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# Temporal and visual source memory deficits among ecstasy/polydrug users.

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*Running head*: source memory deficits and illicit drug use.

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**Abstract**

Objectives: The present paper seeks to investigate whether source memory judgements are adversely affected by recreational illicit drug use.

Method: Sixty-two ecstasy/polydrug users and 75 non ecstasy users completed a source memory task, in which they tried to determine whether or not a word had been previously presented and if so, attempted to recall the format, location and temporal position in which the word had occurred.

Results: While not differing in terms of the number of hits and false positive responses, ecstasy/polydrug users adopted a more liberal decision criterion when judging if a word had been presented previously. With regard to source memory, users were less able to determine the format in which words had been presented (upper versus lower case). Female users did worse than female nonusers in determining which list (first or second) a word was from. Unexpectedly, the current frequency of cocaine use was negative associated with list and case source memory performance.

Conclusions: Given the role that source memory plays in everyday cognition, those who use cocaine more frequently might have more difficulty in everyday tasks such as recalling the sources of crucial information or making use of contextual information as an aid to learning.

**Key words**: source memory, context memory, MDMA, cocaine, SDT sensitivity

The purpose of the present paper is to investigate the integrity of source memory processes in recreational ecstasy/polydrug users. Source memory is concerned with the ability to recall the contextual and other episodic details in which a specific behaviour, idea or event occurs or a stimulus is encountered, for example, where a specific piece of information was originally encountered, in which particular shop a desired product had previously been seen or what time a specific medication was last taken. Source memory judgement may also involve distinguishing between external sources, i.e., determining which particular person was the source of a specific piece of information. Also distinguishing between internal sources, e.g., whether a particular course of action was actually carried out or just considered. Source memory also involves the ability to retrieve relevant contextual information (perceptual, spatial, temporal, semantic and affective) that was associated with a particular item or behaviour at encoding (Johnson et al. 1993). This may involve recalling which particular person was responsible for providing a particular piece of information and perhaps the time and context in which it was provided. In that sense source memory is a multidimensional phenomenon in that multiple and qualitatively different aspects of the context are encoded and potentially retained along with the actual information itself.

Depending on the conditions at encoding (motivational factors, the time available, the level distraction and the integrity of attentional processes) in some instances this process may result in rich source information in which multiple contextual attributes can be retrieved while in other cases relatively little source detail may be available (Johnson et al. 1993). It is also the case that some source information can be retrieved automatically and effortlessly along with the content of the memory at the point of recollection while in other situations the contextual and perceptual characteristics of the item recalled are not immediately available and have to be actively reconstructed often through a process of deduction (Johnson & Raye, 1981).

Despite its multidimensional nature, experimental paradigms typically focus on single contextual dimensions such as whether a word was presented by a male or female voice (Lindsay et al, 1991), or at the right or left hand side of a computer display (Johnson et al, 1982) or the colour in which the word was presented (Chalfonte & Johnson, 1996). Recalling whether or not a particular word was previously presented is referred to as item memory. Recalling the context in which that word was presented (e.g., as part of the first or second list, in red or green, at the top or bottom of the screen, or auditory features such as male or female voice) is characterised as source memory.

Source memory is known to play a vital role in everyday life. For example, the ability to accurately recall the source of some piece of crucial information and more importantly its veracity, is potentially of critical importance in everyday decision making (Johnson et al. 1993). The physical or temporal context in which objects or ideas are experienced frequently act as an aid to recall when these elements need to be retrieved. Indeed, in terms of the general acquisition of knowledge and factual information, research has shown that a positive relationship exists between the level of comprehension achieved and the ability to recall the source of the information that has been learned (Strømsø et al. 2012). Furthermore, misattributing the source of information, for example the mistaken belief that a person that you have encountered in one context was the actual protagonist in another, may have serious consequences and has been a factor in compromising the value of eye-witness testimony (Davis and Loftus, 2007; Zaragoza and Lane, 1994). There is clear evidence from studies of clinical populations, e.g., persons with brain injury, those with dementia or psychoses, of the severe consequences which emerge when source memory is impaired (Mitchell and Johnson, 2009).

There is now a considerable body of evidence for the separable nature of item and source memory. For example the latter has been shown to deteriorate faster as a consequence of cognitive ageing (Kausler & Puckett 1980; 1981; Burke & Light, 1981; Ferguson et al. 1992) or with the progression of dementia (Multhaup & Balota, 1997) and the recollection of the source of information has been found to be differentially impaired in patients with frontal lobe lesions (Shimamura, 2002). The neural basis of source and item memory has also been extensively studied. For example, neuroimaging evidence suggests that, relative to item memory judgements, source memory results in greater activation in left hemisphere pre-frontal cortical structures (Kahn et al. 2004; Mitchell et al. 2008). Source memory can also have a temporal dimension and in common with other types of source memory judgements, paradigms involving temporal judgements, for example, identifying which of two ***temporally*** separated lists targets were from, also recruit left hemisphere PFC structures but also other cortical regions including the right hemisphere PFC and the orbito-frontal cortex (OFC) (Duarte et al. 2010). Thus item and source memory and indeed different types of source memory judgements appear recruit qualitatively different prefrontal resources again consistent with the separability of the two constructs. Lastly, experimental manipulations which have been found to enhance source memory performance have been found to have no effect on item memory, while manipulations which improve recognition have been found to actually hamper source memory (Lindsay & Johnson, 1991).

Meta analytic studies have suggested that ecstasy/polydrug users perform significantly worse on a number of executive sub processes that are known to rely on prefrontal cortical resources. This has been demonstrated both in relation to verbal (Murphy et al. 2009; Nulsen et al. 2010) and visuo-spatial processing (Murphy et al. 2012). Regarding item memory, a number of researchers have found that ecstasy/polydrug users perform worse on the Rey Auditory Verbal Learning Test (RAVLT) (e.g., Bedi & Redman, 2008; Schilt et al. 2008). While there has been a considerable degree of controversy concerning the causes of the performance decrements that have been observed, it has been argued that they are at least in part attributable to ecstasy use (e.g., Parrott, 2013). In view of the importance of effective source memory processes for everyday functioning, and given that ecstasy/polydrug users have been observed to perform worse on various tasks which appear to recruit the same prefrontal and medial-temporal cortical resources that support source memory, it would be of value to establish whether or not individuals with a history of illicit drug use were less competent in terms of their source memory performance.

It is predicted that ecstasy/polydrug users will produce fewer correct source memory judgements relative to non ecstasy users. In view of the prevalence of polydrug use among ecstasy users, source memory performance will be correlated with various measures of illicit drug use. It is predicted that source memory performance will be negatively associated with the amount of ecstasy consumed and the frequency of use.

## METHOD

### *Participants*

Sixty-two ecstasy/polydrug users (including 37 males, 25 females) and 75 non ecstasy using controls (including 27 males, 48 females) from universities in the North West of England participated in the study. The control group included drug naïve, cannabis only and some cocaine users. Potential participants responded to advertisements placed around campus and via an on-line participant panel. They were initially informed that the study was concerned with the effects of illicit drugs on aspects of cognitive functioning and that both users and nonusers of illicit drugs could participate. Those with current or previous psychiatric diagnosis or treatment (including flashbacks, panic attacks, paranoia, schizophrenia, phobia) were excluded from the study (see Bedi & Redman, 2008). Although details of ethnic origin were not recorded, the sample consisted predominantly of ‘White

British'. Participants were asked to abstain from cannabis use for at least 24 hours prior to testing and from other illicit drugs for at least 7 days prior to testing.

*Materials*

The use of ecstasy and other drugs was assessed by means of a self-report questionnaire. For all illicit drugs that were regularly consumed, participants estimated their typical dose and frequency of use for each year since they began using. This allowed the long term average dose per session and total lifetime use for each drug to be estimated. Participants also indicated their current frequency of use and period of abstinence Current use of alcohol and cigarettes and demographic variables including age and gender were also recorded and fluid intelligence was measured through Raven's Progressive Matrices (Raven et al. 1998).

Source Memory Task: The task was based on paradigm developed by Meiser and Broder (2002). Participants were asked to make judgements as to the spatial location, temporal order and format (upper versus lower case) of previously presented words. These types of judgement are commonplace in source memory research (see Meiser & Broder, 2002 for a summary of the relevant research). More specifically, 64 words (one or two syllable nouns) were presented each for 4 seconds on a computer monitor. Thirty two words were presented in List One and 32 in List Two. For each list, half the words were presented in the top section and half in bottom section of the computer monitor. For each of the resulting four sets, each word was presented in either upper or lower case. Words were randomly assigned to each list. Case and position were also determined in a quasi-random manner subject to the requirement that each list had 16 words in upper case of which eight were presented in the top and eight at the bottom of the screen and 16 words in lower case again with eight presented at the top and 8 at the bottom of the screen. In the recognition phase all 64 words were presented with 64 new words.

Participants were asked to indicate (by pressing one of two computer keys) whether each presented word had been seen previously and if so to whether it was in the top or bottom half of the screen, in upper or lower case, and in list one or list two. In terms of item memory, the data recorded included the number of hits (previously seen words correctly identified), the number of false positive responses (new words mistakenly identified as previously seen), an estimate of sensitivity as defined in Signal Detection Theory (SDT), i.e., $z(\text{H}) – z(\text{F})$ (where H is defined as the proportion of correct responses and F the proportion of false positive responses) and SDT decision criterion, i.e., $–[z(\text{H}) +z(\text{F})] /2$ (Green & Swets, 1974). In relation to source memory, for those previously presented words that were correctly identified (hits), the percentage of correct source memory judgements was calculated with respect to list (first or second), position (top or bottom) and case (upper or lower).

*Procedure*

The research was approved by the Ethics Committees of the University of Central Lancashire and Liverpool John Moores University and was conducted in accordance with the requirements of the Declaration of Helsinki except that participants provided **verbal** consent in order to protect the anonymity of the illicit drug users in the sample. The tests were administered in the following order: background drug use questionnaire, Ravens Progressive Matrices and the source memory task. A number of other measures was also administered the results of which are outside the scope of the present study. These included tests of prospective memory and associative learning. In total the test battery took between two and three hours to administer. At the end of the session, participants were debriefed, paid 20 UK pounds in the form of a supermarket (grocery store) gift card, and provided with drug education leaflets.

*Design and Statistics*

A between groups design was used with ecstasy use (ecstasy/polydrug users versus non ecstasy users) and gender between participants. Gender was included in order to establish whether any group related effects were consistent between males and females. Dependent variables were the proportions of correct position, list, and case **source** memory judgements. Regarding item memory, dependent variables were the SDT sensitivity and decision criterion values and the number of hits and false positive responses. Correlations between various indicators of illicit drug use and the source and item memory outcome measures were also explored.

RESULTS

Inspection of Table 1 reveals that the two groups did not differ significantly on most of the background measures. Ecstasy/polydrug users were slightly but significantly older and had significantly more years of education. Although cannabis use was generally more prevalent among the ecstasy/polydrug users, the two groups did not differ significantly on the majority of measures. By way of exception, in relation to period of abstinence, non-ecstasy users were abstinent from cannabis for significantly longer. There was also a significant interaction between gender and group with male ecstasy/polydrug users having a larger long term average dose of cannabis per session compared to the other three groups (see Table 2).

<Insert Tables 1 and 2 about here>

In relation to the item and source memory results, inspection of Table 3 reveals that ecstasy users performed worse than controls on the majority of measures. Specifically male ecstasy users achieved the smallest proportion of correct position and case source memory judgements; female ecstasy users achieved the smallest proportion of correct list source memory judgements. Male ecstasy users recorded the greatest number of false positives, they exhibited the lowest level of sensitivity and the most liberal decision criterion.

<Insert Table 3 about here>

A series of ANOVAs were conducted with group (ecstasy/polydrug versus non-ecstasy user) and gender between participants. Regarding the item memory outcomes, neither of the group effects or the interactions were statistically for hits and false positive responses, F<1, in all cases (except for the effect of gender on hits, F=2.18, p=.143, $\eta_p^2$ =.016, and false positive responses, F=2.62, p=.108, $\eta_p^2$ =.019, and the effect of user group on false positive responses, F=2.74, p=.100, $\eta_p^2$ =.020) all on 1,133 DF. The ecstasy/polydrug-related effect for the SDT sensitivity measure was statistically significant, F=4.01, p=.047, $\eta_p^2$ =.031, users exhibited lower levels of sensitivity. The gender effect and the interaction were not significant, F<1 in both cases; all on 1,124 DF. There was a significant effect of gender for the SDT decision criterion measure, F=5.55, p=.020, $\eta_p^2$ =.043, females adopted a more stringent decision criterion. The drug related group effect and the interaction were not significant, F=1.05, p=.307, $\eta_p^2$ =.008, and F<1 respectively; all on 1,124 DF.

Considering the source memory outcomes, on the list measure, the gender effect was non-significant, F<1, as was the overall group effect, F=1.73, p=.191, $\eta_p^2$ =.013. However, there was a significant interaction between group and gender, F=3.99, p=.048, $\eta_p^2$ =.029. The trends in the cell means are displayed in Figure 1. There was little difference in list memory performance between male users and nonusers. Female users registered the worst performance while female non ecstasy users achieved the best score. Post hoc tests revealed that female users were significantly worse than female nonusers, p=.048, two tailed, but did not differ from either male users, or male nonusers, p>.05 in both cases. Regarding the other two source memory measures, the effect of group was statistically significant for case source memory F=5.40, p=.022, $\eta_p^2$ =.039. Users performed significantly worse when making case source memory judgements. The gender effect was also significant F=4.81, p=.030, $\eta_p^2$ =.035, with females performing better than males overall. The interaction was non-significant, F<1. For the position source memory judgement, neither the ecstasy/polydrug related effect, nor the interaction were statistically significant, F<1 in both cases. The gender effect approached significance, F=3.25, p=.074, $\eta_p^2$ =.024, with females performing better than males overall. All the above mentioned source memory effects were on 1,133 DF.

The association between aspects of illicit drug use and the source memory outcomes are set out in Table 4. Where test results and the probabilities associated with them are conditionally dependent, (as is the case with the present study, where there are multiple interrelated outcome variables and multiple inter-correlated drug use measures) full Bonferroni correction greatly inflates the likelihood of Type 2 error (e.g., Narum, 2006), so an alternative procedure (Benjamini and Yekutieli, 2001) which more effectively controls the Family Wise Error (FWE) rate was used. With 90 correlations reported in Table 4, an alpha value of .00942 controls the FWE <.05 two tailed (From Appendix A, Narum, 2006).

<Insert Table 4 about here>

On this criterion, the current frequency of cocaine use was significantly and negatively correlated with list source memory performance, p<.001, and the correlation approached significance for case source memory, p=013. Thus those with a higher current frequency of use had poorer source memory for whether the word was presented in list 1 or list 2 and for the case in which the word was presented. Period of abstinence from cocaine was significantly correlated with the position source memory component, p=.008, and the correlation approached significance for case source memory (p=.0103). Thus as the period of abstinence from cocaine increased so source memory performance with respect to case and position improved. Contrary to expectation, only one of the indicators of ecstasy use was significantly associated with the memory outcomes at the adjusted alpha level: as the long term average dose of ecstasy per session increased, so list source memory deteriorated, p=.009.

Of those associations that were in the predicted direction, a further two were associated with p<.05, and three with p<.10, two tailed. For these, increased drug use and shorter periods of abstinence were associated with worse memory performance. In four instances the associations relate to source memory outcomes while the remaining case relates to the SDT D-Prime measure. Three are related to aspects of cocaine use, one to ecstasy and one to cannabis use. With one exception, none of the indicators of cannabis use were significantly associated with the source or item memory outcomes even at the unadjusted alpha level p=.10. The association between the total consumption of ecstasy and case source memory was not in the predicted direction with higher lifetime consumption associated with better case source memory and although not significant at the adjusted alpha level, p value was <.10 two tailed.

In view of the prevalence of cocaine use among the ecstasy users in the sample and vice versa, those zero order correlations that were statistically significant at p<.05 were repeated this time controlling for ecstasy or cocaine use as appropriate. The resulting partially correlations revealed that the current frequency of cocaine use remained significantly correlated with list and case source memory and the SDT sensitivity measure following controls for the frequency of ecstasy use, $r_p$( df=41) = -.535, p<.001; -.347, p<.05; and -.309, p<.05; respectively. Likewise the period of abstinence from cocaine remained significantly correlated with case source memory, $r_p$ (df=43) = .414, p<.01, and the correlation with position source memory approached significance, $r_p$ (df=43) = .280, p=.063, following control for the period of abstinence from ecstasy. Finally the partial correlation between the long term average dose of ecstasy per session and list source memory remained statistically significant after controlling for the long term average dose of cocaine per session $r_p$ (df=36) = .339, p<.05.

Inspection of Table 4 reveals that the use of cocaine within the previous 10 days was negatively correlated with list memory performance, p<.05. Similarly the period of abstinence from cocaine was positively associated with list memory performance, p<.10 and with case memory, p<.05. Although these associations were not significant at the adjusted alpha level, it is possible that some of the variance shared between the current frequency of use and, respectively, list and case memory, overlaps with the common variance shared with recent use within the previous 10 days and period of abstinence. In other words at least part of the significant relationship between current frequency of cocaine use and list and case memory might be attributable to very recent patterns in cocaine use. To evaluate this possibility a partial correlation was run between the current frequency of use and list memory, controlling for recent use within the last 10 days and period of abstinence. The relationship between current frequency and list memory remained statistically significant, $r_p$=-.490, d.f.= 45, p<.001. The equivalent partial correlation between case source memory and the current frequency of cocaine use also remained statistically significant (on an unadjusted basis) following the same controls, $r_p$=-.363, d.f.= 45, p<.05.

DISCUSSION

It is worthy of note that the performance of ecstasy/polydrug users did not differ significantly from nonusers in terms of three of the item memory measures, specifically they the groups did not differ significantly in terms of the number hits, false positive responses and the SDT sensitivity measure. Users did appear to adopt a significantly more liberal decision criterion when judging whether or not a word had occurred previously, that is to say, they required less evidence or confirmatory information before making an affirmative response.

In relation to source memory, ecstasy/polydrug users did significantly worse relative to non-ecstasy users on case judgements. In the present context they were less able to recall whether a previously seen word was originally presented in upper or lower case letters. Assuming that the results can be applied to visual processing more generally, this supports the proposition that they are less able to recall the physical or visual form in which information is presented. In the present context list source memory reflected the ability to recall the temporal order in which words were presented. Female ecstasy/polydrug users registered the worst performance in this area while female non-ecstasy users achieved the best performance. The performance of males appeared to be unrelated to the ecstasy/polydrug user-nonuser distinction and was intermediate in magnitude. Lastly, the two groups did not differ in terms of the proportion of correct position source memory judgements which suggests that, at the group level, source memory for spatial location is unaffected by ecstasy/polydrug use.

With regard to the correlational analyses, only one aspect of ecstasy use, long term average dose per session, appeared to be significantly related to source memory performance. The typical dose per session (number of tablets typically consumed on each occasion of use) averaged over the entire period of use was found to be inversely related to source memory for temporal information.  Lifetime use was not significantly associated with list memory. Thus it is the typical dose rather than total lifetime exposure which appears to be important. Evidence has emerged from structural and functional MRI studies of currently abstinent ecstasy/polydrug users, linking reduced SERT distribution volume ratios (DVRs) with maximum and typical ecstasy dose per session (Kish et al., 2010; McCann et al., 2005, 2008; Thomasius et al., 2006). Thus, it could be that higher ecstasy doses give rise to source memory deficits as a consequence of their detrimental effect on SERT DVRs. Nonetheless such a possibility needs to be treated with a degree of caution since there is no obvious reason why this particular aspect of source memory should be particularly susceptible to the effects of ecstasy and it is worthy of note that the association between total lifetime use and case source memory was actually positive, (although at $p<.10$ two tailed, given the directional nature of the prediction this aberrant result is below significance even at an unadjusted alpha level).

Among the illicit drug users tested here it appears that cocaine use was associated with adverse outcomes on a number of the source and item memory measures. The current frequency of cocaine use was found to be significantly correlated with temporal source memory (the list measure) and, on an unadjusted basis, with source memory for presentation format (the case measure). In both cases higher frequency of use was associated with worse performance. Furthermore, it appears that the magnitude of the source memory deficit declines as the period of abstinence from cocaine increases. This was true for source memory for spatial position (the position measure) and, on an unadjusted basis, for presentation format source memory (the case measure). While the deficit was apparently related to the frequency with which cocaine was used, the effects observed do not appear to relate to recent use since the source and item memory outcomes either appear unrelated to recent cocaine use or the current frequency effect observed remains significant following statistical control for aspects of recent use. Three of the other measures of cocaine use were associated with various source and item memory outcomes at $p<.05$ or $p<.10$ two tailed although these failed to reach significance at the adjusted alpha level. As far as the authors are aware the present study is the first to link recreational use of cocaine with source memory deficits.

Regarding the apparent cocaine-related effect reported here and given the reliance of source memory performance on executive processes, it is worthy of note that, in previous research, performance deficits on a number of executive function tasks have been observed among currently abstinent cocaine users (Berry et al. 1993; Rosselli et al. 2001; Beatty et al. 1995). Furthermore, Tomasi et al's (2007) fMRI results demonstrated that compared to controls, cocaine users exhibited reduced levels of activation in the prefrontal regions relative to nonusers during the performance of a task loading on executive resources. Thus the cocaine-related deficit in source memory functioning may reflect a more general cocaine-related limitation in executive functioning. However, a degree of caution is warranted here since the present student sample will no doubt differ in many respects from the chronic cocaine users which featured in the above mentioned studies. It is also worthy of note that virtually all of the cocaine users in the present study also used ecstasy so the possibility that the two drugs interact in some way to produce the adverse effects observed here cannot be ruled out.

Both item and source memory involve the differential activation of information (e.g., in semantic memory) at encoding with source memory associated with greater levels of differentiation Anything that compromises attentional resources at the time of encoding (e.g., divided attention, brain damage) compromises source memory (Johnson et al. 1993). The integrity of attentional resources has been investigated in ecstasy/polydrug users. For example, Indlekofer et al. (2009) administered the Test for Attentional Performance (TAP) which examines several aspects of attentional processes. Following controls for age, sex, IQ, and the use of other illicit drugs and alcohol, aspects of ecstasy use significantly predicted omissions/errors on several of the TAP measures including alertness, managing stimulus incompatibility and vigilance (Indlekofer et al., 2009). It is possible therefore that the source memory deficits observed here may be a corollary of more general attentional problems. However, only one of the ecstasy use measures was significantly associated with source memory while aspects of current cocaine use were more important in this regard. Thus the proposition that attentional resources may be responsible with the results obtained here is only partially supported.

A number of limitations need to be acknowledged in relation to the present study. In common with much of the existing literature, this study has relied on self-report data in relation to drug use. However, while objective measures would have been desirable, research suggests a high degree of concordance between self-report and objective measures of recent drug use from saliva (Yacoubian and Wish, 2006) and of longer term use from hair (Scholey et al. 2011; Vignali et al. 2012). Furthermore, concordance between self-reports and objective measures of drug use has been demonstrated for multiple illicit drugs (Vignali et al. 2012), cannabis and cocaine (Vignali et al. 2012; Zaldívar et al. 2009) and ecstasy (Scholey et al. 2011; Yacoubian and Wish, 2006).

A procedural limitation must also be acknowledged. As noted above, at the initial presentation words were either presented in upper or lower case. However, in the subsequent recognition test the words were all presented in upper case. In general terms, there is little doubt that reinstatement of contextual cues present during learning, facilitates memory performance at the time of recall/recognition. This has been demonstrated in a meta-analysis (Smith and Vela, 2001). Thus by implication, in the present study where the stimulus characteristics at initial learning and subsequent recognition were congruent (i.e., when the word was in upper case on both occasions) some facilitation might be expected. It is also possible that learning might be impaired when the characteristics were incongruent. Thus the group-related deficit we observed may stem from the fact that ecstasy/polydrug users were less able to benefit from the facilitatory effects of presentational congruence or more susceptible to the negative effects of incongruence. There is evidence to suggest that illicit drug users may be adversely affected in the incongruent condition of the Stroop test (e.g., Halpern et al. 2004). However, there is reason to believe that such context dependent effects may be moderated by working memory (WM) capacity. Paradoxically although high WM persons benefited more than low WM when encoding and retrieval conditions matched, when they did not there was no effect of WM suggesting that high WM persons may be more disrupted by incongruity than low WM (Unsworth et al. 2011). In view of the fact that ecstasy/polydrug use has been associated with WM deficits (Murphy et al.2009) it may be that ecstasy/polydrug users in the present study may have been less affected by incongruence than the control group.

With regard to our findings, while we have noted the apparent role that cocaine has played in accounting for our results, we cannot exclude the possibility that other drugs may have played a part. Virtually all of the cocaine users in the present study also used ecstasy and cannabis. Therefore while the results obtained appear to relate to cocaine use we cannot exclude the possibility that cocaine might interact with other illicit drugs to produce its apparent effects in the present sample. It must also be acknowledged that despite the apparent dose related link between cocaine use and some aspects of source memory, the presence of cocaine use may be an indicator of other important lifestyle or premorbid characteristics which may be associated with worse cognitive outcomes in their own right as well as resulting in illicit drug use.

Lastly, it is noteworthy that there is a degree of missing data which is readily apparent comparing the sample sizes associated with the various measures in Table 2. Generally, participants were better able to report on the extent of their recent use and make categorical distinctions, e.g., whether or not they had ever used a particular drug, as opposed to confidently reporting longer term trends. In a few instances, responses were missing from the questionnaire possibly due to questions being overlooked. A degree of missing data is not uncommon in studies of this kind (e.g., Bedi & Redman, 2008; Indlekofer et al. 2009). However, while we wished to avail ourselves of the largest possible sample for each of the comparisons in question, it should be borne in mind that some of the significant associations (or lack of them) reported in Table 2 relate to sub-sets of the data.

In conclusion, subject to the limitations noted above, to the authors' knowledge, the present study is the first to demonstrate source memory deficits among ecstasy/polydrug users. Furthermore these deficits appear to be associated with aspects of cocaine use. While they may diminish with increasing abstinence, in view of the role that source memory plays in everyday cognition, the presence of deficits among regular cocaine users is a cause for concern.

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References.

Beatty WW, Katzung VM, Moreland VJ, Nixon SJ. 1995. Neuropsychological performance of recently abstinent alcoholics and cocaine abusers. *Drug Alcohol Depend* **37***:* 247-253.

Bedi G  Redman J, 2008. Ecstasy use and higher-level cognitive functions: weak effects of ecstasy after control for potential confounds. Psychol Med 38: 1319–1330.

Benjamini Y & Yekutieli D. 2001. The control of the false discovery rate in multiple testing under dependency. *Ann Stat* **29**: 1165–1188.

Berry J, van Gorp WG, Herzberg DS, Hinkin C, Boone K, Steinman L & Wilkins JN. 1993. Neuropsychological deficits in abstinent cocaine abusers: preliminary findings after two weeks of abstinence. *Drug Alcohol Depend* **32**: 231-237.

Burke DM Light LL. 1981. Memory and aging: The role of retrieval processes. Psychol Bull 90: 513-546.

Chalfonte BL, Johnson MK. 1996. Feature memory and binding in young and older adults. Mem Cognition 24: 403-416.

Davis D, & Loftus EF. 2007. Internal and external sources of misinformation in adult witness memory. In Toglia MP, Read JD, Ross DF, Lindsay RCL . (Eds.). *The Handbook of Eyewitness Psychology*, Vol  I: Memory for Events.  195-237. Mahwah, NJ, US: Lawrence Erlbaum Associates Publishers.

Duarte A, Henson RN, Knight RT, Emery T, Graham KS 2010. Orbito-frontal cortex is necessary for temporal context memory. *J Cogn Neurosci* **22***:* 1819-1831.

Ferguson S, Hashtroudi S, Johnson MK. 1992. Age differences in using source relevant cues. Psychol Aging 7: 443-452

Green DM, & Swets JA. 1974. *Signal Detection Theory & Psychophysics (2nd ed.)*. New York, NY: Krieger.

Halpern, J. H., Pope, H. r., Sherwood, A. R., Barry, S., Hudson, J. I., & Yurgelun-Todd, D. (2004). Residual neuropsychological effects of illicit 3,4-methylenedioxymethamphetamine (MDMA) in individuals with minimal exposure to other drugs. *Drug And Alcohol Dependence*, *75*(2), 135-147.

Indlekofer F, Piechatzek M, Daamen M, Glasmacher C, Lieb R, Pfister H, Tucha O, Lange KW, Wittchen HU, Schütz CG. (2009). Reduced memory and attention performance in a population-based sample of young adults with a moderate lifetime use of cannabis, ecstasy and alcohol. J Psychopharmacol 23: 495-509.

Johnson MK, Hashtroudi S, Lindsay DS. 1993. Source monitoring. *Psychol Bull* **114***:* 3-28.

Johnson MK, Raye CL, 1981. Reality monitoring. Psychol Rev 88: 67-85

Johnson MK, Raye CL, Foley MA, Kim JK. 1982. Pictures and images: Spatial and temporal information compared. B Psychonomic Soc 19: 23-26.

Kahn I, Davachi L, Wagner AD. 2004. Functional-Neuroanatomic Correlates of Recollection: Implications for Models of Recognition Memory. *J Cogn Neurosci* **24***:* 4172-4180.

Kausler DH, Puckett JM. 1980. Adult age differences in recognition memory for a nonsemantic attribute. Exp Aging Res 6: 349-355

Kausler DH, Puckett JM. 1981. Adult age differences in memory for sex of voice. J Gerontol 36: 44-50

Kish SJ, Lerch J, Furukawa Y, Tong J, McCluskey T, Wilkins D, Houle S, Meyer J, Mundo E, Wilson AA, Rusjan PM, Saint-Cyr JA, Guttman M, Collins DL, Shapiro C, Warsh JJ, Boileau I (2010). Decreased cerebral cortical serotonin transporter binding in ecstasy users: A positron emission tomography/[$^{11}$C]DASB and structural brain imaging study. Brain: 133, 1779-1797.

Lindsay DS, Johnson MK,. 1991. Recognition memory and source monitoring. B Psychonomic Soc 29: 203-205

Lindsay DS, Johnson MK, Kwon P. 1991. Developmental changes in memory source monitoring. J Exp Child Psychol 52: 297-318

McCann UD, Szabo Z, Seckin E, Rosenblatt P, Mathews WB, Ravert HT, & ... Ricaurte, G. A. (2005). Quantitative PET Studies of the Serotonin Transporter in MDMA Users and Controls Using[$^{11}$C]McN5652 and [$^{11}$C]DASB. *Neuropsychopharmacology 30:* 1741-1750.

McCann UD, Szabo Z, Vranesic M, Palermo M, Mathews WB, Ravert HT, & ... Ricaurte, G. A. (2008). Positron emission tomographic studies of brain dopamine and serotonin transporters in abstinent (±)3,4-methylenedioxymethamphetamine ('ecstasy') users: Relationship to cognitive performance. *Psychopharmacology 200:* 439-450.

Meiser T, Bröder A. 2002. Memory for multidimensional source information. *J Exp Psychol Learn Mem Cogn* **28:** 116-137.

Mitchell KJ, Johnson MK. 2009. Source monitoring 15 years later: What have we learned from fMRI about the neural mechanisms of source memory? *Psychol Bull* **135***:* 638-677.

Mitchell KJ, Raye CL, McGuire JT, Frankel H, Greene EJ, Johnson MK. 2008. Neuroimaging evidence for agenda-dependent monitoring of different features during short-term source memory tests. *J Exp Psychol Learn Mem Cogn* **34***:* 780-790.

Multhaup KS, Balota DA. 1997. Generation effects and source memory in healthy older adults and in adults with dementia of the Alzheimer type. Neuropsychology 11: 382-391

Murphy PN, Bruno R, Ryland I, Wareing M, Fisk JE, Montgomery C, Hilton J. 2012. The effects of 'ecstasy' (MDMA) on visuospatial memory performance: Findings from a systematic review with meta-analyses. *Hum Psychopharmacol Clin Exp* 27: 113-138.

Murphy PN, Wareing M, Fisk JE, & Montgomery C. 2009. Executive Working Memory Deficits in Abstinent Ecstasy/MDMA Users: A Critical Review. *Neuropsychobiology* **60:** 159-175.

Narum SR. 2006. Beyond Bonferroni: Less conservative analyses for conservation genetics. *Conserv Genet* **7***:* 783–787

Nulsen CE, Fox AM, Hammond GR. (2010). Differential effects of ecstasy on short-term and working memory: A meta-analysis. Neuropsychol Rev 20: 21-32.

Parrott AC. 2013. MDMA, serotonergic neurotoxicity, and the diverse functional deficits of recreational 'Ecstasy' users. .Neurosci Biobehav Rev 37: 1466– 1484

Raven J, Raven JC, Court JH. 1998. *Manual for Raven's Progressive Matrices and Vocabulary Scales.* Oxford, UK: Oxford Psychologists Press.

Rosselli M, Ardila A, Lubomski M, Murray S, King K. 2001. Personality profile and neuropsychological test performance in chronic cocaine-abusers. Int J Neurosci **110***:* 55-72.

Schilt T, de Win MML,Jager G, Koeter MW, Ramsey NF, Schmand B, van den Brink W. 2008. Specific effects of ecstasy and other illicit drugs on cognition in poly-substance users. Psychol Med 38: 1309-1317.

Scholey AB, Owen L, Gates J, Rodgers J, Buchanan T, Ling J, ... Parrott AC. 2011. Hair MDMA samples are consistent with reported ecstasy use: findings from a study investigating effects of ecstasy on mood and memory. *Neuropsychobiology,* **63***:* 15-21.

Shimamura AP. 2002. Memory retrieval and executive control processes. In Stuss DT, Knight RT. (Eds.). *Principles of Frontal Lobe Function.* 210-220. New York, NY, US: Oxford University Press.

Smith SM, Vela, E (2001). Environmental context-dependent memory: A review and meta-analysis. Psychonomic Bulletin & Review 8: 203-220.

Strømsø HI, Bråten I, Britt MA. 2012. Reading multiple texts about climate change: The relationship between memory for sources and text comprehension. *Learning and Instruction,* **20***:* 192-204.

Thomasius R, Zapletalova P, Petersen K, Buchert R, Andresen B, Wartberg L, Nebeling B. Schmoldt A. (2006). Mood, cognition and serotonin transporter availability in current and former ecstasy (MDMA) users: The longitudinal perspective. *J Psychopharmacol* 20: 211-225.

Tomasi DD, Goldstein RZ, Telang FF, Maloney TT, Alia-Klein NN, Caparelli EC, & Volkow ND. 2007. Widespread disruption in brain activation patterns to a working memory task during cocaine abstinence. *Brain Res* **1171***:* 83-92.

Unsworth N, Brewer GA, Spillers GJ (2011). Variation in working memory capacity and episodic memory: Examining the importance of encoding specificity. Psychonomic Bulletin & Review 18: 1113-1118.

Vignali C, Stramesi C, Vecchio M, Groppi A. 2012. Hair testing and self-report of cocaine use. *Forensic Sci Int* **215***:* 77-80.

Yacoubian GS Jr, Wish ED. 2006. Exploring the validity of self-reported ecstasy use among club rave attendees. *J Psychoactive Drugs* **38***:* 31-34.

Zaldívar BF, García MJM, Flores CP, Sánchez SF, López RF, Molina MA. 2009. Validity of the self-report on drug use by university students: correspondence between self-reported use and use detected in urine. *Psicothema.* **21***:* 213-219.

Zaragoza MS, & Lane SM. 1994. Source misattributions and the suggestibility of eyewitness memory. *J Exp Psychol Learn Mem Cogn* **20**: 934-945.

Table 1 Demographic indicators by gender for ecstasy users and non-ecstasy users

| | Ecstasy Users | | | | | | Non ecstasy users | | | | | | p (two tailed) | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Male | | | Female | | | Male | | | Female | | | Drug | Gender | Drug* Gender |
| | Mean | SD | n | Mean | SD | n | Mean | SD | n | Mean | SD | n | | | |
| Age | 22.59 | 2.52 | 37 | 21.60 | 2.10 | 25 | 21.19 | 1.82 | 27 | 20.48 | 2.27 | 48 | .002 | .033 | .715 |
| Ravens progressive matrices (maximum 60) | 45.83 | 6.63 | 35 | 41.32 | 9.18 | 25 | 45.48 | 8.21 | 27 | 43.98 | 8.51 | 46 | .427 | .040 | .302 |
| Years of education | 16.18 | 1.71 | 30 | 16.70 | 1.84 | 23 | 15.83 | 1.52 | 24 | 15.55 | 1.77 | 44 | .022 | .730 | .220 |
| Alcohol (units per week) | 14.36 | 10.13 | 35 | 11.44 | 8.90 | 24 | 13.69 | 10.43 | 26 | 12.21 | 12.02 | 39 | .979 | .260 | .713 |
| Alcohol (length of use: weeks) | 392.59 | 189.50 | 35 | 387.21 | 138.00 | 24 | 372.53 | 195.51 | 23 | 292.72 | 131.43 | 41 | .062 | .164 | .224 |
| Cigarettes per day | 6.47 | 4.21 | 16 | 6.11 | 4.45 | 13 | 8.67 | 2.31 | 3 | 7.75 | 5.24 | 8 | na | na | na |

Table 2 Measures of drug use by sex for ecstasy users and non-ecstasy users

| | Ecstasy Users | | | | | | Non ecstasy users | | | | | | p (two tailed) | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Male | | | Female | | | Male | | | Female | | | Drug | Gender | Drug* Gender |
| | Mean | SD | N | Mean | SD | N | Mean | SD | N | Mean | SD | N | | | |
| Total Prior Consumption | | | | | | | | | | | | | | | |
| Cannabis (joints) | 1772.34 | 3140.60 | 31 | 425.28 | 937.20 | 20 | 1812.77 | 3051.17 | 10 | 292.83 | 439.02 | 16 | .937 | .016 | .882 |
| Cocaine (lines) | 424.11 | 759.80 | 24 | 1003.45 | 1558.94 | 16 | 4.16 | - | 1 | 104.39 | 100.56 | 2 | na | na | na |
| Ecstasy (tablets) | 629.81 | 1897.22 | 35 | 834.19 | 2705.61 | 22 | - | - | - | - | - | -- | - | .739 | - |
| Long-Term Average Dose per Session | | | | | | | | | | | | | | | |
| Cannabis (joints) | 3.00 | 1.92 | 31 | 1.51 | 0.81 | 20 | 1.82 | 1.31 | 10 | 1.79 | 0.81 | 16 | .211 | .034 | .041 |
| Cocaine (lines) | 5.64 | 4.78 | 24 | 8.09 | 11.01 | 16 | 1.00 | - | 1 | 6.25 | 2.47 | 2 | na | na | na |
| Ecstasy (tablets) | 2.66 | 2.03 | 35 | 3.04 | 2.85 | 22 | - | - | - | - | - | - | - | .559 | - |
| Current Frequency of Use (times per week) | | | | | | | | | | | | | | | |
| Cannabis | 3.87 | 11.08 | 32 | 1.00 | 1.91 | 21 | 1.37 | 2.57 | 13 | 0.46 | 1.02 | 18 | .352 | .248 | .547 |
| Cocaine | 0.21 | 0.34 | 25 | 0.74 | 1.16 | 18 | 0.02 | 0.03 | 2 | 0.27 | 0.34 | 4 | na | na | na |
| Ecstasy | 0.21 | 0.41 | 37 | 0.23 | 0.44 | 25 | - | - | - | - | - | - | - | .807 | - |
| Amount Consumed in Previous 10 days | | | | | | | | | | | | | | | |
| Cannabis (joints) | 4.94 | 15.25 | 34 | 2.25 | 8.48 | 22 | 1.60 | 3.07 | 15 | 0.89 | 2.00 | 18 | .316 | .468 | .672 |
| Cocaine (lines) | 1.42 | 4.95 | 26 | 3.60 | 7.10 | 20 | 0.50 | 0.71 | 2 | 1.60 | 3.58 | 5 | na | na | na |
| Ecstasy (tablets) | 0.49 | 2.08 | 37 | 0.37 | 1.08 | 25 | - | - | - | - | - | - | - | .793 | - |
| Weeks Since Last Use | | | | | | | | | | | | | | | |
| Cannabis | 26.05 | 46.99 | 33 | 43.03 | 76.66 | 22 | 80.85 | 92.24 | 15 | 55.87 | 98.07 | 17 | .048 | .813 | .216 |
| Cocaine | 33.05 | 59.71 | 25 | 25.49 | 57.07 | 20 | 10.43 | 13.54 | 2 | 16.69 | 21.87 | 5 | na | na | na |
| Ecstasy | 50.87 | 69.70 | 37 | 54.74 | 82.68 | 25 | - | - | - | - | - | - | - | .843 | - |

Table 3. Outcomes for source and item memory measures by sex for ecstasy users and non-ecstasy users

| | Ecstasy Users | | | | | | Non ecstasy users | | | | | | p (two tailed) | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Male | | | Female | | | Male | | | Female | | | Drug | Gender | Drug* Gender |
| | Mean | SD | N | Mean | SD | N | Mean | SD | N | Mean | SD | N | | | |
| Source Memory Component (% of Hits) | | | | | | | | | | | | | | | |
| Position | 58.78 | 16.28 | 37 | 65.46 | 18.07 | 25 | 60.91 | 17.02 | 27 | 65.03 | 16.84 | 48 | .776 | .074 | .670 |
| List | 61.23 | 10.16 | 37 | 56.26 | 17.89 | 25 | 59.53 | 9.63 | 27 | 64.50 | 16.34 | 48 | .191 | 1.000 | .048 |
| Case | 58.37 | 14.04 | 37 | 62.28 | 19.25 | 25 | 62.61 | 14.63 | 27 | 69.87 | 11.36 | 48 | .022 | .030 | .512 |
| Item Memory Outcomes | | | | | | | | | | | | | | | |
| Hits (number) | 34.70 | 10.23 | 37 | 33.44 | 11.21 | 25 | 37.70 | 11.29 | 27 | 33.42 | 10.29 | 48 | .430 | .143 | .423 |
| False Positives (number) | 13.32 | 12.09 | 37 | 9.96 | 10.25 | 25 | 9.89 | 9.74 | 27 | 7.21 | 9.88 | 48 | .100 | .108 | .855 |
| SDT Sensitivity (d prime) | 1.08 | 0.70 | 35 | 1.18 | 0.87 | 23 | 1.40 | 0.82 | 26 | 1.43 | 0.78 | 44 | .047 | .635 | .811 |
| SDT Decision Criterion | 0.41 | 0.49 | 35 | 0.58 | 0.48 | 23 | 0.48 | 0.40 | 26 | 0.69 | 0.43 | 44 | .307 | .020 | .788 |

Table 4 The relationship between aspects of illicit drug use and source and item memory performance.

| | Mean | SD | n | Zero-Order Correlation with: | | | | |
|---|---|---|---|---|---|---|---|---|
| | | | | Source Memory Component | | | SDT Measures | |
| | | | | Position | List | Case | D Prime | Criterion |
| Alcohol | | | | | | | | |
| Units per week | 13.11 | 10.61 | 125 | .005 | -.090 | -.026 | .062 | .016 |
| Recent use (units, previous 10 days) | 18.27 | 16.10 | 108 | -.032 | -.041 | .095 | .000 | .000 |
| Length of Use (weeks) | 353.74 | 167.24 | 124 | -.057 | -.144 | -.059 | -.056 | -.100 |
| Illicit Drugs | | | | | | | | |
| Total Prior Consumption | | | | | | | | |
| Cannabis (joints) | 1119.18 | 2384.65 | 78 | -.093 | -.099 | -.007 | -.053 | .079 |
| Cocaine (lines) | 601.52 | 1123.45 | 44 | -.008 | -.110 | .158 | .022 | -.095 |
| Ecstasy (tablets) | 696.75 | 2205.02 | 58 | .018 | -.176 | .238(†) | .030 | .183 |
| Long-Term Average Dose per Session | | | | | | | | |
| Cannabis (joints) | 2.23 | 1.55 | 78 | -.171 | -.093 | -.154 | -.049 | -.063 |
| Cocaine (lines) | 6.37 | 7.56 | 44 | .000 | -.050 | .051 | .010 | .003 |
| Ecstasy (tablets) | 2.76 | 2.37 | 58 | -.080 | -.340** | .133 | .071 | .081 |
| Current Frequency of Use (times per week) | | | | | | | | |
| Cannabis | 2.09 | 7.05 | 85 | -.202† | .176 | -.101 | -.004 | .066 |
| Cocaine | 0.40 | 0.77 | 50 | .171 | -..529*** | -.347* | -.300* | .119 |
| Ecstasy | 0.22 | 0.42 | 63 | -.125 | -.105 | .012 | -.172 | .076 |
| Amount Consumed in Previous 10 days | | | | | | | | |
| Cannabis (joints) | 2.94 | 10.41 | 90 | -.011 | .007 | .049 | .017 | -.006 |
| Cocaine (lines) | 2.19 | 5.64 | 54 | .044 | -.300* | .142 | .133 | .132 |
| Ecstasy (tablets) | 0.43 | 1.72 | 63 | -.019 | -.033 | .075 | -.004 | .143 |
| Weeks Since Last Use | | | | | | | | |
| Cannabis | 45.10 | 75.99 | 88 | -.050 | -.034 | .114 | .050 | .060 |
| Cocaine | 27.25 | 54.09 | 53 | .359** | .253† | .350* | .223 | .216 |
| Ecstasy | 51.65 | 74.23 | 63 | .242† | .155 | .116 | .151 | -.032 |

*** p<.001; ** p<.01; * p<.05 † p<.10 two tailed

**Figure 1:List Memory Judgements by User Group and Gender**