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Measuring alcohol consumption while watching sport events: a feasibility and validity study comparing ecological momentary assessments and transdermal alcohol monitors

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\textbf{ABSTRACT}

\textbf{Background:} This feasibility and validity study aimed to evaluate and compare ecological momentary assessment (EMA) surveys and transdermal SCRAM-CAM monitors to measure drinking while watching Australian Rules Football (AFL).

\textbf{Methods:} During 29 events, 13 participants wore a SCRAM-CAM monitor while completing EMA surveys. Correspondence in the alcohol levels detected and correlation between the self-reported drinks and transdermal alcohol concentration (TAC) were measured. An exit survey assessed participant experiences.

\textbf{Results:} Alcohol consumption was self-reported on 24 (83.3\%) of 29 events, with an average of 5.0 standard drinks consumed over 2.3 hours. Correspondence in the levels of alcohol detected was good at 0.62. TAC curves showed large-sized correlations to the number of self-reported drinks ($r=0.55$–$0.67$). Some participants noted discomfort from the SCRAM-CAM, whilst others reported annoyance completing EMA surveys during a match.

\textbf{Conclusions:} EMA surveys are a cost-effective method for collecting information on drinking as well as contexts and other factors such as harms. A clear benefit of the SCRAM-CAM is the ability to provide detailed information on intoxication trajectories. We suggest that a combination of the two methods will inform the most meaningful approaches for prevention and intervention strategies to reduce harmful drinking among sport spectators.

\textbf{Introduction}

International research has identified a connection between heavy drinking and sports spectatorship (Estrada & Tryggvesson, 2001; Nelson & Wechsler, 2003; Palmer, 2011). Sports spectators consume more alcohol than non-sports spectators (Nelson & Wechsler, 2003), and studies have identified a link between excessive alcohol use and alcohol-related harm, violence, and crime among sport spectators (Glassman et al., 2007; Kalist & Lee, 2016; Kingsland et al., 2013; Palmer, 2011). High rates of alcohol-related ambulance and emergency department attendances are recorded after major Australian Rules Football (AFL) matches (Lloyd et al., 2013), which is the most popular sport in Australia (Australian Bureau of Statistics, 2010). However, to our knowledge, no studies have investigated quantities of alcohol consumed while watching AFL matches. This is important because we need to know how much, and in what ways, AFL spectators are consuming alcohol to meaningfully inform policy and prevention strategies.

To measure quantities of alcohol consumed, alcohol researchers most commonly use self-reported data (Livingston et al., 2018). However, most self-reports are completed retrospectively over longer periods and are subject to recall bias, which makes them ill-suited to measure drinking at an event level (Kuntsche & Labhart, 2012). Ecological Momentary Assessments (EMA) are better suited to event level research, by asking participants to report data on their drinking in the moment (Kuntsche & Labhart, 2013, 2014). It has been observed that EMA methods record higher alcohol consumption than retrospective methods, as well as higher agreement with breathalyzer data (Mun et al., 2021). Notably, EMA surveys can be collected using smartphone applications, making them affordable and convenient to implement (Kuntsche & Labhart, 2013). However, collecting real-time EMA data requires active and regular participation, which can influence participants’ willingness to engage (Piasecki, 2019). EMA is also subject to some of the typical challenges of self-report, including missing data, participant error and recall bias (particularly during higher consumption events).

When it comes to objective measures of intoxication during sporting events, researchers have commonly used breathalyzer data. For example, in the US, when 747 baseball spectators were cross-sectionally breathalyzed upon entrance to the match and then again during the match, 41\% tested positive...
for alcohol, with 8.4% testing at or above the US legal breath alcohol concentration (BrAC) driving limit of 0.08% (Wolfe et al., 1998). Comparable results were found in a sample of 4420 Swedish Premier Football League spectators, with 46.8% testing positive for alcohol during the match, and 8.9% testing above 0.1% BrAC (Durbeej et al., 2017). While providing an objective measurement of intoxication, breathalyzers only measure alcohol at a specific time-point, missing information on drinking patterns over time. They also require active researcher engagement and are thus costly and time intensive to administer.

Transdermal alcohol monitors, such as the Secure Continuous Remote Alcohol Monitor Continuous Alcohol Monitoring (SCRAM-CAM™; Alcohol Monitoring Systems Inc., Highlands Ranch, CO), are a promising tool to monitor drinking objectively and continuously over several days without active participation from the participant. These monitors measure alcohol consumption by analyzing the alcohol that is secreted through skin. SCRAM-CAMs are not as accurate as breathalyzers. They have been found to detect approximately 73% of 690 self-reported drinking episodes (Barnett et al., 2014), and 65% of 324 self-reported drinking days (Karns-Wright et al., 2018). Further, previous research using SCRAM-CAMS has reported user discomfort (Caluzzi et al., 2019), and given they were originally developed to monitor drinking among offenders (Flango & Cheesman, 2009; Voas et al., 2011), some participants have reported concern about wearing the monitor in public (Marques & Scott McKnight, 2007). Finally, due to the ethanol transportation through the skin being physiologically complex, they can exhibit low sensitivity to lower-level alcohol consumption (Roache et al., 2019), and significant delays in alcohol detection have been found, with lag times reported up to four hours (Fairbairn & Kang, 2019; Karns-Wright et al., 2017; Leffingwell et al., 2013).

In a recent review of transdermal technology, Fairbairn and Bosch (2021) suggested that additional research is required to explore the validity of transdermal monitors within real-world contexts and in large and diverse populations of drinkers. Along this line, studies measuring real-time alcohol consumption with the use of EMA and transdermal monitors have found a correspondence of 73% in a homeless population (Mun et al., 2021) and 86% in a young adult population (Simons et al., 2015) and a significant correlation between the two methods (Mun et al., 2021). Among young adults who wore the monitors for five days, Russell et al. (2022) identified a strong association between transdermal alcohol concentration (TAC) and daily EMA reports, but only a moderate association with episodic EMA data. Norman et al. (2020) tested the feasibility of EMA and transdermal monitors when measuring alcohol consumption during an event (a music festival), recommending the use of both measurements to provide the most comprehensive overview of intoxication. How this translates to sport spectators who are watching a sporting event in real-time, and not wanting to miss the events of the game, is unclear.

At present, there is no one-size-fits-all solution to measuring drinking in field studies. This means investigators must make considered choices concerning their need for precision of alcohol dose estimates, coverage of drinking episodes, and assessment burden (Piasecki, 2019). Given sport spectatorship presents an arena for heavy drinking and possible alcohol-related harms, it is important to understand how sports spectators consume alcohol while watching sporting matches to inform policy and prevention strategies. However, there are clearly challenges with regards to the best way to collect and measure alcohol consumption while watching sport. Our primary aim is to investigate the feasibility of EMA surveys and SCRAM-CAM monitors in measuring alcohol consumption during sporting event drinking occasions. In order to determine the feasibility of future field research using these methodologies our secondary aim is to provide preliminary indications of the validity of these two measures. This is central to determining the utility of these methods for future field research; however, we acknowledge that only limited inferences can be made about validity given the limitations of our sample size.

Material and methods

Study recruitment

Our predetermined sample size for this feasibility and validity study was 15 participants, given we had limited access to a maximum of 15 SCRAM-CAM monitors. This was deemed sufficient given the feasibility focus of the study. We used a street intercept approach at Melbourne’s largest AFL stadium, the Melbourne Cricket Ground (MCG). Researchers engaged spectators entering the MCG to watch an AFL match. Prospective participants completed a screening survey and were contacted later by phone for in-depth screening and detailed study information.

Inclusion criteria were: being aged 18 years or older; regular consumption of alcohol while watching AFL; watching their AFL team at least fortnightly; owning a smartphone; and being able to read and understand English. Exclusion criteria included medical conditions that prohibited use of the SCRAM-CAMs (e.g., circulation problems, pregnancy). Written consent was collected from participants. The study was approved by the Human Research Ethics Committee at La Trobe University (HEC18524).

Study procedure

Participants were asked to nominate three consecutive weeks where they planned to watch their AFL teams’ matches (either at the stadium or another location). Twelve participants participated during all three matches, two participants participated during two matches, and one participant during one match, resulting in data collection for 15 participants and a total of 41 days a match took place. Participants wore a SCRAM-CAM ankle monitor for two to three days during the weekend (fitted and removed by researchers) and downloaded a smartphone application for the EMA component (LifeDataTM Inc.). AFL matches are played on Friday nights, Saturdays, and Sundays, with the earliest match time beginning 1.10 pm and the latest being 7.50 pm. AFL matches have four quarters of approximately half an hour in duration. Surveys were tailored to each participant and sent ten
minutes before the match, at quarter time break, half-time break, three-quarter time break, after the match, and then every two hours until midnight. The maximum number of surveys a participant would receive was 10 per day. Participants were reimbursed AUD$50 per weekend, provided at the monitor removal appointment.

**Measures**

**Self-reported events**

The survey prior to the match asked how many standard drinks (10 g of ethanol) they had consumed up until that time. Participants were provided with an image displaying the number of standard drinks in typical beverages. All following surveys asked the number of standard drinks since the last survey. Out of the total 41 matches, missing data occurred for 11 matches (26.2%), due to missing the initial survey which then did not trigger match-day surveys (unknown whether this was caused by non-completion or technical issues), resulting in a total of 30 self-reported events from 13 participants.

The number of drinks was a sum of the reported standard drinks across all surveys completed over the self-reported event. The only previous available study looking at correspondence between daily self-reports and TAC data classified both the self-reported drinking and TAC data into categories to improve interpretation (Karns-Wright et al., 2018). Using these same methods, drinking was categorized as follows: None: no drinking; Moderate: >0 drinks and <= 5 drinks for men (<= 4 drinks for women); and Heavy: >5 drinks for men (>4 drinks for women).

**TAC events**

TAC events were identified following the nine TAC research rules as developed by Roache et al. (2019). A TAC event is defined as a non-zero (positive) TAC reading preceded and followed by at least two zero TAC readings (Roache et al., 2019). During the 41 days, participants reported viewing an AFL match, a total of 45 TAC events were identified, with some multiple TAC events within a single day. Following the TAC research rules (Roache et al., 2019), 417 individual TAC datapoints were excluded because of an inter-reading interval smaller than 20 minutes instead of the regular 30-minute interval (n = 397), or due to steep reading-to-reading slope rises (>0.182 g/dl/hour) or drops (<-0.126 g/dl/hour) (n = 20). Twelve full TAC events were removed due to: an implausibly high start TAC reading (n = 1), the event consisted of a single TAC reading (n = 9), the event had all negative slopes after the first TAC reading (n = 1), and because the peak TAC was below 0.01 g/dl, spanning for more than 240 minutes (n = 1). This resulted in a total of 33 TAC events from 15 participants.

As with self-reported events, TAC events were classified following the categories used by Karns-Wright et al. (2018): None: 1 non-zero TAC readings; Low: 3 or more TAC readings >0 but no readings >0.01 g/dl; Moderate: ≥3 TAC readings above 0 and ≥1 TAC reading above 0.01 g/dl but <2 readings above 0.02 g/dl; Heavy: 2 or more TAC readings >0.02 g/dl.

Finally, peak TAC was calculated by taking the highest point in the TAC curve. Area under the curve (AUC) was computed using the trapezoidal rule (Dodd & Pepe, 2003). In the event that there were multiple TAC events, the sum of the AUC was calculated.

**Exit survey**

After the final AFL match participants were asked to complete an exit survey to understand their experiences of both the EMA and SCRAM-CAM components. This consisted of five open-ended questions which took approximately five minutes to complete.

**Data analysis**

From the 30 self-reported events (n = 13) and 33 TAC events (n = 15), we only included data where we could match the EMA and TAC findings resulting in a final sample of 29 drinking events from n = 13 participants. The data was processed in R version 4.0.2. and then further analyzed using IBM SPSS Statistics for Windows, version 27 (IBM Corp., Armonk, N.Y., USA). Descriptive statistics were calculated to measure alcohol consumption during the drinking event. The time of a self-reported drinking event was measured from the first survey the participant reported alcohol consumption until the last survey completed. The time window of the TAC event was measured from the zero TAC value preceding the first positive TAC value, to the next zero TAC value or the last point of the TAC event. The intraclass correlation coefficient (ICC) was used to test correspondence. A two-way random-effect model based on single ratings and absolute agreement assessed the correspondence between the self-reported and TAC events. Interpretation was as follows: below 0.40, poor; between 0.40 and 0.59, fair; between 0.60 and 0.74, good; 0.75 or above, excellent (Cicchetti, 1994). Pearson’s correlation coefficients were computed to analyze the relationship between the TAC curve characteristics (peak and AUC) and the total self-reported number of drinks per event. A Pearson’s r correlation of 0.10, 0.30, 0.50, and 0.70, was considered to indicate a small, medium, large, and very large effect (Cohen, 2013; Maher et al., 2013). The content of the exit surveys was analyzed thematically and the quantitative frequency of themes was collated (Züll, 2016).

**Results**

**Participant demographics**

Table 1 shows the participant demographics of the final sample (N = 13).

**Drinking events reported and identified**

The average number of drinks reported across the 29 drinking events was 5.0 standard drinks (Table 2). These drinks were
reported to be consumed in 2 hours and 15 minutes on average. While the transdermal drinking events lasted an average of 5.5 hours, they could last up to 27.5 hours.

Correspondence between self-reported and TAC events

Overall, the ICC between the self-reported and TAC events was considered to be good at 0.62.

Out of the 29 matched events, positive TAC events (low, moderate, or heavy) occurred for 20 (69.0%) events and self-reported drinking (moderate and heavy) occurred for 25 events (81.0%) (Table 3). This means that for nine events, there was no TAC event (SCRAM-CAM did not detect any alcohol) and for four events the participants did not report any drinking (Table 3).

When participants did not report any drinking, moderate TAC events were detected for 40% of the events. When heavy drinking was reported, TAC detected heavy drinking for 88.9% of events and with one occasion of moderate drinking detected (11.1%). All self-reported heavy drinking events were therefore detected by the SCRAM-CAM.

Correlations between TAC characteristics and self-reported number of drinks

Correlations between AUC and the total number of self-reported drinks were positive and large-sized; r = 0.549. Peak TAC values also showed a large-sized correlation with the self-reported number of drinks; r = 0.673 (Figure 1).

Exit survey

The main critical feedback offered by participants was divided into those who found the SCRAM-CAM uncomfortable and those who had issues with either the survey application or the questions in the EMA component. Three participants had no issues with the SCRAM-CAM monitors, three indicated it was very uncomfortable, and the remainder noted it was somewhat uncomfortable (although most noted that they had adjusted to a level of comfortability by the second week). Two participants had difficulty getting the survey application to function properly for them, one participant said the questions became harder to answer after drinking more alcohol, and another suggested that it was annoying to have to answer questions during the match.

Discussion

With regards to empirical findings, according to EMA data, alcohol was consumed during 24 (83.0%) of the 29 events, with the SCRAM-CAM detecting alcohol for 19 (69.0%) events. Participants reported drinking an average of 5.0 standard drinks over 2.3 hours while watching AFL, which is considered risky drinking (defined by the Australian government as more

Table 1. Participant demographics.

<table>
<thead>
<tr>
<th></th>
<th>N = 13</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sex (% female)</td>
<td>2 (15.4%)</td>
</tr>
<tr>
<td>Age (years)</td>
<td>32.1 (13.1)</td>
</tr>
<tr>
<td>Ethnicity</td>
<td></td>
</tr>
<tr>
<td>Caucasian</td>
<td>12 (92.3%)</td>
</tr>
</tbody>
</table>

Frequency of watching an AFL match

Once a week or more: 11 (84.6%)
Once a fortnight to once a month: 2 (15.4%)

Level of risky drinking

Lower risk: 0 (0.0%)
Moderate risk: 4 (30.8%)
High risk: 6 (46.2%)
Possible dependence: 3 (23.1%)

This table shows the demographics of the final sample N = 13 participants. Data is reported as the number of participants (percentage of final sample), except from age which is reported as the mean (standard deviation).

*Level of risky drinking classification is determined by using AUDIT-C scores. Women; 0–2, 3–5, 6–7, 8–12, is categorized as low, moderate, high risk, and possible dependence, respectively.

Men; 0–3, 4–5, 6–7, 8–12, is categorized as low, moderate, high risk, and possible dependence, respectively.

Table 2. Drinking events reported and identified: means and range.

<table>
<thead>
<tr>
<th></th>
<th>Mean (SD)</th>
<th>Median</th>
<th>Range</th>
</tr>
</thead>
<tbody>
<tr>
<td>EMA</td>
<td>5.0 (4.9)</td>
<td>2.0</td>
<td>0–20</td>
</tr>
<tr>
<td>Number of drinks</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Time of event (hrs)</td>
<td>2.3 (2.7)</td>
<td>1.5</td>
<td>0–9</td>
</tr>
<tr>
<td>TAC</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Peak AUC (0.085)</td>
<td>0.009</td>
<td>0.000–0.316</td>
<td></td>
</tr>
<tr>
<td>AUC</td>
<td>0.352 (0.873)</td>
<td>0.020</td>
<td>0.000–3.900</td>
</tr>
<tr>
<td>Time of event (hrs)</td>
<td>5.6 (6.4)</td>
<td>4</td>
<td>0–27.5</td>
</tr>
</tbody>
</table>

Shown are means with standard deviations.

Table 3. Agreement between self-reported and TAC drinking categories.

<table>
<thead>
<tr>
<th></th>
<th>None</th>
<th>Moderate</th>
<th>Heavy</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>TAC events category</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>None</td>
<td>2 (40.0%)</td>
<td>7 (46.7%)</td>
<td>0 (0.0%)</td>
<td>9 (31.0%)</td>
</tr>
<tr>
<td>Low</td>
<td>1 (20.0%)</td>
<td>3 (20.0%)</td>
<td>0 (0.0%)</td>
<td>4 (13.8%)</td>
</tr>
<tr>
<td>Moderate</td>
<td>2 (40.0%)</td>
<td>2 (13.3%)</td>
<td>1 (11.1%)</td>
<td>5 (17.2%)</td>
</tr>
<tr>
<td>Heavy</td>
<td>0 (0.0%)</td>
<td>3 (20.0%)</td>
<td>8 (88.9%)</td>
<td>11 (37.9%)</td>
</tr>
<tr>
<td>Total</td>
<td>5 (17.2%)</td>
<td>15 (51.7%)</td>
<td>9 (31.0%)</td>
<td>29</td>
</tr>
<tr>
<td>AMS confirmed</td>
<td>0 (0.0%)</td>
<td>0 (0.0%)</td>
<td>7 (77.8%)</td>
<td>7</td>
</tr>
</tbody>
</table>

Numbers represent the number of drinking events detected by the SCRAM-CAM, or self-reported. Percentages show the percentage of TAC events in a certain self-reported category.

Pearson Chi-square analysis: χ² (6) = 17.1, p = .009, phi coefficient is considered strong (ϕ = 0.767).

TAC events were classified into the following categories: None: >1 but <2 non-zero TAC points; Low: 3 or more TAC readings>0, but no readings >0.1 g/dl; Moderate: ≥3 TAC points above 0 and ≥1 TAC point above 0.01 g/dl but <2 points above 0.02 g/dl; Heavy: 2 or more readings >0.02 g/dl.

Self-reported Classifications: None: no drinking; Moderate: >0 drinks but <5 drinks for men/4 for women; and Heavy: ≥5 drinks for men/ >4 drinks for women.
than 4 standard drinks [NHMRC, 2020]). This is congruent with studies measuring moderate to high levels of intoxication as measured with breathalyzers among sport spectators in Sweden and the United States (Durbeej et al., 2017; Wolfe et al., 1998).

With regards to feasibility and preliminary validity, there are several considerations to bear in mind. Using the TAC criteria as recommended by Karns-Wright et al. (2018) increased the sensitivity to lower alcohol consumption and resulted in the SCRAM-CAM detecting more than half of the moderate self-reported drinking events. In total, of the 24 self-reported drinking events, a positive TAC event was detected for 16 (66.6%) of these events. Good correspondence between self-reported and TAC events was identified, with an ICC coefficient of 0.62. A previous study reported that 86% of the self-reported drinking events were detected using a WrisTAS wearable transdermal device (Simons et al., 2015), however, this is the first study to test correspondence between EMA and transdermal methods during a sport event. It is important to note that a significant amount of moderate drinking was still missed by the SCRAM-CAM and higher correspondence was found with heavy drinking events. These findings suggest that the SCRAM-CAM monitors may only be useful for studies concerned with detecting heavier drinking practices.

On the other hand, during heavy drinking episodes the SCRAM-CAM can potentially measure alcohol when the ability to self-report is decreasing. Previous research has found that heavy drinking can increase errors in self-reported drinking (Davis et al., 2010; Livingston & Callinan, 2015). Indeed, for 40.0% of the detected TAC events categorized as moderate participants reported they did not drink, and for a further 18.0% of the detected TAC events categorized as heavy, participants reported only moderate drinking events. It is unclear whether these discrepancies resulted from problems with self-reporting or false-positive TAC events (e.g., alcohol being spilled near the monitor or alcohol in the carpet). Further research is needed to determine the magnitude and direction of these disagreements to come to stronger conclusions.

In line with previously reported limitations of the use of EMA surveys (Piasecki, 2019), the main issue reported by participants was the response burden. Some participants had trouble with the functionality of the application, completing surveys with increased alcohol consumption, and having to complete the surveys when watching an AFL match. However, due to a limitation in the design of the EMA surveys, most missing data was due to participants missing the first survey, resulting in subsequent surveys not being triggered. This could have been solved if participants had the option to initiate the surveys during a game themselves. Unfortunately, due to the choice of EMA application software, this was not possible.

Given that the EMA application could easily be downloaded on participants’ smartphones without any support from the researchers, EMA surveys are likely to be more suitable than SCRAM-CAMs for collecting data from sports spectators in larger studies. In contrast, SCRAM-CAMs were burdensome to fit and remove for each session, and their high cost meant we had to limit our sample size. Moreover, TAC detection shows substantial delays due to the way ethanol is excreted through the skin (Karns-Wright et al., 2018). This makes it harder to know when a participant has started drinking. Though some participants reported discomfort, congruent with both Australian festival attendees (Caluzzi et al., 2019) and a young adult population in the United States (Marques and McKnight 2007), most adjusted to a certain level of comfort by the second week.

This study provides the first investigation of quantitative methods measuring alcohol consumed in an AFL spectator sample, however some limitations are present. Notably, the participant sample of only 29 usable drinking events with matched EMA and TAC data from 13 participants. We only had access to 15 monitors given the high cost per device and additional daily monitoring fees which means we can only suggest preliminary validity, with further research required. TAC drinking events are difficult to interpret in terms of the amount consumed, however researchers are currently developing software to convert TAC data to BrAC estimations which could lead to a better correspondence and understanding of the TAC data (van Egmond et al., 2020; Leffingwell et al., 2013; Luczek et al., 2015). Finally, due to response burden, participants only self-reported their drinking up until midnight.

Figure 1. (a) Scatterplot of AUC values on self-reported number of drinks, (b) Scatterplot of TAC peak values on self-reported number of drinks.
Implications and future directions

Given higher rates of ambulance and emergency department presentations after AFL matches (Lloyd et al., 2013), accurate and nuanced information about the relationship between sports spectatorship, alcohol consumption, and alcohol-related harms is necessary to inform meaningful approaches to prevention and intervention. This feasibility and validity study found that it is feasible to monitor alcohol consumption using both EMA and TAC monitors in an AFL spectator sample. The next steps are to investigate consumption patterns in a larger sample (allowing for additional covariates) and investigate the relationship between heavy drinking while watching sport and resultant experience of harms. Using EMA surveys will enable researchers to collect more information on drinking contexts, such as location or company, and any harms that might have occurred. A clear benefit of the SCRAM-CAM is the ability to provide detailed information on intoxication levels and drinking patterns, by studying the absorption and elimination rates. This information will deepen our understanding of the time-sensitive relationship between AFL sport spectatorship, drinking patterns, contexts, and alcohol-related harms. We suggest that a combination of the two methods will inform the most meaningful approaches for prevention and intervention strategies to reduce harmful drinking among sport spectators.

Disclosure statement

No potential conflict of interest was reported by the author(s).

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