

Calculating Alcohol Risk in a Visualisation Tool for Promoting Healthy Behaviour

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Abstract

There is an urgent need for interventions to assist teenagers and young adults in appreciating the physical and social risks of binge drinking. While research on the health risks associated with alcohol abuse is well developed, the translation and communication of this knowledge to young people is not. This paper describes a prototype visualisation tool, an Alcohol Risk Calculator, that provides personalised information on risks associated with alcohol consumption based on individual drinking habits. Its design is informed by studies of graphical literacy, evidence on forms of presenting risk that aid understanding, and theory that provides insight into changing health damaging behaviour.

Introduction

There is no shortage of literature on the risks of drinking, and there can be no doubt that alcohol affects health. There have been a number of studies, proving beyond doubt that as an individual's alcohol intake increases, so does their likelihood of fatality (Rehm, Room and Taylor, 2008; Single, Robson and Rehm, 1999; WHO, 2002). This is supported by a wealth of studies, including a meta-analysis of studies of alcohol-drinking showing a strong dose-risk relation between alcohol and neoplasms (i.e., cancers) (Bagnardi et al., 2001); studies showing a strong dose-risk relation between alcohol and trips to the emergency department (Borges et al., 2006; Corrao et al., 1999); and a 2007 World Health Organisation (WHO) report showing that, on average, 20% of injuries involve alcohol, and that the majority of these patients were under the age of 35, and often of low to middle socio-economic status.

However, despite numerous public campaigns to promote healthy drinking, their impact on behaviour remains generally low. Indeed, research shows that people's perception of the risks of alcohol differs markedly from other hazardous activities: while they are generally able to appreciate the risks that alcohol brings to members

of their peer group, they tend to disassociate this from the risks to themselves (Moreira, Smith and Foxcroft, 2009; Sjöberg, 1998). This, together with the 'communication gap' that holds between the risk information that is provided to the public and the way it is understood and appreciated by them, appear to be important contributors to the low impact of public campaigns.

This paper describes preliminary work on the development of a visualisation tool for communicating to young people the long- and short-term risks of alcohol consumption (see Figure 1). Its intended purpose is to provide the user with information about their drinking behaviour in relation to national guidelines and about the health risks that they face.

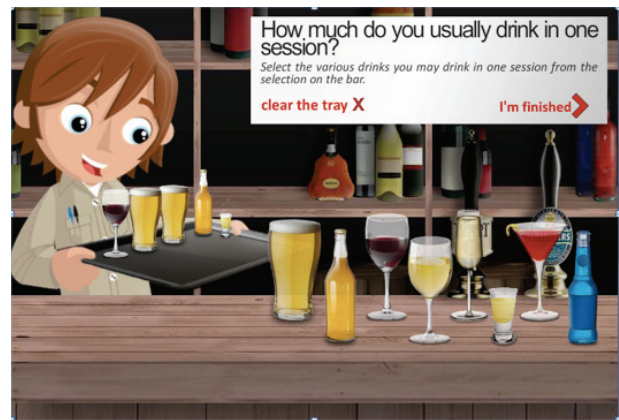


Figure 1: 'Jim the bartender' graphical interface for drinks selection in the Alcohol Risk Calculator (Bissett, 2010).

A key aspect of the tool is to personalise risk information for the individual in relation to their drinking habits. The work forms part of a study concerned specifically with curbing the damaging health consequences of binge drinking in young adults and teenagers. Key elements of the study are:

- informing individuals about the consequences of their behaviour in a manner that supports their motivation and perceived self-efficacy to reduce the damage to their health and general well-being;
- identifying methods to communicate risk that are effective for the target audience of teenagers and young adults; and
- identifying features of potential visualisation tools that will engage the target audience, and thereby lead them to discover the impact of their drinking habits on their own health and to explore the potential benefits (or otherwise) of changes in their drinking pattern.

The idea of a risk calculator is not a new one. For example, the Harvard Cancer Risk Index, first printed in 1997, has been developed into ‘Your Disease Risk’, a calculator that works out the risk of developing a range of cancers (URL 1). There are also similar calculators linked more directly to alcohol consumption, which calculate aspects of the user’s drinking habits such as Blood Alcohol Concentration (BAC), the number of calories consumed or how much money is spent. However, none of these inform the user of the risk of personal injury based on the amount they drink. Many of the existing alcohol calculators are also unexciting for young people. We believe that a calculator is more likely to engage young people, and thus have a better chance of influencing their behaviour, if it can be made to be entertaining and interesting.

Background

Our work builds on the large and growing body of research on the factors that influence healthy behaviours, promote understanding of risk statistics, and determine risk.

Influencing Health-Related Behaviour

There is general agreement that human behaviour is goal-directed; actions are controlled by intentions. The most influential, theoretical accounts of this relationship are provided by Azjen and his colleagues. The Theory of Reasoned Action (TRA) proposes that actions can be traced through causal links from beliefs, through attitudes and intentions to the resulting behaviour (Azjen and Fishbein, 1980). This theoretical account has been further extended to include consideration of the individual’s perceived behavioural control in realising their intentions, in the Theory of Planned Behaviour (TPB) (Ajzen, 1985).

The TRA is based on the assumption that human beings largely behave in a sensible manner, that they consider available information and implications, and that it is the individual’s intentions that are the determinants of their action. The determinants of intentions are twofold:

Personal: the individual’s evaluation of and attitude toward the behaviour in question. These are said to arise from ‘behavioural beliefs’.

Social: the individual’s perception of the social pressures put upon them, particularly their views on whether trusted others would approve or disapprove of their behaviour. Ajzen (1980; 1985) terms this the ‘subjective norm’ giving rise to ‘normative beliefs’.

Their relative weights can vary from person to person and from behaviour to behaviour. According to the theory, the beliefs of a given individual represent the information that he or she has about the world. Therefore, by changing information, it is possible to change behaviour.

The likelihood of success, and how one’s peers view success or failure at the task, are also said to play a role. If a task has a low likelihood of success, and one’s peers look badly upon failure, it is less likely that a person will attempt the task.

Whereas the TRA applies to behaviours that are under volitional control, the TPB extends to external factors beyond the subject’s control. The following statement encapsulates the relevance of this theoretical framework to the current study.

... a person will attempt to perform a behaviour if he believes that the advantages of success (weighted by the likelihood of success) outweigh the disadvantages of failure (weighted by the likelihood of failure), and if he believes that referents with whom he is motivated to comply think he should try to perform the behaviour. He will be successful in his attempt if he has sufficient control over internal and external factors which, in addition to effort, also influence attainment of the behavioural goal (Ajzen, 1985, p36).

Supporting Understanding of Statistics

It is well known that many people do not fully comprehend health statistics. This common problem of ‘collective statistical illiteracy’ can have serious consequences for health and applies not only to patients but to physicians themselves.

In the most influential work on this topic, Gigerenzer and his colleagues claim that at the root of the problem is the use of non-transparent statistics (Gigerenzer et al., 2008). According to them, statistics should be presented in terms of *natural frequencies* instead of the commonly used *conditional probabilities* (see Table 1). Natural frequencies are preferred because they facilitate computation.

Table 1: Conditional versus natural frequencies (Gigerenzer et al., 2008).

Conditional Probabilities:	Natural Frequencies:
• The probability that a woman has breast cancer is 1%. (prevalence) • If a woman has breast cancer, the probability that she tests positive is 90%. (sensitivity) • If a woman does not have breast cancer, the probability that she nevertheless tests positive is 9%. (false positive rate)	• Ten out of every 1000 women have breast cancer. (prevalence) • Of these 10 women with breast cancer, 9 test positive. (sensitivity) • Of the 990 women without cancer, 89 nevertheless test positive. (false positive rate)

Gigerenzer and his colleagues further suggest that patients do not understand that there is no certainty – no zero-risk groups, and no certain way to prevent a disease – only probabilities. And where such probabilities can be shown, issues such as, ‘Do the numbers reflect the risk of getting symptoms, getting the disease, or dying from the disease?’; ‘Is the risk one year? Ten years? Lifetime?’; ‘Does it apply to me?’, etc. need to be made very clear.

Recent research suggests that the issue of ‘Does it apply to me?’ plays a special role in the context of alcohol-related risks. In brief, those young people who drink more tend to be optimistic about the risks to themselves, to live more ‘for the moment’, and to perceive themselves as having greater self-control than their peers.

A study of college students’ perceptions of problems due to alcohol has shown that there was a strong positive relationship between subjects’ ‘unrealistic optimism’ at the beginning of a 2 year study and the number of alcohol-related negative events (hangovers, missed classes, and arguments with friends) that they experienced 6 months, 1 year and 1.5 years later (Dillard, Midboe and Klein, 2009).

Henson et al. (2006) studied the effect of undergraduates’ time perspectives upon a range of health behaviours including alcohol consumption and found that people who had a hedonistic ‘enjoy life now’ perspective were associated with greater alcohol use than those who gave more consideration to the future.

A meta-analysis comparing alcohol to other hazards such as smoking found that personal risk is often perceived to be lower than the risk for other people (Sjoberg, 2000). The study also found that risk-denial is positively correlated with perceived control.

Calculating Risk

We summarise briefly here the accepted methods for calculating the risk of acute and chronic outcomes of alcohol consumption. These are employed directly in our tool.

Acute Risk

We make use of a formula developed by Rehm, Room and Taylor (2008) for the probability of death based on a baseline level of risk, a relative level of risk based upon how much the person drinks, a risk period (also based on alcohol consumed) and how frequently the person drinks.

Total Risk. Using the mortality rates in Alcohol Attributable Fractions for England (Jones et al., 2008) for the year 2005, Total Risk is calculated by dividing the number of deaths from a specific injury in a specific age group, SI, by the population for that age group, AGP, and then multiplying that number by 1000 (see equation 1). The figure for AGP is taken from the Office for National Statistics (2005).

$$\text{Total Risk} = SI / AGP * 1000 \quad (1)$$

Relative Risk. Following Rehm, Room and Taylor (2008), Relative Risk is calculated as by Borges et al. (2006) (for non-fatal injury) based on 12.5g of ethanol per unit. The non-linear relationship between alcohol consumption and injurious effect is reconstructed by plotting the Borges et al. data points on a scatter graph and fitting them using a quadratic approximation. The extrapolation is capped at 30 units. This is further adapted, from the international standard of 12.5g of ethanol per unit, to the UK standard of 8g a drink.

Risk Period. This reflects the amount of time the liver takes to metabolize the alcohol consumed. When the level of alcohol in the blood returns to zero, the subject is no longer at risk. Rehm, Room and Taylor’s formula calculates this as the number of hours in the day (24), divided by Hours at Risk (formulaically based on number of drinks consumed), multiplied by 365 days in a year. However, a more precise value can be calculated using the actual number of Drinking Occasions, DO, per year, combined with a more precise calculation of Blood Alcohol Concentration (BAC) divided by 0.015, the average rate of metabolism, to give the number of hours it would take BAC to return to zero, as shown in equation (2). The resulting value gives a more precise Risk Period calculation giving a Risk Period of 0.8 hours per year for a male drinking 1 drink, once a year.

$$\text{Risk Period} = DO * (BAC / 0.015) \quad (2)$$

Blood Alcohol Content (BAC). BAC is calculated following the National Highway Traffic Safety Administration (1994), as shown in equation (3), where A stands for the total amount of alcohol ingested, in grams (8 per unit), divided by Total Body Water (TBW). TBW is multiplied by .806 (the percentage of blood that is water), then by 100 to give the total number of grams of ethanol in 100ml of blood, the standard method for expressing BAC. Alcohol metabolism starts mere seconds after ingestion begins. To reflect this, the number of Drinking Hours, DH, multiplied by the metabolic rate, is subtracted from BAC as shown in equation (3). TBW is the amount of water in the body that the alcohol can dissolve into, and is calculated, using age (men only), height and weight (Watson, Watson and Batt, 1981, pg 550).

$$BAC = (A / TBW * .806 * 100) - (0.015 * DH) \quad (3)$$

Chronic Risk

The risk associated with chronic diseases centres around a measure of ‘Lifetime Risk’ based on Total Risk and Relative Risk.

Total Risk. The formula for this is the same as that used to calculate acute risk (see equation 1).

Relative Risk and AAF. Rehm, Room and Taylor (2008) calculate Relative Risk on the basis of disease prevalence. However, published Alcohol-Attributable Fractions (AAF) (Jones et al., 2008) were found to provide a more reliable calculation of the one year risk, per 1000 people, of developing the chronic injury, and are used here.

Lifetime Risk. This is obtained by multiplying the one-year risk by the number of years for that age band, YAB, as shown in equation (4).

$$\text{Lifetime Risk} = \text{Total Risk} * \text{AAF} * \text{YAB} \quad (4)$$

Risk of Hospital Admission. Risk of hospital admission for both acute and chronic injury involves calculating Total Risk on the basis of hospital admissions rather than deaths.

Risk Presentation

Risks can be presented numerically, graphically, textually or in combination, and it is generally accepted that the use of combined media leads to better understanding. However, while there is a wealth of research on the effect of various numerical presentations (relative risk, absolute risk, etc.) on risk perception, relatively little is known about the effect of the various types of visual displays independently, or in combination with numerical or textual translations (see Linkus and Holland, 1999 for a review). Additionally, there is a noticeable absence of studies addressing teenagers. Our aim is to explore these issues through empirical studies with teenagers using the Alcohol Risk Calculator, also incorporating in the calculator the outcomes of new studies as they appear.

The Alcohol Risk Calculator

The Alcohol Risk Calculator¹ is designed to be highly accessible to a wide variety of users and adheres to Nielsen and Mack's (1994) design heuristics. Its current design is inspired by the findings in the literature reported above, in addition to a survey of 25 existing web-based calculators (see Bissett, 2010).

In order to make it effective, we chose in our initial prototype to:

- personalise the communication of risk. In this, we are inspired by the finding that risk information relevant to individuals is of greater value than average population data (Edwards et al, 2000);
- use a combination of all three media: text, numerical information, and simple graphics;
- for numerical data, to focus on absolute risk (following Gigerenzer et al, 2008); and
- graphically, to use bar charts. We took as inspiration the results of reviews by Linkus and Holland (1999) and Edwards et al (2002) which suggest that bar charts are generally well understood by patients, and often preferred over other formats (e.g., pie-charts, pictograms, survival curves). Further motivation came from a small study of young adults' interpretations of 6 formats: bar chart, compound bar chart, pictogram, pie chart, choropleth and histogram (Bissett, 2010).

¹ Implemented in Adobe Flash CS4.

In order to make it more entertaining and informal, a theme was created whereby users would visit a virtual, interactive, bar, where they would engage with a barman, 'Jim', who would ask them a series of questions. The use of text is minimised wherever possible in favour of interactive graphical elements, with many questions presented pictorially; although these tend to take longer to complete than traditional response field questionnaire formats, such questions were thought to be more engaging and entertaining for the user. Users were also able to make use of pictorial elements when answering questions. For example, to answer questions about what type of drink (and how many) they would have, the user would engage with the interface to move drinks from the bar to a tray.

Questions. The questions are based on some of those from the NHS binge-drinking questionnaire (URL 2). They are designed to extract the following details from the user: height, weight, age, drinking pattern, drinking volume, and time of drinking. The user is taken through five input pages into which they enter various parameters (age, gender, weight, height) followed by their alcohol drinking profile. An overview screen leads users to requests for more detail contingent upon earlier responses using 'jump-to' links such as those found in online survey systems such as SurveyMonkey.

User Answers. A translucent question box slides in, asking the user to enter their details in various response fields. There is a field for their age, a dropdown (male/female), and fields for height and weight. Radio buttons, sliders, and drop down boxes were all considered but text response fields were ultimately chosen for maximum clarity and to prevent constraining the user's input.

The manner of selecting drinks took inspiration from the Drink Diary (URL 3). From the prior observations of similar calculators, it is known that there are a huge variety of possible drink selections, but that a large quantity of drink options makes the search for the desired choice laborious. One possibility was to have choices appear when the type of drink was selected, but this too seemed overcomplicated and was thus rejected. Further, many drink options are very similar, and so for the Alcohol Risk Calculator, the minimum number of drink choices were chosen: Beer, Cider, Wine, Champagne, Spirits and Alcopops.

Beer and cider often have a similar percentage of alcohol, and come in similar measurements, so were represented by the same drink icon, but with two possible measurements: pints and bottles.

Wine was separated into red and white wine. Although there is no real distinction between red and white wines and champagne in terms of alcohol content (and thus their effect on personal risk), we decided to include them as separate items for purposes of naturalness and engagement. It was also easy to find distinctive icons for each of them.

Spirits are consumed mostly in two ways; simply by themselves, usually by a UK standard shot measurement of 25ml, or mixed into a 'long drink' or cocktail. Given the wide range of cocktails, for simplicity we presented only a

generic cocktail representing 1 unit of alcohol. The number of units in the other drinks can be calculated by using the formula shown in equation (5).

$$\text{Units} = \text{Strength} \times \text{Volume} / 1000 \quad (5)$$

System responses. The calculator's responses to the user are based on two sets of information: (1) that provided by the user in answer to the questions posed by Jim the barman; and (2) data from the Alcohol-Attributable Fractions (AAF) for England, taken from a study by Jones (Jones et al., 2008). Alcohol-attributable fractions (AAFs) describe the percentage of incidents that would not occur in the absence of alcohol. The AAF is 1 for entirely attributable chronic conditions that would never occur in a world without alcohol. For all other chronic and acute conditions, the fraction is expressed as a decimal number between 0 and 1.

The study provides mortality and hospital admission data from 2005 for England, as well as AAFs for a wide range of acute and chronic injuries. Among the findings of this study, it reports that 3.1% (14,982) of all deaths in England in 2005 were attributable to alcohol consumption. Of these, men fare worse than women, with 4.4% of male deaths being attributable to alcohol, compared with just 2% for females. Depending on the person's age, risks are twofold: those under 35 years old are more at risk of acute injuries, while those over the age of 35 are more likely to contract or die from chronic injury.

The following figures show screenshots of the system in action. Figures 1 and 2 demonstrate different forms of user interaction in answering questions. In Figure 2, the user answers personal demographic information. In Figure 1 (shown earlier) the user is chatting to Jim the barman, responding to a question about his or her typical drinking behaviour by selecting drink icons and moving them onto Jim's tray.

The screenshot shows a cartoon barman character behind a bar. A form titled "Please enter your details below:" is overlaid on the right. The form contains fields for Age (years), Height (cm), Gender (Male), and Weight (kg). There are also checkboxes for "Metric" and "Imperial" units. A red "continue" button with a right-pointing arrow is at the bottom right of the form.

Figure 2: Screen requesting demographic data for use by risk calculation formulae.

Figures 3, 4 and 5 show examples of the system's response to the user. In Figure 3 the system tells the user what his Blood Alcohol Concentration is, reminding him of the

drinks he has consumed and how much time he took to drink them, and relating his BAC to the national guidelines for alcohol consumption.

Note that the user is also given the option to get more information: in this case about the concomitant risks or the likely symptoms of his level of inebriation.

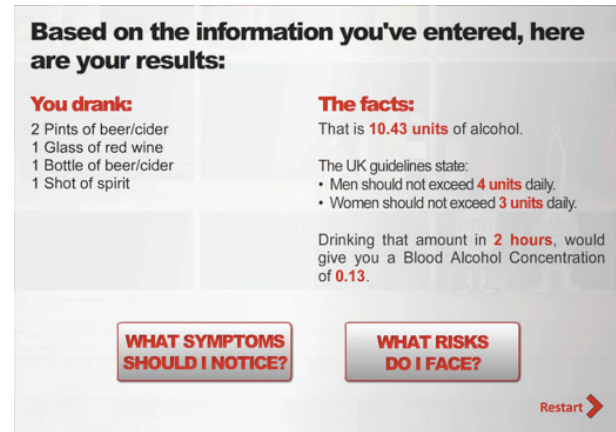


Figure 3: Display of BAC and units consumed in the Alcohol Risk Calculator

Figure 4 shows the system's response to the user clicking on the "What symptoms should I notice?" button in Figure 3. The screen display shows some of the symptoms typically experienced by individuals suffering from the same state of inebriation.

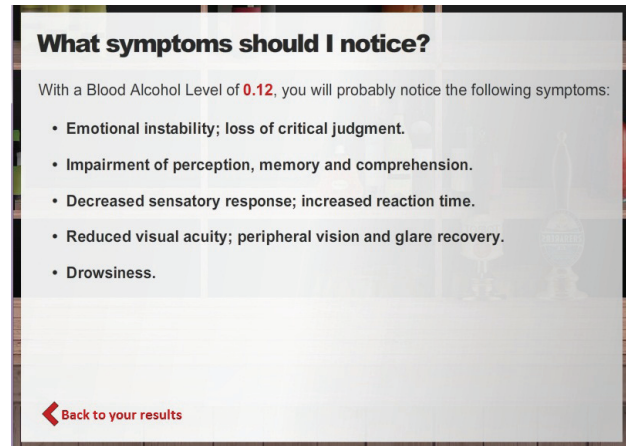


Figure 4: Results page showing range of symptoms induced by alcohol consumed.

Figure 5 shows the system's response to the user clicking on the "What risks do I face?" button in Figure 3. The user is presented with a mixture of graphical and text formats, with the key information highlighted, and with the combined use of natural frequencies and bar chart.

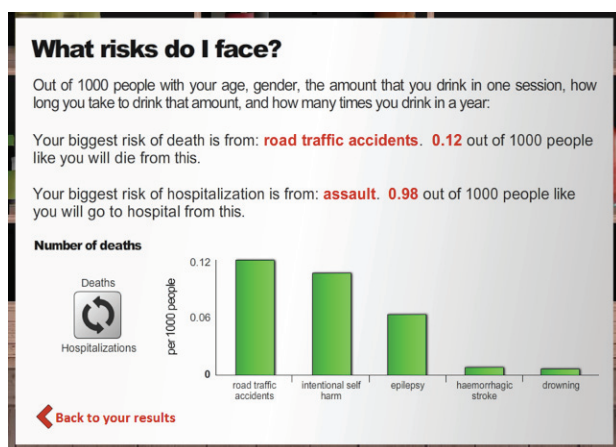


Figure 5: Results graph (bar chart) showing five top risks to life.

An Early Evaluation

We have conducted an early evaluation of the calculator, investigating attitudes to ease of understanding, enjoyability, engagement and whether the results were understood for six young adults (graduates) aged 21-26 (see Bissett, 2010). Each participant used the calculator on a laboratory laptop then completed the following paper-based questionnaire:

Did you understand how to use the program? All the participants said that they were able to understand how to use the program successfully.

Did you enjoy using the program? Four of the participants said that they enjoyed using the calculator, one remarking that they liked ‘Jim’ the barman, and another that “It’s quite fun!” Two participants were less enthusiastic although still positive, one commenting “In so far as one can enjoy a program like this, it’s different to many of this sort of calculator” thus implying the Alcohol Risk Calculator was relatively enjoyable for its genre.

Did you feel engaged with the program? The same two participants said they did not engage with the calculator. However, the other four indicated that they did find it engaging, one alluding to ‘Jim the bartender’ who provided an informal front to the system and made it ‘seem friendly’. One participant suggested that engagement might be improved by incorporating sound.

Did you understand the results of the program? Everyone said they understood the results, although one person stated they did not really understand what was meant by Blood Alcohol Concentration.

Summary. Despite its obvious limitations, this small study of reactions to the Alcohol Risk Calculator has already provided valuable insights for the next iteration of its design – especially through the criticisms received. For example:

- one person suggested that engagement would be enhanced with the inclusion of sound. An obvious

extension of this idea would be to make use of animated conversational agents;

- another user indicated they would like to know how the results were calculated – an issue of transparency. This, together with the above-mentioned comment on Blood Alcohol Concentration, could be addressed by incorporating links to explanatory information for key concepts; and
- two users indicated they found the risks displayed surprisingly low. We will discuss this in more detail below.

Discussion

This paper presents early work on an Alcohol Risk Calculator designed to appeal to young adults, set within a larger endeavour to communicate to young adults and teenagers the risks to health from binge drinking.

It is very difficult for teachers, doctors and parents to identify binge-drinkers while they are not engaged in the behaviour, and so the problem at an individual level often goes undetected. We hypothesise that teenagers will be willing to expose their binge-drinking behaviour to a computer program (compared to, say, the family doctor) and that they will be more truthful in their responses (for example, in parts of the UK binge-drinking is a ‘badge of honour’, and so teens are prone to exaggerating their consumption when reporting back to their peers).

Issues of confidentiality and privacy are obviously paramount in work of this kind, and this is also likely to affect both the take-up of the tool (willingness to use it) and the validity of the information that is imparted by the user (and the concomitant validity of the feedback from the system). On the other hand, teenagers make widespread use of social media sites to chat about their drinking and share photos of their latest drinking exploits with friends.

As mentioned before, our aim in developing an Alcohol Risk Calculator is to provide a test-bed for exploring the efficacy of AI-inspired solutions to communicating the health risks associated with binge-drinking to a target population of those most likely to engage in this type of behaviour – teenagers. Not surprisingly, our initial prototype has raised more questions than it has provided solutions. We touch on a selection of them here.

Our work will need to be evaluated on at least two strands. On the one hand, we will have to examine the efficacy of the tool as a mechanism for successfully communicating the risks to a given teenager arising from his or her binge drinking activity. On the other hand, will be the issue of efficacy of the tool as a health intervention for reducing binge-drinking among teenagers. These will require rather different types of treatment. For example, the first may involve comparative risk-comprehension studies with other forms of communication and other existing calculators, while the second will require longitudinal studies. Each of these will pose challenges of their own.

Another issue that concerns us is how can or should we address the short-term, hedonistic outlook that many binge-drinking teenagers seem to have? This view clearly affects their behaviour and so methods for getting them to appreciate the medium- to long-term effects on their health will clearly be important. AI-based solutions such as applying face- and body-morphing software for before-and-after pictures (this is what you'll look like in 5, 10, 20 years if you carry on drinking like this, compared to if you don't) may, we think, prove effective.

The findings of Sjöberg (2000), Henson et al., (2006) and Dillard, Midboe and Klein (2009) are particularly revealing in identifying the relationship between attitude and both alcohol use in particular and risk-taking in general. These findings suggest that potential targets for attitude, knowledge and (ultimately) behavioural change include changing optimism to realism, changing hedonistic present-time perspectives to future-time perspectives, and addressing high levels of risk denial, and these findings will further inform our future work within the framework of the Theory of Planned Behaviour (Ajzen, 1985), in particular through addressing the role of attitudes and norms in influencing intent. For example, Moreira, Smith and Foxcroft (2009) identify that peer influence is largely due to incorrect perceptions of attitudes and behaviours, and that how much an individual believes that their peers drink heavily will, in turn, influence the amount of alcohol that they themselves drink.

According to Kreuter et al. (1998) the more we understand about the relationship between these factors, the more accurately our interventions can be designed to influence behaviour in the desired direction; significantly, they point out that by ignoring these factors, we may inadvertently doom an intervention because it overlooks the attitudes and norms that influence intent and motivate behavior. There is evidence such misperceptions might be overcome by personalized normative feedback interventions, such as that proposed here, that can provide users with more accurate information about actual drinking norms (Walters, 2004).

Finally, there is the issue raised before of determining the most effective method of communicating risk. We know that some methods are better for some types of data than others. For example, line graphs are better for conveying trends than histograms etc. However, what is also clear is that following accepted wisdom may not always lead to the desired effect. An example in point is the use of absolute risk (e.g., 1 in 1000) and not relative risk (e.g., 10% increase), as proposed by Gigerenzer and his colleagues (2008). We see this at first hand in the reaction of some users (including some of the authors) to the information given in Figure 6: the risks appear to be almost negligible. The issue here is that absolute risks are typically small numbers and their corresponding numbers for relative changes will be big. On the other hand, we know that information on relative risk is more persuasive than absolute risk (Edwards et al 2002). An obvious

solution would be to provide both types of information. Comparison with everyday risks may also be very helpful.

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