p*=.748, ηp2= .001, 95% CI -4.59, 6.37. There was no significant glass shape x stone condition interaction, *F* (1, 122) = 2.23, *p*=.138, ηp2=.018.

**Insert Table 1 about here**

***Unit estimation***

When asked to estimate the amount of units they had poured, participants overestimated, stating there to be significantly more units (3.02 ± 1.38) than they actually poured (1.88 ± 0.58), *t* (123) = 9.23, *p*<.001, d*=*1.08, 95% *CI* -.895, -1.38. There was no effect of stone condition, F (1, 122) = 1.09, *p*=.298, ηp2= .009 95% CI -.073, .235, or glass type, *F* (1,122) = 1.80, *p*=.182, ηp2=.015, 95% CI -.157, .821, on alcohol unit estimation. There was also no significant glass shape x stone condition interaction, *F* (1, 122) = 0.38, *p*=.542, ηp2=.003.

***Error margins***

Error margins were significantly greater when stones were present (1.27 ± 1.49) compared to when they were not (1.01 ± 1.37), *F* (1, 122) = 13.33, *p*<.001, ηp2= .098, 95% CI .121, .406. Error margins did not differ between highball and tumbler conditions, *F* (1, 122) = 1.46, *p*=.229, ηp2= .012 95% CI -.190, .787, and there was no glass type x stones interaction, *F* (1, 122) = .162, *p*=.688, ηp2= .001.

**Figures 2 & 3 about here**

**Study 1 discussion**

We found no difference in the amount of liquid people poured between highball and tumbler glasses. We also found an ice substitute to reduce the amount of alcohol people pour but not to affect alcohol unit estimations, this led to increased error. Although we found no effect of order, it can be argued that these results may be due to manipulating the presence of the stones on a within-subject basis. When pouring for a second time participants may be attempting to match the height of the liquid that they first poured. As the stones raise the level of the liquid this would lead to reduced volume when stones are present. For the next study we addressed this by using a between-subject design.

**Study 2: Effect of ice on pouring and estimating the amount of alcohol units in a typical serving**

Data for studies 2, 3 and 4 is available on the Open Science Framework ([https://osf.io/krqzg/).](https://osf.io/krqzg/%29.) Study 2 investigated the effect of an ice substitute on amount of alcohol spirit poured and alcohol unit estimation. For this study the ice substitute was presented on a between-subject basis. We expected people would pour less liquid into glasses containing whiskey stones. Consistent with the findings of study 1 we expected that unit estimates would not differ between conditions but error margins would be greater when whiskey stones are present. Data collection took place during Cheltenham Science Festival.

**Method**

***Participants***

One hundred and six participants took part in study 2. Participants were aged 18-85 and were recruited during Cheltenham Science Festival (Cheltenham, UK), as part of a public engagement demonstration on Portion Size. Researchers were positioned behind a stall which potential participants could freely walk by and observe. These conditions were similar for study’s 3 and 4. Individuals who approached the demonstration were invited to participate, and if they agreed were taken to one-side to complete the study. As this was a public event we tested all people who wished to take part during the event. We recruited using this method for studies 2, 3 and 4. Data was collected throughout three days of the festival, during the hours of 10am-8pm.

***Materials***

*AUDIT-C*

The AUDIT-C (Bush et al., 1998) is a short version of the AUDIT and was used to assess hazardous drinking. The AUDIT-C consists of the first three items of the AUDIT scores 0-4 with scores of 4+ indicating hazardous drinking patterns (α=.60).

*Spirit pour frequency*

A single item (‘*how often do you pour your own spirits at home?’*) which assessed how often participants pour their own spirits (never, less than monthly, monthly, weekly, daily or almost daily) scored from 0-4.

*Spirit unit awareness*

This item, adapted from the alcohol units awareness questionnaire from study 1, (‘how many units do you think there are in a single pub measure of spirits?’) asked participants to estimate the amount of units in a single pub measure of spirits.

*Confidence scale*

Participants were asked to indicate from 0 (not at all) to 10 (extremely) how confident they were that they accurately managed to pour their usual serving of spirit.

***Procedure***

After providing consent participants provided demographic details (age and sex) and completed the AUDIT-C, the spirit pour frequency and the spirit unit awareness measure. Participants were then asked to pour their typical serving of spirit from a vodka bottle filled with water into a tumbler glass which either contained three whiskey stones (stones condition) or was empty (empty condition). They were then asked to note down how many UK alcohol units they believed they had poured. Finally, they completed the confidence scale before being debriefed. The procedure took approximately 5 minutes.

**Results**

A series of between-subject t-tests were conducted to assess differences in participant characteristics and pouring confidence between conditions (see table 2). There was a significant difference in age (*p=.*008) with those in the empty condition being significantly older than those in the stones condition. There were no other significant differences (*p’s*≥.441).

***Volume***

As with study 1 prior to analysis, outliers were removed and error margins calculated. One participant was removed[[2]](#footnote-2). A Mann-Whitney U Test revealed there to be no significant difference between the amount of liquid poured into glasses containing stones (*Mdn=*39.00, IQR= 26.00 ml)and those which were empty (*Mdn=* 45.50, IQR= 29.00 ml), *U* (103)= 1157.50, *p*=.159, *p̂a>b*=0.42.

**Insert Table 2 about here**

***Unit estimation***

There was no difference between the stone (*Mdn=*2.00, IQR= 2.00)and empty (*Mdn=*3.00, IQR= 2.00)conditions in unit estimation, *U*(104)=1252.00, *p*=.417, *p̂a>b* =0.45. Consistent with findings from study 1, a Wilcoxon test revealed that participants estimated there to be significantly more units (*Mdn*=3.00, *IQR*=2.00) than they had actually poured (*Mdn*=1.68, *IQR*=1.02), Z(104)= 7.43, *p*<.001, *PSdep*=0.85.

***Error margins***

 There was no significant difference in error margins (stones: *Mdn=*1.08, IQR=2.64; empty: *Mdn*=0.94, *IQR*=1.96), *U*(104)= 1365.00, *p*=.939, *p̂a>b* =0.50.

**Study 2 discussion**

These findings suggest the presence of an ice substitute may not reduce the amount of alcohol which is poured or affect alcohol unit estimation. However, given the findings of study 1, the presence of ice may only affect the amount of alcohol poured when attempting to pour a clearly defined amount or standardised drink (i.e. a shot or a single UK unit). Study 3 aimed to investigate this by having participants attempt to pour a single UK alcohol unit rather than their usual serving.

**Study 3: The effect of ice substitute on pouring a single unit of alcohol**

Study 3 investigated the effect of an ice substitute on accuracy when pouring a single unit of alcohol (25ml of spirit). We expected that people would pour significantly less alcohol when pouring into a glass containing an ice substitute than when pouring into an empty glass. Moreover, given previous research which suggests people tend to over pour when asked to pour a single measure; we hypothesised that participants would be more accurate when pouring into a glass containing the ice substitute.

**Method**

***Participants***

Sixty-four participants took part in study 3. Participants were aged 20-57 and were recruited during a ‘Meet the Scientists’ event at Liverpool World museum (Liverpool, UK) over the course of one day (10am-6pm).

***Materials***

Materials were identical to those used in study 2. The only difference being that the confidence scale was worded differently to ask participants how confident they were that they were able to pour a single UK unit of alcohol *(“How confident were you that you accurately poured the equivalent of one unit of alcohol?”*).

***Procedure***

Participants provided informed consent, completed demographic questions, the AUDIT-C, the spirit pour frequency and the spirit unit awareness item. Participants were then asked to pour a single UK unit of alcohol from a vodka bottle filled with water into a tumbler glass. As with study 2 participants either poured into a glass containing three whiskey stones or into an empty glass. Finally, the confidence scale was completed and they were debriefed.

**Results**

Between-subject t-tests revealed no significant differences between conditions on participant characteristics or confidence (*p’s*≥.268; see table 3).

***Volume***

Using the same criteria as the previous studies one outlier was removed prior to analyses[[3]](#footnote-3) Significantly more liquid was poured into glasses which were empty (29.48 ± 11.13 ml) than those containing ice substitute (21.66 ± 7.24 ml), *t* (61) = 3.32, *p*=.002, *d*=.85, 95% CI -12.54, -3.11, with a mean difference of 7.82ml.

***Accuracy***

To test whether participants poured significantly more than one unit of spirit (25ml) we conducted a one sample t-test comparing ml’s poured with a test value of 25 (ml). Overall, participants did not pour significantly different from one unit of spirit, *t* (62) = 0.40, *p*=.691, *d*=.07, 95% CI -2.03, 3.05. However, when the glass was empty significantly more than one unit was poured, *t* (30) = 2.24, *p*=.032, *d*=.57, 95% CI .40, 8.87, but significantly less than a unit was poured when stones were present, *t* (31) = 2.61, *p*=.014, *d*=.65, 95% CI -5.95, -.73 (*see* fig 3).

**Insert Table 3 & Figure 4 about here**

**Study 3 discussion**

These findings suggest the presence of an ice substitute reduces the amount of alcohol people pour when attempting to pour a standardised amount of alcohol. Using ice may lead to under-pouring while pouring in an empty glass leads to over-pouring. However, people may often pour drinks following alcohol consumption which may have an effect on accuracy of pouring.

**Study 4: The effect of an ice substitute and alcohol consumption on pouring a single unit of alcohol**

Study 4 examined the effect of an ice substitute on pouring a single unit of alcohol. We also examined the association between alcohol consumption and accuracy. We expected to replicate the findings of study 3 and find greater levels of alcohol consumption to be associated with greater error. To ensure transparency we pre-registered the methods and analyses of this study on aspredicted.com (<https://aspredicted.org/23j8v.pdf>).

**Method**

***Participants***

Two hundred and twenty-three participants aged 18-75 took part. The study was conducted at Einstein’s Garden, Green Man Festival (Brecon Becons, Wales), a national music and arts festival over a four day period between the hours of 10am to 7pm.

***Materials***

Materials were similar to study 3 with some additions. AUDIT-C α= .54.

*Subjective Intoxication & Alcohol urge Scales*

Participants were required to indicate from 1(not at all) to 10(extremely) how intoxicated *(“How intoxicated do you feel right now?”*) they felt and how strong their urge to drink alcohol was *(“How strong is your urge to drink alcohol?”*).

*One-day alcohol diary*

Participants were required to complete an alcohol diary which asked them to record which alcoholic drinks they had consumed that day. The total amounts of units consumed were then calculated.

***Procedure***

The procedure for this study was similar to that of study 3. The only difference what that prior to pouring a single unit participants were breathalysed (Lion Alcometer 500, Lion laboratories, Barry, UK), completed the intoxication, alcohol urge scales and the one-day alcohol diary.

**Results**

We planned to remove participants who had poured 3 SD’s above or below the mean were removed from the analysis. However, it was not necessary to remove any participants. Between-subject t-tests revealed a significant difference between conditions on spirit unit estimate (p=.024) with those within the stones condition believing a single pub measure of spirits to contain more units than those in the empty condition. There were no other significant differences (p’s ≥.066; see table 4).

***Volume***

Significantly more liquid was poured when glasses were empty (30.40 ± 9.82 ml) than when glasses contained stones (24.19 ± 9.39 ml), *t* (221) = 4.82, *p*<.001, *d*=.65, 95% CI -8.75- , -3.67.

***Accuracy***

In contradiction to study 3, we found that overall participants poured significantly more than one unit (25ml), *t* (222) = 2.97, *p*=.003, *d*=.28, 95% CI .67, 3.33. Separate one sample t-tests for stones and empty conditions, comparing ml’s poured to a test value of 25, revealed participants to have poured significantly more than a unit when pouring into an empty glass (30.40 ± 9.82 ml), *t*(100)= 5.52, *p*<.001, *d*=.78, 95% CI 3.46, 7.33. However, contrary to the findings in study 3, we found that participants poured no different from one unit when pouring into a glass containing the whiskey stones, *t* (121) = .96, *p*=.342, *d*=.12, 95% CI -2.49, .87.

**Insert Table 4 about here**

***Alcohol consumption***

Within the stones condition 30 participants reported consuming some alcohol on the day of testing, while 35 participants had consumed alcohol within the empty condition. Within the stones condition 24 participants had positive BrAC readings and within the empty condition 27 participants provided positive readings. We correlated BrAC, subjective intoxication and total alcohol units with error margins (ml poured- 25). As this analysis was exploratory we used a more stringent alpha level of p<.01. We conducted these correlations separately for stones and empty conditions. However, BrAC, urge, subjective intoxication and alcohol units were not correlated with error within either condition all *p’s* ≥ .167 rs range from -. 127, to .135) Overall, subjective intoxication was associated with BrAC, rs=.695, p<.001, total units consumed, rs=.715, p<.001 and alcohol urge rs=.437, p<.001. BrAC was also related to total units consumed, rs=.786, p<.001 and alcohol urge rs=.367 p<.001, and total units consumed and alcohol urge were also related rs=.786, p<.001.

**Insert Figure 5 about here**

**General Discussion**

Findings across four studies suggest that participants consistently overestimate the amount of alcohol units they have poured, and tend to significantly over pour when attempting to serve a standardised amount (i.e. a single UK unit) into an empty glass. Furthermore, glass shape (highball/tumbler) and the presence of ice may not affect the amount of alcohol people pour themselves nor affect alcohol unit estimations when people pour their usual serving. However, the presence of ice may reduce the amount poured when pouring a standardised amount, leading to greater accuracy. Alcohol consumption was not found to be associated with error when pouring a standardised drink.

These findings support previous research which suggests that people tend to overestimate the amount of alcohol they pour (Boniface et al., 2013) in direct contrast to that which suggests people tend to underestimate (Wilkinson et al., 2011). Our findings also support the notions that the height of the liquid and relative fullness of a glass is used to perceive volume (Raghubir and Krishna, 1999, Pechey et al., 2015) but this does not seem to be driven by glass shape unlike previous findings (Wansink & van Ittersum, , 2003; 2005) . This may be due to our participants pouring their usual serving of alcohol while the aforementioned studies had participants pour standardised amounts. Indeed, the effect of perceived liquid height on pouring may be increased when attempting to pour a standardised or clearly defined amount of liquid. However, Wansink and colleagues (2003; 2005) also found an effect when participants poured themselves their preferred serving of juice; the reason for this discrepancy is therefore not clear. Finally, our work is consistent with the finding that alcohol consumption does not affect the ability to judge volumes of liquid (Bertrand and Standing, 2008).

Given that participants consistently overestimated the amount of alcohol in a typical serving, self-report measures of alcohol consumption may overstate the amount of alcohol individuals consume. In addition, the amount of alcohol people serve themselves when attempting to pour a standardised measure may vary depending on whether they use ice or ice-substitutes. The amount people report consuming on self-report measures of alcohol consumption may therefore be inaccurate unless the presence of ice is considered. For example, using data from study 4, approx. 30ml was poured into empty glasses while those using ice poured no different from a unit (25ml). So someone who drinks with ice and reports drinking 50 units of spirit would be fairly accurate while for someone reporting the same amount but who does not use ice the amount they consumed may be closer to 60 units. Given that people consistently pour more than a unit when pouring into an empty glass, the use of standardised pouring tools should be encouraged when serving alcohol.

A particular strength of the current research is that, with the exception of study 1, these studies were conducted in a variety of different public engagement events. This method allowed us to gather responses from a broad range of participants. There are, however, several limitations. For practical purposes we used an ice substitute rather than real ice. While whiskey stones are a similar size and shape to ice cubes they are opaque and heavier and so this may exaggerate the effect. Secondly, we did not use real alcohol in this study and instead participants poured from a vodka bottle filled with water. Indeed, exposure to genuine alcohol cues could affect the amount poured given that such cues may affect the ability to inhibit a response (Field and Jones, 2017, Monk et al., 2016). In addition, within study 1, participants completed alcohol use measures following their first pour prior to the second. Participants also completed a unit awareness questionnaire prior to both pours and all other studies included a shortened version of this questionnaire. It is possible that the completion of these measures prior to pouring may serve to prime participants to pour differently (i.e. aim to pour standard measures). It is also possible that participants may have consumed alcohol prior to taking part, although participants were breathalysed only within study 4. However, alcohol was not available on premises for study 1 and 3 and was not permitted at the site of study 2.

While the current findings suggest ice may increase accuracy of pouring standardised measures of alcohol this effect would only occur if individuals place ice in the glass first. Moreover, while pouring may be more accurate when ice is present individuals may concurrently reduce the amount of mixer added to the drink creating a potentially stronger drink or a drink with reduced volume which may be consumed more quickly. Future research should assess the potential effect of ice on multiple drinks, mixer volume and drinking rate. We also found alcohol consumption was not related to error in pouring a single unit of alcohol. However, the amount of alcohol consumed was not manipulated; participants who had already consumed alcohol took part. Therefore, future research should administer alcohol using a placebo controlled design in the lab and aim to use real ice and alcohol.

Finally, a single UK unit is small relative to other international standard measures (Kalinowski and Humphreys, 2016) and the use of these small units may increase the likelihood of overestimation. It is, therefore, unknown how the current findings regarding accuracy and unit estimation may generalise to other countries with different standard drink definitions.

In conclusion, the current research suggests that individuals consistently overestimate the number of alcohol units they have poured. It is also the first to demonstrate that ice may alter how much alcohol people serve themselves when they attempt to pour a standard measure. This is important as it suggests that self-report measures of alcohol use may overstate the amount of alcohol individuals consume and may be more accurate if the presence of ice is considered.

**Acknowledgements**

We thank all students who contributed to data collection for study 1 and that presented as supporting information. We also thank Natasha Clarke, Jay Duckworth, Gregory Keenan, Inge Kersbergen, Lauren McGale, Danielle Reaves and Florence Sheen for their assistance in data collection for studies 2, 3 and 4. We would also like to thank Cheltenham Science Festival, Meet the Scientists (Liverpool World Museum) and Green Man Festival. Studies 2-4 were funded by an ESRC grant (ES/N016211/1) to A.J.

**Declaration of Conflicting Interests**

The authors declare that they have no conflicts of interests concerning their authorship or publication of this article.

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 **Figure Legends**

**Fig 1.** Tumbler and highball (glasses).

**Fig 2.**  Study 1. Amount of liquid poured (in ml) when glass empty and stones present for highball and tumbler conditions. Values are mean ± SEM.

**Fig 3.** Study 1. Error margins when glass empty and stones present for highball and tumbler conditions. Values are mean ± SEM.

**Fig 4.**  Study 3. Volume poured (ml) when glass empty and stones present. One unit indicated. Values are mean ± SEM.

**Fig 5.** Study 4. Volume poured (ml) for stones and empty conditions. One unit indicated. Values are mean ± SEM

Table 1. Study 1 Participant characteristics for tumbler and high ball conditions (values mean ±SD).

|  |  |  |  |
| --- | --- | --- | --- |
| Characteristic | Highball  (*n*=64) | Tumbler (*n*=60) | Sample (*n*=124) |
| Gender (male: female) | 24:40 | 19:41 | 43:81 |
| Age (years) | 19.86 (±0.79) | 20.15 (± 1.15) | 20.00 (±0.99) |
| TLFB | 42.00 (± 33.17) | 36.61 (± 31.06) | 39.39 (±32.15) |
| AUDIT | 13.61(± 6.42) | 13.08 (± 5.41) | 13.35 (± 5.94) |
| LDQ | 5.83 (± 4.78) | 5.10 (± 3.52) | 5.48 (± 4.21) |
| Spirit estimate | 2.24 (± 1.60) | 2.40 (± 1.55) | 2.32 (± 1.57) |

LDQ = scores range from 0 (minimum) to 30 (maximum). Spirit estimate = Participants asked how many units do you think there are in a single pub measure of spirits? (A single pub measure= 1 UK alcohol unit). TLFB= in UK units (1 unit= 8g alcohol), retrospectively recorded over two weeks. AUDIT= scores range from 0(minimum) to 40(maximum).

Table 2. Study 2 Participant characteristics for stones and empty conditions (values mean ±SD).

|  |  |  |  |
| --- | --- | --- | --- |
| Characteristic | Stones  (*n*=51) | Empty (*n*=55) | Sample (*n*=106) |
| Gender (male: female) | 16:31 | 23:25 | 39:56 |
| Age (years) | 39.50 (±13.50) | 47.56 (±15.83) | 43.61 (±15.21) |
| AUDIT-C | 4.22 (±2.34) | 4.39 (±2.15) | 4.30 (±2.23) |
| Spirit pour frequency | 1.41 (±1.10) | 1.35 (±1.24) | 1.38 (±1.17) |
| Spirit unit estimate | 2.19 (±1.11) | 2.06 (±1.47) | 2.12 (±1.30) |
| Confidence | 5.43 (±3.32) | 5.83 (±2.78) | 5.67 (±3.05) |

Gender missing for some participants as they did not record. AUDIT-C= scores range from 0-12. Spirit frequency= answer to question ‘How often do you pour your own spirits at home? (Never, less than monthly, monthly, weekly, daily or almost daily).

Table 3. Study 3 Participant characteristics for stones and empty conditions (values mean ±SD).

|  |  |  |  |
| --- | --- | --- | --- |
| Characteristic | Stones (*n*=32) | Empty (*n*=31) | Sample (*n*=63) |
| Gender (male: female) | 13:19 | 11:20 | 24:39 |
| Age (years) | 37.09 (±8.38) | 36.83 (±8.63) | 36.83 (±8.44) |
| AUDIT-C | 4.25 (±2.86) | 4.87 (±2.42) | 4.56 (±2.65) |
| Spirit pour frequency | 1.00 (±0.92) | 1.13 (±1.09) | 1.06 (±1.00) |
| Spirit unit estimate | 2.21 (±1.01) | 2.10(±0.98) | 2.15 (±2.55) |
| Confidence | 4.34 (±2.59) | 4.74 (±2.53) | 4.54 (±2.54) |

Confidence= answer to question ‘How confident were you that you accurately poured the equivalent of one unit of alcohol?’ (Scored 0-10).

Table 4. Study 4 Participant characteristics for stones and empty conditions (values mean ±SD).

|  |  |  |  |
| --- | --- | --- | --- |
| Characteristic | Stones (*n*=122) | Empty (*n*=101) | Sample (*n*=223) |
| Gender (male: female) | 13:19 | 11:20 | 24:39 |
| Age (years) | 36.95 (±11.50) | 36.68 (±10.51) | 36.83 (±11.02) |
| AUDIT-C | 4.82 (±2.01) | 5.30 (±1.80) | 5.04 (±1.93) |
| Spirit pour frequency | 1.45 (±1.00) | 1.40 (±1.07) | 1.43 (±1.03) |
| Spirit unit estimate | 2.41 (±3.01) | 1.67 (±.81) | 2.07 (±2.30) |
| Confidence | 4.97 (±2.21) | 5.03 (±2.38) | 5.00 (±2.28) |
| Subjective Intoxication | 0.90 (±1.72) | 1.01 (±1.53) | 0.95 (±1.64) |
| Alcohol urge | 2.52 (±2.50) | 2.83 (±2.39) | 2.66 (±2.45) |
| Total units | 1.20 (±3.22) | 1.37 (±3.07) | 1.28 (±3.15) |
| BrAC | 0.05 (±.13) | 0.05 (±.12) | 0.05 (±.13) |

Alcohol urge= How strong is your urge to drink alcohol? (Scored 1-10). Intoxication= How intoxicated do you feel right now? (scored 1-10) Total units= Total amount of UK alcohol units consumed on that day. Total BrAC= breath alcohol concentration. N for each condition uneven due to randomisation.

1. Pattern of results remained the same regardless of exclusion of outlier [↑](#footnote-ref-1)
2. Pattern of results remained the same regardless of exclusion of outlier [↑](#footnote-ref-2)
3. As with previous studies the pattern of results remained the same whether the outlier was included or removed. [↑](#footnote-ref-3)