Self-report reliability and symptomatology of habitual caffeine consumption

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1 A large body of research on the demography of caffeine use and its potential health consequences has been undermined by the absence of empirical data on the reliability of retrospective self-reports of caffeine consumption.

2 The principal aim of the present study was to use standard bioanalytic methods to assess the reliability of subjects' self-reported caffeine use. Saliva samples were obtained from 142 first- and second-year medical students and assayed for caffeine and paraxanthine.

3 Self-reported caffeine use was found to be significantly correlated with salivary caffeine ($r = 0.31$, $P < 0.001$) and paraxanthine ($r = 0.42$, $P < 0.001$), thereby providing qualified support for the use of questionnaires to estimate patterns of caffeine consumption.

4 A secondary aim of the study was to extend previous research concerning the symptomatology of caffeine use by examining the association between caffeine exposure and a variety of measures of somatic and psychological health. Caffeine consumption was reliably associated with the self-reported occurrence of somatic symptoms, but not psychological well-being.

Keywords caffeine self-report questionnaires saliva assays somatic symptoms psychological well-being

Introduction

Several recent literature reviews highlight a growing concern that caffeine may be deleterious to health (e.g., Bruce & Lader, 1986; James & Stirling, 1983; Sawyer *et al.*, 1982; Snyder & Sklar, 1984; Wells, 1984). For example, caffeine has been examined as a factor in the development of cardiovascular disease (Curatolo & Robertson, 1983), for possible teratogenic effects (James & Paull, 1985), and as a potential carcinogen (Grice, 1984). In addition, the American Psychiatric Association (1980) has determined that 'caffeine intoxication' or 'caffeinism' represents a distinct diagnostic category of psychiatric disorder. Attention has also been given to the possible association between caffeine and various pre-

morbid (i.e., subclinical) symptoms of somatic and psychological distress (e.g., Greden *et al.*, 1978; James & Crosbie, 1987; James *et al.*, 1987).

The effects of caffeine may be broadly differentiated into *chronic* and *acute*. While acute effects may be directly observed by administering a caffeine 'challenge' in the laboratory (e.g., Bruce *et al.*, 1986), no equally straightforward method exists for examining the effects of chronic caffeine exposure. Although some prospective experimental manipulations of chronic caffeine consumption have been conducted (e.g., Rapoport *et al.*, 1984), most investigations of chronic effects have relied on retrospective self-

reports of caffeine intake. Typically, a questionnaire is used to elicit information about subjects' caffeine-consuming habits, and these details are examined in relation to various measures of somatic and/or psychological health. While this general approach offers an efficient and potentially important method for elucidating the health consequences of habitual patterns of caffeine consumption, the value of such studies is undermined by the fact that to date no empirical data have been published on the reliability of retrospective self-reports of caffeine consumption.

A large body of research on the demography of caffeine consumption (e.g., Barone & Roberts, 1984) and its potential health consequences (e.g., James & Stirling, 1983) has been seriously confounded by the failure of researchers to employ objective measures of caffeine exposure. For example, apparent differences in caffeine consumption between different studies and different population samples may reflect actual differences in usage (Barone & Roberts, 1984) or error variance in self-reports of caffeine use. Similarly, apparent inconsistencies in the reported relationship between caffeine use and particular health problems such as cardiovascular disease may be indicative of the complexity of underlying associations (e.g., Curatolo & Robertson, 1983) or the inherent unreliability of self-reports of caffeine consumption.

The problem of self-report reliability is not, of course, unique to the assessment of the health consequences of caffeine. Just as bioanalytic techniques for directly quantifying levels of drug exposure have become an integral part of research on other substances (e.g., alcohol, nicotine), objective methods of quantification are also essential to advance our understanding of caffeine and its effects. One aspect of the problem was addressed in a recent study by James *et al.* (1988) in which standard bioanalytic procedures were used to check the reliability of self-reports of caffeine intake amongst a group of chronic 'heavy' users of caffeine. Each subject maintained a comprehensive caffeine 'diary' during the course of an 8-week, caffeine-reduction regimen. Plasma assays of caffeine and its principal demethylated metabolites (paraxanthine, theobromine, and theophylline) were obtained from blood samples obtained at weekly intervals. The assay results indicated that in general subjects were very reliable in reporting their caffeine intake ($r = 0.95$ and above). However, the caffeine diary presents a different set of demands than that posed by a questionnaire on caffeine-consuming habits. The caffeine diary is detailed, specific, ongoing (i.e., prospective), and allows considerable practice for subjects to achieve greater

self-report accuracy over time. In contrast, respondents to retrospective questionnaires usually do not receive any specific training, and their self-reports are typically brief and global. As such, the James *et al.* (1988) study may provide little indication of the reliability of estimates of caffeine consumption that are obtained from retrospective questionnaires.

Hence, the principal aim of the present study was to use standard bioanalytic methods to assess the reliability of subjects' retrospective self-reports of caffeine consumption. The biological material chosen for this study was saliva rather than blood. Recent research has shown that caffeine concentrations in saliva are highly correlated with plasma levels ($r = 0.98$) and that the elimination half-life of caffeine is comparable for the two liquids (Setchell *et al.*, 1987; Zylber-Katz *et al.*, 1984). However, saliva seems to offer certain advantages over blood for use in questionnaire surveys. The process of extracting blood via venepuncture requires trained personnel, and is experienced by most subjects as being at least mildly aversive. Saliva is more easily and economically obtained, the process is non-invasive, and most subjects are likely to find it less discomforting than providing blood. A secondary aim of the study was to extend previous research concerning the symptomatology of habitual caffeine use by examining the association between self-reported caffeine intake and a variety of measures of somatic health and psychological well-being.

Method

Subjects

Subjects were first- and second-year medical students at St George's Hospital Medical School, London University. Students were informed that participation was strictly voluntary, and that they were free to withdraw from the study at any stage without penalty. They were offered £2 for participating, and 142 agreed to do so (acceptance rate in excess of 80%). The sample consisted of 47 females (33%) and 95 males (67%), and ages ranged from 18 to 26 years with a mean of 19.2 years.

Procedure

Although plasma caffeine levels typically increase throughout the day (as a consequence of the intermittent consumption of caffeinated foods), levels tend to plateau by late afternoon and remain relatively stable into the evening. Since

the best single-sample estimate of daily caffeine intake has been shown to be that which is obtained at approximately 17.00 h (Lelo *et al.*, 1986a), subjects were tested shortly after 17.00 h. They were tested in two cohorts consisting of separate first- and second-year lecture groups of roughly equivalent size.

Sources of dietary caffeine

Caffeine consumption was estimated on the basis of subjects' responses to the Symptom Substance Questionnaire (SSQ).¹ The SSQ, which was designed specifically for caffeine research, provides a measure of daily caffeine intake based on estimates of the caffeine content of caffeinated beverages provided by Barone & Roberts (1984). However, since Barone & Roberts (1984) based their estimates on servings of 150 ml, their figures require adjustment. A cup-size of 225 ml appears to be more representative of typical servings of caffeinated beverages (Stavric *et al.*, 1988). Accordingly, total daily consumption in the present study was based on the following estimates: 125 mg per cup for brewed coffee, 90 mg per cup for instant coffee, 4.5 mg per cup for decaffeinated coffee, 60 mg per cup for tea, 20 mg per glass and 40 mg per can for cola drinks, and 5 mg per cup for chocolate drinks (e.g., cocoa, hot chocolate). Previous research has shown that the SSQ possesses good overall measurement properties (James & Crosbie, 1987; James *et al.*, 1987). However, in common with previous caffeine questionnaires, the reliability of the SSQ as a measure of caffeine intake had not been determined previously.

Saliva assays

Mixed saliva samples (approximately 5 ml) were collected over a 10 to 20 min period by direct and continuous unstimulated salivation into a plastic specimen container. The samples were stored at -20°C until assayed for caffeine and paraxanthine using a previously described high performance liquid chromatography (h.p.l.c.) procedure (Scott *et al.*, 1984). The sensitivity limits for caffeine and paraxanthine were 200 and 100 ng ml^{-1} , respectively. The mean overall coefficient of variation for within batch and between batch precision for caffeine determination were 3.9% and 4.6%, respectively. Corresponding values for paraxanthine were 4.1% and 4.1%. Parax-

anthine was measured because (a) it is the principal metabolic product of caffeine (Lelo *et al.*, 1986b), (b) it correlates better with observed caffeine intake than other major demethylated metabolites (theobromine, theophylline) (Lelo *et al.*, 1986a), and (c) it has been found to produce slightly better correlations with diary records than those produced by plasma caffeine (James *et al.*, 1987). The last of these findings is consistent with evidence concerning the pharmacokinetics of caffeine and paraxanthine. Since the formation rate of paraxanthine from caffeine is similar to its elimination rate by hepatic metabolism, plasma concentrations of paraxanthine show less variability during a 24 h period than caffeine (Lelo *et al.*, 1986a). As such, it is to be anticipated that the paraxanthine concentration in a single sample of fluid might provide a more reliable index of an individual's overall exposure to caffeine.

Other substances, somatic and psychological health

Cigarette smoking, and to a lesser extent the consumption of alcohol, have frequently been found to be associated with caffeine use (e.g., Istvan & Matarazzo, 1984). It is therefore desirable that usage of all three substances be assessed when the effects of one or other is examined, due to the possibility that the effects of these three widely-consumed drugs might be confounded. Hence, in addition to caffeine, the SSQ also provides an estimate of cigarette and alcohol usage. In addition, the questionnaire includes two indices of somatic health: a nine-point Likert scale indicating general physical health, and a somatic symptom checklist. The previous version of the SSQ contained 24 symptoms, derived on the basis of knowledge about the pharmacological action of caffeine (Rall, 1985). Although the 24-item checklist was found to be predictive of caffeine use (James & Crosbie, 1987; James *et al.*, 1987), an attempt was made in the present study to further develop its predictive capacity by sampling a broader range of symptoms. Hence, the original list was expanded to 60 items by including physical symptoms and bodily sensations surveyed by Pennebaker (1982) in his work on the psychology of physical symptoms. Subjects were asked to indicate the symptoms which 'on average' they experienced 'once or more a month'. Finally, psychological well-being was assessed by having subjects complete the State-Trait Anxiety Inventory (STAI) (Spielberger *et al.*, 1983) and the 13-item version of the Beck Depression Inventory (BDI) (Beck & Beck, 1972).

¹Copies of the SSQ may be obtained from Jack E. James.

Results

Caffeine exposure

Mean self-reported caffeine intake for the 142 participants was 327 mg day⁻¹, ranging from zero to 1055 mg day⁻¹. Table 1 shows the mean, standard deviation, and percentage contribution of each of the six caffeine-containing beverages to total caffeine intake. It can be seen from Table 1 that the principal source of caffeine was instant coffee, followed by tea. These two beverages accounted for 89% of daily caffeine intake, while brewed coffee and cola drinks accounted for virtually all of the remainder. The caffeine consumed in chocolate drinks and decaffeinated coffee was found to be negligible.

Table 2 provides descriptive statistics, and product moment correlation coefficients for age, gender, and the three measures of caffeine exposure (total self-reported caffeine, and salivary concentrations of caffeine and paraxanthine). All three measures of caffeine exposure were significantly intercorrelated. The strongest correlation was between the two salivary methylxanthine measures ($r = 0.69$, $P < 0.001$), followed respectively by the two correlations that self-reported caffeine yielded with paraxanthine ($r = 0.42$, $P < 0.001$) and caffeine ($r = 0.31$,

$P < 0.001$). In addition, gender was significantly correlated with salivary caffeine ($r = 0.19$, $P < 0.05$), but not with either of the other two measures of caffeine exposure.

It can be seen from the means and standard deviations shown in Table 2 that the three measures of caffeine exposure may have been positively skewed. Tests of significance against the normal distribution indicated that self-reported caffeine intake was not significantly skewed ($S = 0.28$, $P > 0.05$), although a histogram of this variable showed that it was bimodal. This feature is consistent with population surveys (e.g., Barone & Roberts, 1984) in that a proportion of subjects were found to be virtual non-consumers of caffeine while the remainder of the sample (i.e., the regular consumers) reported consumption levels that were roughly normally distributed around a mean intake of approximately 350 mg day⁻¹. The distributions were significantly skewed for salivary caffeine ($S = 0.71$, $P < 0.001$) and paraxanthine ($S = 1.05$, $P < 0.001$), but neither showed any pronounced bimodality. Since skewness in distribution may cause distortion of Type 1 error rate and instability in estimates of regression coefficients (Tabachnick & Fidell, 1983), logarithmic transformations of salivary caffeine and paraxanthine were employed in a re-analysis of the results. However, since the re-analysis had a trivial effect on the coefficients shown in Table 2 (and no effect on the pattern of significant coefficients), only the results for the untransformed scores are reported here.

A multiple-regression analysis was performed to examine whether a linear combination of the two saliva measures could explain a significantly greater proportion of the variance in self-reported caffeine use than could be explained by each saliva measure alone. The analysis indicated that while salivary paraxanthine accounted for 18% of the variance in self-reported caffeine intake, the addition of salivary caffeine to the regression equation added only a negligible 0.04% to the amount of explained variance.

Table 1 Means, s.d.s, and % contribution of specific sources of caffeine to overall daily consumption ($n = 142$)

Beverage	Mean (mg)	s.d. (mg)	% of overall intake ^a
Instant coffee	206	179	63
Tea	85	89	26
Brewed coffee	25	86	8
Cola drinks	9	19	3
Chocolate drinks	1	2	0
Decaffeinated coffee	1	2	0
All sources	327	210	100

^aRounded to the nearest integer.

Table 2 Means, s.d.s, and intercorrelations for age, gender, self-reported caffeine intake, and salivary caffeine and paraxanthine ($n = 142$)

Measure	Mean	s.d.	Measure			
			2	3	4	5
1 Age (years)	19.2	1.2	-0.02	-0.01	-0.06	0.06
2 Gender (47 females, 95 males)	—	—	—	-0.06	0.19*	0.12
3 Self-reported caffeine (mg day ⁻¹)	327	210	—	—	0.31**	0.42**
4 Salivary caffeine (mg l ⁻¹)	0.82	0.65	—	—	—	0.69**
5 Salivary paraxanthine (mg l ⁻¹)	0.35	0.27	—	—	—	—

* $P < 0.05$, ** $P < 0.001$.

Symptomatology

Responses to the SSQ are summarized in Table 3 which shows the means and standard deviations for self-reported caffeine use, the general health scale, the somatic symptom checklist, the three measures of psychological health, and self-reported consumption of cigarettes and alcohol, together with the intercorrelations for the eight variables. Age, gender, and salivary caffeine and paraxanthine were not included in Table 3 because, with one exception, they produced no significant correlations other than those already shown in Table 2. The exception was that there was a significant correlation between gender and alcohol use, with males reporting a higher level of consumption ($r = 0.28, P < 0.001$). In addition, the distributions for several of the variables were significantly skewed. However, as was found for the variables of caffeine exposure, analyses based on logarithmic transformations of the significantly skewed variables produced results that were different in no substantial respect from analyses based on the untransformed scores. Hence, the results presented here are for analyses in which the untransformed variables were employed.

The significant negative correlation between scores on the general health scale and self-reported frequency of somatic symptoms ($r = -0.25, P < 0.01$) is consistent with expectations in that higher general health scores were associated with fewer physical symptoms. However, general health was not significantly correlated with caffeine intake ($r = 0.14, P > 0.05$), nor was caffeine use found to be significantly correlated with any of the three measures of psychological well-being. In addition, neither cigarette smoking nor alcohol consumption was significantly related to caffeine intake or any of the measures of somatic and psychological health. In contrast, caffeine use was found to be associated with a significantly increased number of somatic

symptoms ($r = 0.29, P < 0.001$), and this association was stronger than the correlation of 0.19 ($P < 0.05$) that was obtained when the 24 items contained in the original SSQ (James *et al.*, 1987) were considered as a separate subscale of the 60-item checklist used in the present study. In addition, a scattergram indicated that the association between self-reported caffeine consumption and frequency of somatic symptoms was essentially linear, as has been observed previously (James *et al.*, 1987). Moreover, the reliability of the present and previous results tends to be supported by the fact that the coefficient obtained in relation to the 24-item subscale in the present study was almost identical to the correlation of 0.20 ($P < 0.01$) reported by James *et al.* (1987) for the same 24 items.

The association between caffeine use and somatic symptomatology was further examined by conducting a hierarchical multiple regression analysis with somatic symptoms as the dependent variable. Age and gender were entered at the first step, followed by smoking and alcohol use at the second step, measures of psychological health (STAI state and trait anxiety, and the BDI) at the third step, and caffeine use at the last step. The results of the analysis are summarized in Table 4, which shows that even after the removal of the combined variance attributable to all other variables considered in the analysis, caffeine consumption still reliably predicted somatic symptoms ($F(1, 133) = P < 0.01$).

Discussion

Caffeine exposure and self-report reliability

Although the three measures of caffeine exposure yielded statistically significant intercorrelations, the coefficients were fairly modest. That is, the measures of caffeine exposure apparently con-

Table 3 Means, s.d.s, and intercorrelations for caffeine consumption, somatic health, psychological well-being, and cigarette and alcohol use ($n = 142$)

Measure	Mean	s.d.	Measure						
			2	3	4	5	6	7	8
1 Caffeine (mg day ⁻¹)	237	210	-0.14	0.29***	-0.05	0.07	0.08	0.08	0.05
2 General health	7.1	1.3	—	-0.25**	0.05	-0.05	-0.13	-0.14	0.04
3 Somatic symptoms	10.8	6.0		—	-0.08	0.18*	0.27*	0.01	0.02
4 STAI - state	43.7	4.7			—	0.17*	0.03	-0.01	0.08
5 STAI - trait	44.1	3.8				—	0.32***	-0.01	-0.01
6 Beck depression	3.0	3.5					—	-0.01	-0.05
7 Cigarettes (day ⁻¹)	0.7	2.9						—	0.14
8 Alcohol (ml day ⁻¹)	4.4	5.4							—

* $P < 0.05$, ** $P < 0.01$, *** $P < 0.001$.

Table 4 Summary of hierarchical multiple regression analysis of the SSQ somatic symptoms scale ($n = 142$)

Step	Variables	r^2	r^2 change	df	F
1	Age, gender	0.01	0.01	2, 139	<1
2	Psychological	0.09	0.08	3, 136	4.34*
3	Smoking, alcohol	0.09	0.00	2, 134	<1
4	Self-reported caffeine	0.16	0.07	1, 133	11.29*

* $P < 0.01$.

tained a substantial level of measurement imprecision, suggesting that caution is needed when interpreting the results. As is typical of questionnaire studies, no attempt was made in the present study to control subjects' caffeine intake prior to the test session. Hence, factors such as variations in the recency with which subjects had consumed caffeine-containing foods prior to attending the afternoon test-session may be expected to have had a confounding influence on assessed caffeine exposure. However, it would be unwise to dismiss these results simply because they were obtained under relatively uncontrolled conditions, since these same conditions are characteristic of questionnaire studies in general. Moreover, the observed 48% common variance for salivary caffeine and paraxanthine is comparable in magnitude to the association reported for single-sample plasma caffeine and paraxanthine concentrations obtained by Lelo *et al.* (1986a) under laboratory conditions in which actual caffeine consumption was controlled.

Notwithstanding the need for caution, it is conceivable that subjects' self-reported intake may have provided a better estimate of chronic exposure to caffeine than the single-sample bioassays. Subjects were asked to report 'average' daily consumption, and such estimates may be less sensitive to transient confounds than a single bioanalytic measure. The pattern of inter-correlations obtained in the present study contain some hint of this possibility. While self-reported caffeine consumption was significantly correlated with the salivary measures and self-reported frequency of somatic symptoms, the salivary measures were not significantly correlated with somatic symptoms. This pattern is consistent with the suggestion that self-reported caffeine consumption may have given a reasonably reliable estimate of chronic caffeine exposure, whereas the single-sample bioassays may have been more sensitive to various possible confounds (e.g., differences in individual access to caffeine-containing foods during the period immediately prior to the test session). Hence, any associations between single-sample assays of methylxanthine

exposure and increased frequency of somatic symptoms (a correlate of chronic caffeine exposure) would be undermined. As such, present results may be seen as providing qualified support for the use of retrospective self-reports of habitual caffeine consumption. In summary, while the observed associations between self-reported intake and salivary methylxanthines were relatively modest (suggesting the need for caution when interpreting questionnaire results), convenience and economy would appear to justify the judicious use of retrospective questionnaires. Such information may be especially useful during the exploratory stages of a particular line of research. Once seemingly reliable associations have been identified, researchers may then turn to more precise experimental methods to elucidate findings of interest.

We had some expectation that tea might rival coffee as the principal source of caffeine for the British sample surveyed here. However, without suggesting that the prevailing pattern of caffeine use amongst medical students at London University might be representative of the British population, subjects in the present study showed a preference for instant coffee that was similar to that which has been reported for diverse samples in North America (Barone & Roberts, 1984) and Australia (James & Crosbie, 1987). Average level of consumption was also comparable with previously published estimates (e.g., Barone & Roberts, 1984), being approximately 3 to 4 cups of coffee or 5 to 6 cups of tea per day.

Consistent with theoretical expectations and previous empirical results (James *et al.*, 1988), paraxanthine was found to be slightly better correlated with self-reported caffeine intake than salivary caffeine. A linear combination of the two xanthines did not improve the prediction of self-reported usage, indicating that the common variance between self-reported and salivary caffeine was virtually entirely subsumed by the common variance between self-reported caffeine and salivary paraxanthine. Therefore, in light of the combined results of the present and previous studies, it seems reasonable to conclude that the

late-afternoon level of circulating paraxanthine (whether in saliva or blood) provides the best single-sample estimate of caffeine exposure.

One additional finding that tends to support the reliability of the overall results was that females were assessed to have significantly higher salivary caffeine than males, although there was no significant gender difference with respect to self-reported caffeine use. This result would be expected for two reasons. First, for equivalent levels of caffeine consumption, the generally lower body weight and blood volume of females would result in higher concentrations of circulating caffeine. Secondly, the higher salivary caffeine concentrations for the females may be related to the fact that oral contraceptive steroids significantly increase the elimination half-life of caffeine (Patwardhan *et al.*, 1980). Considering the general age level of the subjects, oral-contraceptive usage may be anticipated for a proportion of the females in the study. Consumers of oral contraceptives would be expected to show higher concentrations of circulating caffeine for equivalent levels of caffeine intake. Hence, in future questionnaire studies of caffeine use, it would be advisable for information to be obtained on body weight and use of oral contraceptives.

Somatic and psychological symptomatology

The principal finding concerning the possible symptomatology of caffeine was that regular usage reliably predicted a variety of common somatic symptoms, a finding that is consistent with a similar result reported by James *et al.* (1987). As in the previous study, a significant proportion of the variance in somatic symptoms was explained by subjects' self-reported caffeine use even after controlling for a variety of other variables including psychological well-being and the consumption of cigarettes and alcohol. The failure of cigarette smoking to be significantly correlated with caffeine consumption or any of the measures of somatic and psychological health differs from results obtained by James *et al.* (1987), who found that smoking was significantly correlated with both caffeine use and general physical health as measured by the SSQ. However, the present null results for smoking may simply reflect the low level of smoking among participants in the present study. Only 11 of the 142 participants (7.7%) reported that they

smoked on a regular basis, and of these only four individuals reported consuming an average of more than 10 cigarettes per day. Alcohol was also unrelated to caffeine consumption and all measures of somatic and psychological health, but again, subjects appear to have been moderate in their habits. The estimated alcohol intake for participants was the approximate equivalent of two glasses of table wine per week. The relatively low level of cigarette and alcohol use evidenced by subjects in the present study suggests that in general the medical student population may be especially suitable for research on the effects of moderate caffeine consumption. In previous studies (e.g., James *et al.*, 1987), it has been necessary to rely on *statistical* controls to try to separate the effects of caffeine from those of smoking and alcohol. However, the pre-existing dietary habits of the subjects in the present study provided a degree of *experimental* control over the potential influences of smoking and alcohol use.

Consistent with the James *et al.* (1987) study, caffeine use failed to predict psychological well-being as measured by the STAI and the BDI. Thus, no support was obtained for the suggestion by Greden *et al.* (1978) that 'average' consumption levels of caffeine are sufficient to produce measurable increases in anxiety and depression. While James & Crosbie (1987) found evidence of increased anxiety and depression amongst 'heavy' users, present results support the findings of James *et al.* (1987) that 'moderate' caffeine consumption is unrelated to psychological well-being as measured by standard psychometric instruments. Both the present and previous study (James *et al.*, 1987) are also in agreement with regard to somatic symptomatology in that both found a positive and essentially linear association between caffeine intake and frequency of self-reported somatic symptoms.

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