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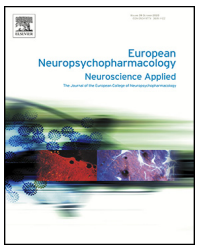

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SHORT COMMUNICATION

Feeding the addiction: Narrowing of goals to habits

J.R. Breedon[a], H. Ziauddeen[a,b], J. Stochl[a,c], K.D. Ersche[a,*]

[a] *University of Cambridge, Department of Psychiatry, Herchel Smith Building for Brain & Mind Sciences, Cambridge Biomedical Campus, Cambridge CB2 0SZ, UK*
[b] *Cambridgeshire and Peterborough NHS Foundation Trust, Cambridge CB21 5EF, UK*
[c] *Department of Kinanthropology and Humanities, Charles University, 16252 Prague, Czech Republic*

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Abstract
Whilst the initiation of cocaine use is typically goal-directed and motivated by the rewarding effects of the drug, drug-taking can become habitual over time, rendering the user less sensitive to cocaine's hedonic value. Experimental studies suggest that patients with cocaine use disorder (CUD) are particularly prone to develop habits, even in non-drug related contexts. CUD patients have previously been shown to consume higher levels of high-calorie foods and report more uncontrolled eating, suggesting a tendency towards habitual or dysregulated food-related behaviours. We investigated this in CUD patients compared with healthy controls. Participants were presented with a series of food images and asked to rate their willingness to pay for, and their motivation to consume the foods. Self-reported motivations for food choices were collected using a validated questionnaire. Our data suggests CUD patients display goal-narrowing towards cocaine, as well as habitual tendencies towards both cocaine and food. These findings stress the importance of addressing non-drug related behaviours when treating CUD patients. Further, they suggest that habits may provide a novel and additional target for psychological interventions, for example, through the retraining of maladaptive habits. Whilst research into the feasibility and efficacy of habit retraining is certainly required, the potential for a new avenue of treatment should not be ignored.

1. Introduction

Our choices are directed towards the goals we define for ourselves (Pezzulo et al., 2014). Within the realm of experimental psychology, behaviours performed in pursuit of such goals are referred to as 'goal-directed'. As they

* Corresponding author.
E-mail address: ke220@cam.ac.uk (K.D. Ersche).

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are orientated towards the outcomes of actions and their represented value to the individual, such behaviours are flexible and are able to adapt to different behavioural contexts (Balleine and Dickinson, 1998). This sensitivity of goal-directed behaviours to outcomes can be demonstrated experimentally, revealing its dependence upon what is theoretically referred to as the 'response-outcome (R-O) association' (Vlaev et al., 2011). In contrast, habitual behaviours are triggered by environmental cues, or stimuli, and are insensitive to changes in the R-O contingency or the value of the outcome (Balleine and O'Doherty, 2010). These behaviours are thought to be driven by the contextual cues preceding the behaviour, and are therefore 'stimulus-response (S-R) associations' (Dickinson et al., 1985, 2002). Individuals naturally make use of both these types of behaviour in collaboration; regular repetition of goal-directed behaviours leads to increasing autonomy of the behaviour from the goal, and greater reliance upon habitual action (Balleine and Dezfouli, 2019). In drug addiction, this natural behavioural control is disturbed. Over time, an individual's goals narrow towards drug use whilst simultaneously becoming less intentional and more triggered by environmental cues. A contemporary theory explains this phenomenon as a shift in the balance from goal-directed to habitual behaviour (Everitt and Robbins, 2005), and this transition has been shown to be facilitated by stimulant drugs such as amphetamines and cocaine. These drugs are thought to both facilitate the transition between these behavioural control mechanisms and weaken top-down inhibitory control of behaviour (Nelson and Killcross, 2006; Takahashi et al., 2007).

Patients with cocaine use disorder (CUD) have been shown to exhibit a strong bias towards appetitive habits and this has been experimentally demonstrated even with behaviours unrelated to drug-taking (Ersche et al., 2016). Specifically, this bias has been demonstrated for approach behaviours, which include the seeking of natural rewards such as drugs or food. CUD patients have also been shown to consume significantly higher levels of dietary fat and carbohydrates and exhibit increased levels of uncontrolled eating (Ersche et al., 2013), suggesting a predilection for highly reinforcing foods and poor regulatory control. However, it has yet to be demonstrated whether the habitual tendencies and narrowed goals of CUD patients extend to food-related behaviours.

In the context of food, the relative importance of the two controlling factors might be investigated experimentally by testing the reliance upon R-O associations (Dickinson, 1985). Individuals favouring goal-directed behaviour are more able to change their behaviour in response to outcome devaluation (Olmstead et al., 2001), for example when pre-test satiation decreases the motivation to consume foods. Thus a bias towards habitual behaviour may be evidenced by persistence of behaviours despite changes in motivational state, or lack of relation between the motivation for and the behaviour towards an outcome. We propose here that this can be explored by simulating theoretical food-related decision behaviour. Through this we can explore an individual's willingness to pay for specific food items and their motivation to consume the same items. Similar to how experimental performance adapts to outcome devaluation when it is predominantly goal-directed; if simulated decision behaviours are predominantly goal-directed, they should relate to the motivation values attached to the foods. By contrast, habitual tendencies may be reflected in a mismatch between the decisions and the motivational state. Additionally differences in the subjective valuation of foods in CUD patients compared with controls may suggest a narrowing of goals towards cocaine, and self-reported motivations for food choices may provide insight into whether food purchasing is more goal-directed or habitual (Wood and Rünger, 2016; Ersche et al., 2017).

Those with a bias towards habitual behaviour will persist with similar patterns of behaviour despite changes in motivational state. We suggest here novel approaches to assessing habitual tendencies and goal-directed choices outside of the outcome devaluation paradigm. Insights into behavioural tendencies may be gained through simulating theoretical food-related behaviour e.g. willingness to pay for specific food items, and their associated motivational states e.g. motivation to consume foods. Experimental performance adapts to outcome devaluation when predominantly goal-directed; similarly, these simulated behaviours ought to reflect the motivational value attached to a food item if the food-related decisions are predominantly goal-directed. In contrast, habitual tendencies may be reflected in a mismatch between the decisions and the motivational state. Differences in subjective valuation of foods may suggest a narrowing of goals towards cocaine. Finally, self-reported motivations for food choices via questionnaires may reveal different behavioural tendencies when buying food (Wood and Rünger, 2016; Ersche et al., 2017).

In summary, CUD patients have been shown to exhibit a behavioural bias towards habits that is not just limited to drug-taking. Such a bias may be the result of developed habits generalising to other stimuli, or due to a creature of habit character trait. Whilst habits are often probed experimentally using an outcome devaluation paradigm, we suggest that analogue inferences may be made from simple measures of behavioural response, motivational state, and the relationship between them. Given the previous evidence suggesting a predilection for uncontrolled eating, we hypothesise that CUD patients' food-related choices will be more repetitive and habit-like, rather than purposeful and goal-directed. We predicted that food-related choices would mirror, albeit to a lesser degree, the habitual patterns of cocaine-related choices.

2. Experimental procedures

We recruited 78 participants who met the DSM-IV criteria (APA, 2000) for cocaine dependence (average cocaine use duration of 16 years) from treatment centres and by word-of-mouth. Whilst the majority of the cocaine-using participants had comorbid drug dependencies, cocaine dependence was the primary disorder in all patients. Individuals meeting these criteria will henceforth be referred to as patients with cocaine used disorder (CUD), in line with the more recent terminology endorsed by DSM-5 (APA, 2013). Additionally, we recruited 56 healthy volunteers with no history of drug or alcohol dependence from the local community. The protocol was approved by the National Research Ethics Committee (NREC-10/H0306/69; PI: KD Ersche). All participants provided written informed consent. More information about the sample can be found in the supplementary material.

We presented participants with 40 food photographs on a computer screen, in randomised order. The photographs were selected

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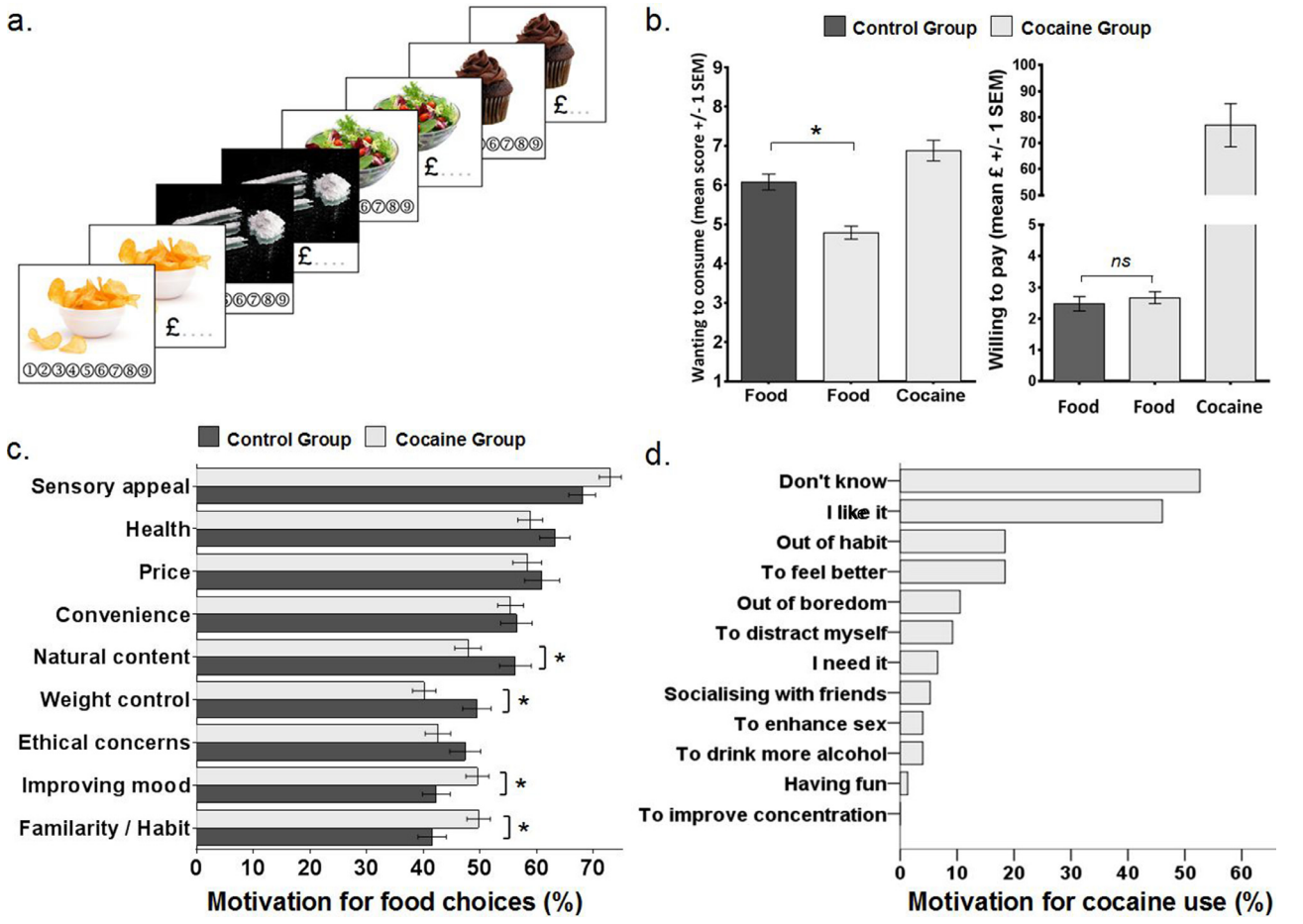

Fig. 1 (a) Rating task: We presented participants a series of food and cocaine pictures on the computer screen and asked them to rate on a 9-point Likert scale how much they would like to eat the food or use the cocaine (1= not at all, 9= very much), and to indicate how much they would be willing to pay for it. (b) Mean scores for wanting to consume and willingness to pay for food and cocaine respectively. (c) We asked participants what they considered as important factors for determining what food they eat on a typical day, using the Food Choice Questionnaire. (d) We also asked CUD patients why they used cocaine: 53% spontaneously answered 'I don't know'. We then read out to them 11 examples of reasons for cocaine use and asked them to indicate whether this was a reason for their cocaine use; multiple answers were possible.

from a pool of 100 pictures downloaded from the internet. To ensure correct valence classification, all pictures were rated online for pleasantness and arousal using a 9-point Likert scale (1 = not at all, 9 = very much) by 159 volunteers in the general population prior to experimental testing. In the present study, we asked participants to rate for each of the 40 photographs their motivation to eat the displayed item and indicate how much they were willing to pay for it. CUD patients were additionally shown 20 cocaine photographs interleaved in a pseudorandomised fashion (i.e. a random cocaine image was programmed to appear every few food images) to minimise systematic differences between the two image sets, which may have occurred if chunked together. CUD patients were also asked to provide analogous ratings of their motivation to use cocaine and the amount they would be willing pay for it (Fig. 1a). The cocaine pictures were selected from 30 photographs downloaded from the internet and rated on the same 9-point Likert scales by three independent CUD patients, who did not take part in the study.

As chronic cocaine use is associated with appetite suppression (Billing and Ersche, 2015; Kuhar, 2016) and low socioeconomic status (Williams and Latkin, 2007), we assessed general appetite using the self-reported Simplified Nutritional Appetite Questionnaire (SNAQ) (Wilson et al., 2005), and collected data on participants' income and weekly food expenditure. We assessed their motivations for food choice and cocaine use using the Food Choice Questionnaire (FCQ) (Steptoe et al., 1995) and a semi-structured interview respectively (see supplemental material).

Data were square-root transformed to reduce skewness for parametric analyses, including t-tests and analysis of covariance, using the Statistical Package for the Social Sciences V22 (SPSS IBM); untransformed values are displayed in the figures and tables. We also replicated the analysis using equivalent non-parametric approaches implemented in R package sm (version 2.2-5.6)(Bowman and Azzalini, 2018), see supplemental material. The SNAQ total score was included in the analysis of the FCQ; for the analysis of task performance, both the SNAQ and food expenditure were included as covariates. All statistical tests were two-tailed and significance levels were set at 0.05.

3. Results

The groups were reasonably well-matched, but differed with respect to verbal intelligence (t_{128}=8.90,p<0.001) and body mass index (t_{131}=3.14,p = 0.002), but as these were not correlated with any of the outcome measures in either

groups, they were not included as covariates (see supplementary material).

Compared with controls, CUD patients reported significantly less motivation to consume food ($F_{1,128}$=19.9, p<0.001,η^2 = 0.134), but did not differ in food valuation (willingness to pay for food) ($F_{1,128}$=0.22,p = 0.639, η^2 = 0.002). However, CUD patients' motivation for and willingness to pay for cocaine exceeded that for food (Fig. 1b). The ratings to eat and value food were significantly correlated in both groups (controls: r = 0.49,p<0.001; CUD: r = 0.28,p = 0.013), suggesting that food valuation was influenced by the degree of wanting in both groups. Disposable income was related to weekly food expenditure only in the controls (r = 0.41,p = 0.002) but not in the CUD patients (r = 0.08,p = 0.478), suggesting that CUD patients give less weight to financial means when buying foods. However, in the context of cocaine, the correlations between 'wanting to use' and 'willingness to pay' did not yield meaningful relationships, as the motivation to use was restricted by the 9-point rating scale, resulting in a ceiling effect (see also supplementary material).

The factors determining food choice also differed significantly between the groups (Fig. 1c). Whilst sensory appeal, health considerations, food price, ethical concerns, and convenience were equally important factors in both groups, CUD patients were significantly more influenced by prior experiences with a food ($F_{1,130}$=5.04, p = 0.026,η^2 = 0.037), supporting the notion of habitual tendencies. They were also more likely to choose foods because they made them feel better ($F_{1,130}$=4.04,p = 0.046,η^2 = 0.030), whereas controls participants were more concerned about the natural ingredients of food ($F_{1,130}$=5.34,p = 0.022,η^2 = 0.039) and its potential impact on their weight ($F_{1,130}$=9.19,p = 0.003,η^2 = 0.066). CUD patients' habitual choice tendencies were also mirrored in the context of cocaine, such that 53% of CUD patients spontaneously reported that they did not know their motivation(s) for using the drug i.e. why they use cocaine and this is indicative of habitual behaviour. On further probing, they endorsed 'liking for cocaine' (42%) and 'out of habit' (18%) as the key motivations (Fig. 1d).

4. Discussion

Whilst a habitual bias for cocaine use has been suggested by the extant literature and been anecdotally reported in patients with CUD, this study provides evidence of goal-narrowing towards cocaine as well as self-reported tendencies of habitual drug use. The habitual tendencies seen in CUD may also extend to other appetitive behaviours such as eating. Despite reporting less motivation to consume the presented food, the CUD patients were willing to pay as much as the control group, suggesting less reliance upon R-O associations, and perhaps more upon S-R associations. Compared with control volunteers, CUD patients' food choices appeared significantly more driven by factors indicative of habit such as familiarity with certain foods. In as much as repeated actions transform into automated habits, the subjective feelings towards the stimuli concerned (e.g. particular foods) are experienced as familiar. In other words, familiarity with stimuli may reflect a subjective component of stimulus-response habit learning. Although participants' decisions were also influenced by goal-orientated factors such as the price of food, convenience or health-related issues, the contribution of these factors was less pronounced in the CUD patients compared with the healthy controls. It is possible that some of the goals that were relevant for the control participants were not relevant for CUD patients (e.g. weight control, natural content of food), and this may have contributed to these results. Possibly, this lack of goal relevance may have led to a greater reliance on the habit system. Our data thus concords with suggestions that both regulatory systems act in conjunction rather than through competition (Miles et al., 2003) and at present the nature of the assumed imbalance between the goal-orientated and the habit system in CUD remains unclear.

Like other experimental procedures for investigating habits, this task is limited by its inability to distinguish between reduced goal-directed behaviour (decreased R-O reliance) and increased habit formation (increased S-R reliance) (Vandaele and Janak, 2018). In addition, it is important to highlight that this task does not involve outcome devaluation or contingency degradation procedures, and we should therefore be cautious about drawing too strong conclusions from these data without further investigation. Nevertheless, these results do suggest that in future outcome devaluation procedures in drug-addicted patients, food rewards may not necessarily provide a stable comparator for detecting changes in motivational states towards drug rewards.

These data simultaneously suggest a narrowing of goals towards cocaine and a broadening of habitual bias to include behaviours related to eating. These results may have important therapeutic implications. Conventional therapies for CUD are based on a goal-directed rationale, namely inducing behavioural change by increasing the motivation for alternative, non-drug-related goals (i.e. motivational interviewing (Goncalves et al., 2017)) or by deliberately modifying maladaptive behaviour through insight into the consequences of one's actions (i.e. CBT) (Carroll et al., 2004). However CUD patients' bias towards habitual responding could be targeted directly by treatment, for example, by training desirable habits to displace maladaptive drug-taking habits. Further research should consider including measures of consume behaviour and clinical data to investigate the potential for such treatment. Our results add further impetus to the need to recognise that CUD, and addiction in general, is about more than drugs and has far-reaching implications for patients' lives. Future research and treatment strategies should evolve accordingly in order to best serve those afflicted with drug use disorders.

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Contributions

KDE acquired funding, designed the study and wrote the protocol. JRB managed the literature searches, analysed the data and wrote the first draft of the manuscript. JRB conducted the analysis with the help of JS. KDE and HZ contributed to the interpretation of the data. All authors contributed to and have approved the final manuscript.

Declaration of Competing Interest

All authors declare no conflict of interest.

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Supplementary materials

Supplementary material associated with this article can be found, in the online version, at doi:10.1016/j.euroneuro.2020.11.002.

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