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SOCIABILITY/IMPULSIVITY AND ATTENUATED DOPAMINERGIC AROUSAL: CRITICAL FLICKER/FUSION FREQUENCY AND PROCEDURAL LEARNING

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Summary—Two experiments examined the interaction of sociability (Soc) and impulsivity (Imp) components of extraversion and reduced dopamine activity (by haloperidol) on critical flicker/fusion frequency change scores (ΔCFFT) and procedural learning. In double-blind designs, subjects received either haloperidol (5 mg) or placebo; Soc and Imp were randomly sampled. In Experiment 1, Drug × Imp, and Drug × Imp × Soc interactions were found on ΔCFFT; in Experiment 2, a drug × Soc interaction was found on procedural learning. In both experiments, introverts seemed over-aroused under placebo (putatively due to the medical context), more optimally aroused under haloperidol; for procedural learning, extraverts seemed more optimally aroused under placebo, less optimally aroused under haloperidol. These data indicate that both Soc and Imp mediate the effects of arousal; Drug × Imp effects my conceal joint effects of Soc × Imp; and that Soc shows more consistent effects than Imp. These data complement a previous study of Soc/Imp and caffeine-induced arousal (Corr, Pickering & Gray, 1995), and lend support to H. J. Eysenck's (1967) arousal model of Extraversion. © 1997 Elsevier Science Ltd

INTRODUCTION

The role of sociability (Soc) and impulsivity (Imp) in arousal-mediated performance remains a contentious issue in Extraversion research. Although Soc and Imp are correlated (sometimes ≈ 0.50), they are often seen as separate factors (e.g. Carrigan, 1960; Guilford, 1975), both in terms of their factorial unity (Rocklin & Revelle, 1981) and their theoretical bases (Humphreys & Revelle, 1984). The distinction between Soc and Imp is even seen in H. J. Eysenck's structural model of personality, where Imp (formerly part of the EPI extraversion scale; Eysenck & Eysenck, 1964) has been removed from more recent questionnaire measures of extraversion (Eysenck & Eysenck, 1975, 1991), which now are composed largely of Soc items. However, H. J. Eysenck (Eysenck & Eysenck, 1985) continues to associate both Soc and Imp in arousal-mediated performance. The precise role of Soc and Imp in these arousal effects has not been adequately clarified.

There is a body of evidence supporting the role of Imp in arousal-based performance, comprising effects of caffeine on intelligence test performance (Revelle *et al.*, 1980); experimental manipulation of stimulus intensity in classical conditioning (Barratt, 1971; Eysenck & Levey, 1972); and electrodermal activity (e.g. Smith, Rypma & Wilson, 1981). However, other experimental evidence favours a role for Soc, and not Imp in arousal-mediated effects (e.g. Matthews, Davies & Lees, 1990; Wilson, 1990).

In an attempt to derive converging evidence of Soc and Imp effects (cf. Bullock & Gilliland, 1993), Corr, Pickering and Gray (1995) examined the interaction of Soc/Imp and caffeine-induced arousal on two very different task measures: critical flicker/fusion frequency (CFF), and a phylogenetically old associative process, known as procedural learning (e.g. Hartmann, Knopman & Nissen, 1989; Lewicki, Czyzewska & Hoffman, 1987). Corr *et al.* reported that Soc moderated the effects of caffeine on both tasks, and Imp either had a much weaker, and secondary influence (on CFF), or no influence at all (on procedural learning). In the report of Corr *et al.*, Soc and Imp were randomly sampled, therefore both factors had an equal chance of mediating caffeine-induced arousal. Nevertheless, although Soc effects are sometimes more important than Imp effects, as noted by Corr *et al.*, "The consistent finding of (usually EPI) impulsivity in arousal-mediated performance

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(e.g. Eysenck & Levey, 1972; Revelle *et al.*, 1980) cannot be simply ignored" (p. 728). These inconsistent results have given rise to a number of theoretical positions.

Soc effects are sometimes postulated to reflect Imp variance (e.g. Revelle *et al.*, 1980). This 'redundant trait hypothesis' implies that Soc and Imp do not possess additive variance; that is, controlling for influences of Imp, drug × Soc effects should disappear. This hypothesis is not consistent with studies that have controlled for Imp yet still found a unique effect of Soc (e.g. Corr *et al.*, 1995). However, it is also obvious that unique Imp effects sometimes reported (e.g. Revelle *et al.*, 1980) are not secondary effects of Soc. Research to date thus seems to show compelling evidence for the unique roles of *both* Soc and Imp.

The 'redundant trait hypothesis' may be contrasted with the 'additive trait hypothesis', which assumes that Soc and Imp represent lower-order traits of a higher-order general arousal factor (e.g. Eysenck & Eysenck, 1985). This alternative hypothesis predicts that Soc + Imp influences are most pervasive, although given the vicissitudes of measurement error, sometimes Imp might appear more predictive, at other times Soc. The resulting extraversion scale would thus run from Soc − /Imp − to Soc + /Imp + . Depending on the precise pattern of personality and arousal effects, these additive effects might appear as drug × Soc × Imp interaction terms.

The present experiment aimed to contrast the 'redundant trait hypothesis' and 'additive trait hypothesis' in order to address the respective roles of Soc and Imp in arousal-mediated performance. The design and tasks used by Corr *et al.* (1995) were repeated. However, this time the focus of interest was on the effects of Soc/Imp in low arousal states. The rationale for this research strategy was that if Soc/Imp truly mediate the effects of arousal, then they should also mediate the effects of under-arousal.

The predictions tested in this study were based upon Eysenck's (1967) personality theory, which postulates that introversion–extraversion reflects differential reticulocortical activating system (ARAS; Morruzi & Magoun, 1949) functioning. According to this theory, introverts have relatively low thresholds of response, and in consequence rapid excitation and high cortical arousal; extraverts relatively high thresholds of response, and slow excitation and low cortical arousal. As a result of these differential arousal effects, introverts' performance should be least impaired by under-arousal, extraverts most impaired. Support for these predictions comes from studies that show that introverts do outperform extraverts on conditioning tasks (Franks, 1956, 1957); that stimulant drugs (e.g. dexamphetamine) facilitate conditioning, while depressant drugs (e.g. sodium amobarbital) impair conditioning (Franks & Trouton, 1958); and that introversion–extraversion and stimulant/depressant drugs interact to affect performance (e.g. Gupta, 1970, reported that extraverts' conditioning performance was impaired by the sedating barbiturate, phenobarbital).

In order to produce an attenuated state of arousal, haloperidol, a non-selective (D1/D2) dopamine receptor antagonist, was used. Several lines of reasoning suggested that haloperidol and introversion–extraversion should interact in a reverse manner to the arousing properties of caffeine reported by Corr *et al.* (1995).

Firstly, dopaminergic transmission has been suggested as being the most important component in ARAS arousal (e.g. Le Moal & Simon, 1991). In support of a dopamine and ARAS arousal association, in lower animals, haloperidol has sedative effects on ARAS-related EEG activity (Ongini *et al.*, 1992); and at higher doses produces sedation to the point of behavioural passivity (Corbett, 1995). In human *S*s, haloperidol slows down RTs during attentional search (Coull, Sahakian, Middleton, Young, Park, McShane, Cowen & Robbins, 1995), induces sedation (Lewander, 1994; Jackson, Ryan, Evenden & Mohell, 1994), and produces cognitive dulling (Silva, Munoz, Daniel, Barickman & Freidhoff, 1996).

Secondly, dopamine and introversion–extraversion have been empirically associated. Using positron emission tomography (PET), Fischer, Wik and Fredrikson (1996) reported that, compared to extraverts, introverts had higher levels of activity in subcortical, but not cortical, areas of the brain, which have high concentrations of dopamine terminals and which have been implicated in learning, motor and vigilance performance. Behavioural associations between putative dopamine activity and introversion–extraversion have also been reported (Stelmack & Pivik, 1996). It is also known that positive emotionality, which is highly correlated with extraversion, has a dopamine basis (Depue *et al.*, 1994).

Taken together, these data suggest that dopamine antagonism should lead to a reduction in

general arousal, which in turn should be mediated by introversion–extraversion. However, as with caffeine-induced arousal, the pattern of drug effects may not be simple. To illustrate this point, haloperidol has been reported to improve cognitive performance (e.g. Parrott & Hindmarch, 1975); for example, King and Henry (1992) found that haloperidol led to critical flicker fusion improvement. As Eysenck (e.g. 1967) has repeated on numerous occasions, if putative drug × personality effects are not considered, then inconsistent patterns of drug effects may simply reflect the moderating influence of personality.

In terms of arousal-attenuating (sedative) drugs, Eysenck's model predicts that: (i) under placebo, introverts should be more aroused/arousable than extraverts, and therefore should show better performance (providing that the experimental setting is not too stimulating); (ii) under sedative drugs, extraverts should show a marked impairment in performance, introverts less of a decrease or, depending on the arousal status of the experimental setting, an actual increase in performance (by virtue of the lowering of putative over-arousal induced by the environment of the experiment).

Consistent with the 'additive trait hypothesis', Eysenck's theory predicts that Soc should mediate the effects of under-arousal; Imp may also be important, but there is little reason to assert that its effects should take priority over Soc effects: their joint effects should be complementary. In contrast to this position, the 'redundant trait hypothesis' predicts that where Soc effects are found, they will be secondary to Imp effects (i.e. they will be weaker, less consistent, and, after controlling for Imp, non-significant).

METHOD

Subjects

Separate samples of 40 right-handed male volunteers served in Experiment 1 (mean age = 27.43, SD = 6.34) and Experiment 2 (27.88, 6.41) *Ss* were recruited through a local newspaper advertisement. Before selection, *Ss* underwent a semi-structured medical screening test for a number of contra-indications to haloperidol: thyroid dysfunction, glaucoma, heart disease, hypo- and hypertension, history of severe mental illness, anorexia, violent or rapid mood changes, regular medical prescription, alcohol dependency, and drug abuse (ascertained by urine analysis). The sample was limited to males to reduce error variance in physiological reactions to haloperidol. All *Ss* received £50.00 payment.

Design

Two Drug levels (haloperidol 5 mg and placebo) were administered double-blind. Allocation of 20 *Ss* to each Drug condition was random. The experimenter was blind to personality status (questionnaires were scored after the experiment), drug allocation and physiological recordings taken throughout the experiment.

Drug administration

Placebo (PLAC; empty capsule) and haloperidol (HAL; 5 mg) were administered orally. Haloperidol latency was determined on the basis of previous studies (3 hr; Nordstrom, Farde & Halldib, 1992).

Ss were also given a single oral dose of Orphenadrine (50 mg) after completion of the experiment in order to counteract possible extrapyramidal reactions to haloperidol. Medical cover was made available for a period of 24 hr after completion of the experiment.

Personality questionnaires

Sociability (Soc) was measured by the Extraversion scale of the Eysenck Personality Questionnaire (EPQ) (Eysenck & Eysenck, 1975). As noted by Rocklin and Revelle (1981), this measure of extraversion has been largely divested of its impulsivity items. Impulsivity (Imp) was measured by the Impulsiveness scale of the IVE Questionnaire (part of the Eysenck Personality Scales, EPS; Eysenck & Eysenck, 1991). Questionnaires were administered during medical screening (i.e. prior to the experimental session).

Procedure

Ss were told that the study was concerned with the psychological effects of a drug on task performance. They were requested to have a light breakfast on the day of testing and to abstain from alcohol for at least 12 hr prior to their appointment. Once informed consent had been obtained, the drug capsules were given (by a nurse), followed by a 3-hr waiting period; throughout the session measurements of heart rate and blood pressure were taken by a qualified nurse.

Testing took place in a small testing room. Drugs were administered between 9.00 a.m. and 11.30 a.m., and task performance was measured between 12.00 a.m. and 4.00 p.m. Ethical considerations were assessed by the Ethics Committee of the Institute of Psychiatry (University of London).

Statistical analysis

A regression approach was adopted to testing the significance of drug and personality effects. This multivariate technique is preferable to taking median splits because of the preservation of statistical power (Cohen, 1968) and reduction of statistical artefacts (Bissonnett *et al.*, 1990); in addition, the flexibility of regression analyses allowed an optimal set of predictors to be identified. Follow-up conventional median-split analysis of variance (ANOVAs) were used for descriptive purposes.

Multiple regression (stepwise) analyses included the following variables; (i) main effects of Drug, Soc and Imp; (ii) all possible two-way interactions between Drug, Soc and Imp; and (iii) a three-way interaction between Drug × Soc × Imp. Variables were centred prior to computation of interaction crossproducts (Aiken & West, 1991); these crossproducts are comparable to ANOVA-type interactions and may be interpreted accordingly.

EXPERIMENT 1: CRITICAL FLICKER/FUSION FREQUENCY

The CFF apparatus and procedure has been described by Corr *et al.* (1995). In brief, a method of limits procedure was adopted in which the *S* viewed the flicker ascending from 25 Hz and descending from 50 Hz. This method yields two parameters: (i) the frequency at which two intermittent lights fuse into a single percept (fusion threshold); and (ii) the frequency at which the single percept separates to form two flickering lights (flicker threshold). The mean of fusion and flicker thresholds represents the CFF threshold (CFFT). Four ascending and descending readings were taken in alternating order.

The means of ascending and descending trials were computed; readings that were greater than 45 were excluded in order to reduce the error of measurement (readings were rarely lower than 30 hz and rarely higher than 40 hz). The mean was used for analysis only if at least two readings were within the permitted range.

The first CFF reading was taken immediately after drug administration (i.e. before any psychopharmacological effect). Therefore, this first reading may have been sensitive to the drug administration procedure; this aspect of the design was important because any differences between pre- and post-readings could not be attributed to drug administration *per se*, but specifically to the pharmacological action of haloperidol.

Results and Discussion

Descriptive statistics for Soc and Imp were, respectively: means, 15.92, 9.70; standard deviations, 4.28, 3.88; medians, 16.50, 10; and min.–max values, 8–22, 3–17. Soc and Imp were uncorrelated ($r = 0.13$, ns).

Table 1 shows the means and standard deviations for pre- and post-task CFF thresholds, and the correlations between these measures, in each of the drug conditions.

Validation checks

Two-way analysis of variance (ANOVA) confirmed that there were no significant Soc/Imp × Drug interactions on the distribution of weight ($M = 73.48$ kg, SD = 8.16). Mean Soc and Imp scores were comparable in PLAC ($M = 15.70$, 9.20, SD = 4.34, 3.40) and HAL ($M = 16.50$, 10.20, SD = 4.28, 4.34) conditions, respectively.

Table 1. Means (standard deviations, SD) and Pearson product–moment correlations for (EPQ) sociability (Soc), (EPS) impulsiveness (Imp) and critical flicker/fusion frequency (CFF) thresholds (upper diagonal, placebo; lower diagonal, haloperidol)

	Placebo Mean (SD)	Haloperidol Mean (SD)	1	2	3	4	5	6
1. ASC1	35.99 (1.93)	37.14 (3.22)	—	0.63	0.90	0.56	0.53	0.57
2. DES1	36.19 (1.94)	37.40 (4.20)	0.82	—	0.91	0.64	0.82	0.78
3. T1	36.09 (1.75)	37.23 (3.55)	0.94	0.97	—	0.66	0.74	0.73
4. ASC2	35.71 (2.19)	39.06 (3.12)	0.73	0.59	0.68	—	0.76	0.91
5. DES2	36.13 (2.81)	37.97 (3.26)	0.53	0.52	0.55	0.88	—	0.95
6. T2	35.92 (2.35)	38.82 (3.28)	0.71	0.62	0.69	0.97	0.97	—

Note: All correlations are significant at the 5% level.
ASC1/DES1 = ascending/descending thresholds taken before task; T1 is the mean of these ascending and descencing thresholds.
ASC2/DES2 = ascending/descending thresholds taken after task; T2 is the mean of these ascending and descending thresholds.

The CFF measure used for analysis of personality factors represented the difference between mean ascending/descending thresholds (CFFT) taken pre-task and post-task (ΔCFFT; an increase in ΔCFFT was represented by a positive value, a decrease by a negative value).

Regression of initial CFFT levels on Drug and personality factors did not show Drug or Drug × personality interactions, which indicated that any effect of these treatments on ΔCFFT would not be confounded by initial CFFT values. The only personality effect observed was a positive effect of Imp ($\beta = 0.38$), $F(1,36) = 6.15$, $P < 0.05$, suggesting that Imp+ *Ss* were more optimally aroused than Imp− *Ss*, possibly by virtue of over-arousal of the latter (see General discussion).

Drug effects on ΔCFFT

A one-way ANOVA revealed a significant effect of drug, $F(1,35) = 5.80$, $P < 0.05$, revealing that ΔCFFT was higher in HAL ($M = 1.59$, SEM = 0.62) than in PLAC ($M = -0.17$, SEM = 0.36). King and Henry (1992) reported a similar effect. However, as discussed in the Introduction, such findings should be treated with caution in lieu of consideration of drug × personality effects (see below).

Personality effects

The overall regression model was significant, $F(2,34) = 10.00$, $P < 0.01$ ($R^2 = 0.61$), with significant effects of Drug × Imp ($\beta = -0.35$, $t = 2.58$, $P < 0.05$), and Drug × Soc × Imp ($\beta = 0.47$, $t = 3.14$, $P < 0.01$).

Drug × Imp. The regression of ΔCFF on Imp in PLAC ($\beta = 0.29$, $t = 1.20$, ns) was weak, but in HAL it was stronger and opposite in sign ($\beta = -0.47$, $t = 2.19$, $P < 0.05$). A conventional ANOVA with median splits on Soc and Imp also showed this interaction, $F(1,24) = 5.89$, $P < 0.05$: Imp− *Ss* differed under PLAC ($M = -0.84$, SEM = 0.27) and HAL ($M = 2.47$, SEM = 1.20), $t = 3.03$, $P < 0.05$; Imp+ *Ss* did not differ (PLAC: 0.21, 1.14; HAL; 0.81, 0.70), $t = 0.47$, ns. Taken in conjunction with the effect of Imp on initial CFFT levels, this interactive effect suggests that Imp+ *Ss* were optimally aroused in PLAC, Imp− *Ss* in HAL.

If it is assumed that Imp− *Ss* were over-aroused in PLAC, then their relative improvement in HAL is explicable: they became less, and more optimally, aroused: conversely, Imp+ *Ss* suffered under, less optimal, arousal in HAL. However, these conclusions are modified by a triple interaction effect.

Drug × Soc × Imp. A conventional ANOVA with median splits on Soc and Imp also uncovered this three-way interaction, $F(1,24) = 5.97$, $P < 0.05$, revealed by regression analysis. For clarity of exposition, the means from this ANOVA model are shown in Fig. 1. The only effect of the Drug was evident in the Soc−/Imp− group: under PLAC there was a decline in score, under HAL an increase in score. All other Soc/Imp groups showed comparable scores in PLAC and HAL. Within PLAC, the Soc−/Imp− group clearly differed from the other three groups, and the same was true

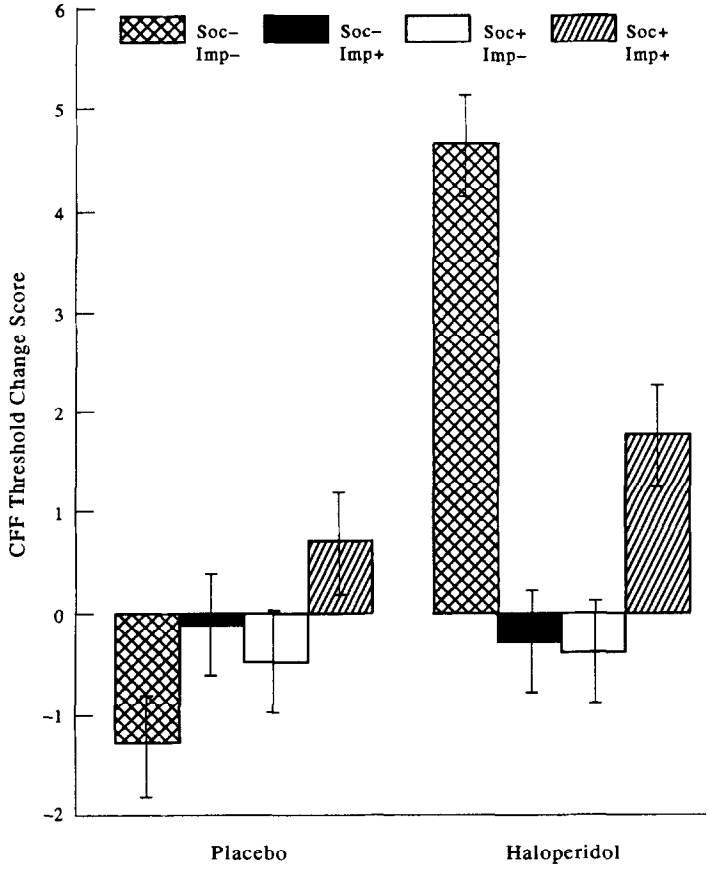

Fig. 1. Mean (±1 SEM) CFF threshold change scores in placebo and haloperidol for low/high sociability (Soc−/Soc+) and impulsivity (Imp−/Imp+) groups. (Positive values indicate a pre- to post-increase in CFFTs).

in HAL. The Soc+/Imp+ group seemed more aroused in both PLAC and HAL, but the difference between the Drug conditions was not significant.

Drug × *Soc+Imp*. The possibility that Soc+Imp might mediate low arousal may be discounted. A regression model including Drug × Imp, Drug × Soc, Drug × Soc × Imp, and Drug × Soc+Imp, revealed only the Drug × Imp and Drug × Soc × Imp interactions already reported.

The nature of the triple interaction effect is consistent with the 'additive trait hypothesis', and highlights the fact that Drug × Imp, but not Drug × Soc, interactions may appear even when both Soc and Imp are contributing to arousal effects. It is difficult to reconcile the 'redundant trait hypothesis' with these findings: if Soc effects are merely a reflection of Imp effects, then why did the two factors interact? The clear implication of these data is that Soc and Imp contain unique arousal-related variance.

Introverts seemed most sensitive to the sedative effects of haloperidol on ΔCFF; extraverts, responded with relative indifference to haloperidol, showing, if anything, a slight increase in performance in HAL. This pattern of results suggests that sedative effects reduce arousal in the already over-aroused (i.e. introverts), leading to optimal performance; but in the already optimally aroused *Ss* (extraverts), haloperidol at 5 mg does not have a large sedative effect. A larger dose of haloperidol might have led to performance impairment in extraverts.

These findings make good sense if it is assumed that introverts were over-aroused in PLAC. The ambient conditions of the experiment may have been stimulating for introverts: it was a medical context (hospital ward), blood pressure was taken, instructions of the possible adverse effects of haloperidol were made plain, etc.

Corr *et al.* (1995) did not consider interactions between Soc and Imp in relation to caffeine-induced arousal on CFF; therefore, a re-analysis of Corr *et al.*'s data were undertaken for comparability with

Table 2. Mean (ms; SD) RTs to predictable and random trials over the six segments of the task and in each of the experimental conditions

	Placebo		Haloperidol	
Segment	Random	Predictable	Random	Predictable
1	561 (46)	557 (45)	566 (32)	560 (32)
2	558 (51)	554 (56)	568 (37)	569 (31)
3	534 (35)	528 (39)	595 (28)	588 (34)
4	539 (43)	529 (44)	590 (42)	589 (38)
5	542 (74)	533 (75)	581 (43)	584 (40)
6	538 (64)	523 (70)	593 (48)	590 (47)

the present results: no Drug × Soc × Imp effects were found. These differing findings may suggest that the personality effects of haloperidol were, compared with caffeine, relatively weak, with only extreme scorers (Soc−/Imp−) *S*s showing any effect. This conclusion suggests that, where arousal effects are strong, Soc is more influential than Imp.

EXPERIMENT 2: PROCEDURAL LEARNING

For a full description of the procedural learning task, see Corr *et al.* (1995). In brief, the learning task consisted of a long series of reactions to a target that moved between four locations on a computer monitor. Some of these target movements were random, others followed specific patterns and were thus predictable. *S*s pointed to the target with a wand that activated a touch-sensitive screen; the target then moved to another location; *S*s continued to follow the target as it moved between the four locations. As shown by Lewicki, Hill and Bizot (1988), there is a selective decline in RTs to predictable targets, relative to RTs to random targets; this difference represents procedural learning.

The major difference between the present task and the findings of Corr *et al.* (1995) was the number of segments (i.e. blocks) used; in the present experiment, six segments were used.

Data reduction and scoring

For each segment, the mean reaction time (RT) for random and predictable trials were recorded, the difference (Trial Type) represented the learning score. RTs that exceeded 1 sec were excluded from the calculation of mean performance. Very few errors are made on this task.

Results and Discussion

Descriptive statistics for Soc and Imp were, respectively: means 17.4, 9.23; standard deviations, 4.06, 4.85; medians, 18, 10; and min–max values, 8–23, 1–18. Soc and Imp were weakly but significantly correlated ($r = 0.34$, $P < 0.05$).

Validation checks

Two-way analysis of variance (ANOVA) confirmed that there were no significant effects of Soc/Imp × Drug interactions on the distribution of weight ($M = 75.57$, kg; SD = 11.15). Mean Soc and Imp scores were comparable in PLAC ($M = 17.00$, 8.95; SD = 4.30, 4.81) and HAL (17.74, 9.52; 3.87, 5.00) conditions, respectively.

Task analysis

A three-way ANOVA were performed on Trial Type, Segments and Drug. This ANOVA comprised: (1) one between-*S*s Drug (HAL vs PLAC) condition; and (2) two repeated measures (a) Trial Type (RTs on predictable and random trials), representing learning, and (b) Segments (RTs across the six segments of the task). Table 2 gives RTs to random and predictable trials under Drug conditions.

RTs. A main effect of Drug, $F(1,37) = 10.83$, $P < 0.01$, revealed that RTs were longer in HAL ($M = 581$, SEM = 6) than in PLAC ($M = 541$, SEM = 10), confirming the sedative effect of HAL

(haloperidol at 3 mg has previously been reported to slow down RTs; Rammsayer, Netter & Vogel, 1993).

A Segments × Drug interaction, $F(5,185) = 7.16$, $P < 0.001$, showed that whereas RTs in PLAC showed a gradual decline over the task, RTs in HAL showed an increase over the six segments (see Table 2).

Learning. A main effect of Trial Type, ($F(1,37) = 10.11$, $P < 0.01$, showed that RTs on predictable trials ($M = 558$, SEM = 7) were faster than those on random trials ($M = 564$, SEM = 7), confirming that procedural learning took place. The Trial Type × Drug interaction, $F(1,37) = 2.76$, $P = 0.10$, missed formal significance.

Personality effects

RTs. In order to examine whether Drug × personality effects were found on non-specific RTs, six regression models were run on RTs to random targets in the six segments of the task. In segments three to six, there were significant effects ($P < 0.05$) of Drug (positive βs), reiterating the effect reported above: HAL slowed down RTs. No main or interaction effects involving personality were observed.

Learning. First, regressions of learning in each of the six segments on non-specific RTs showed no significant effects, supporting the contention that procedural learning is a central process that is independent of response speed (non-specific RT was therefore dropped from subsequent regression models). These results indicate the personality effects on learning were not caused by effects on non-specific RTs.

The overall personality regression model was significant for asymptotic learning at segment 6, $F(1,37) = 5.35$, $P < 0.05$, showing an interaction of Drug × Soc ($\beta = -0.35$). A conventional ANOVA with a median split on Soc also showed this two-way interaction, $F(1,31) = 4.86$, $P < 0.05$ (Fig. 2). This crossover interaction revealed that, under PLAC, Soc+ *S*s underperformed Soc− *S*s;

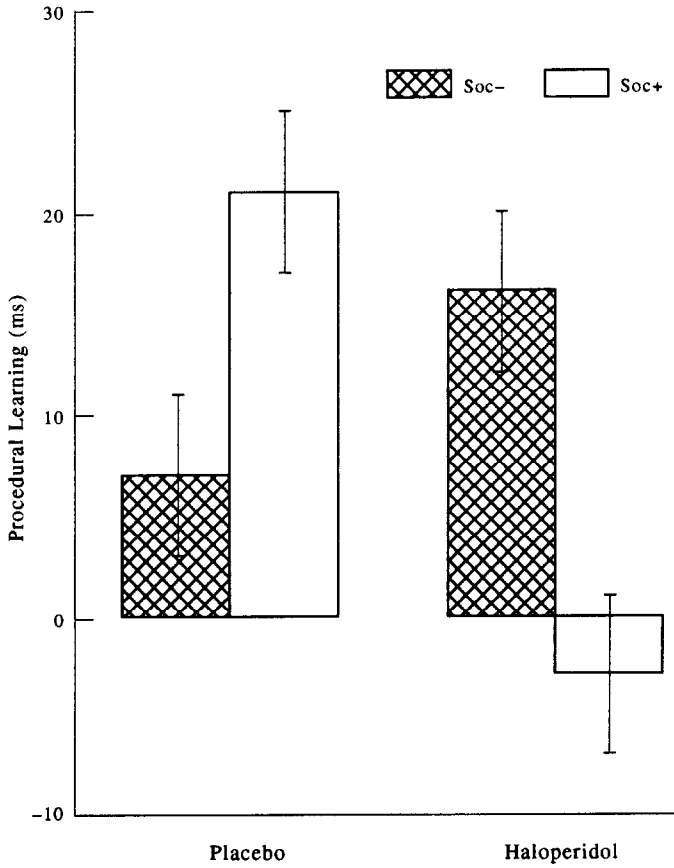

Fig. 2. Mean (±1 SEM) procedural learning in placebo and haloperidol for low/high sociability (Soc−/Soc+) groups.

under HAL, Soc− *S*s showed improved performance, whilst Soc+ *S*s showed a complete abolition of learning.

Drug × *Soc* + *Imp*. A regression model including Drug × Imp, Drug × Soc, Drug × Soc × Imp, and Drug × Soc + Imp, revealed only the Drug × Soc interaction already reported.

These data are consistent with the view that, under PLAC, Soc+ *S*s were more optimally aroused than Soc− *S*s, again putatively due to over-arousal of Soc− *S*s. In support of this interpretation, under HAL Soc− *S*s showed improved performance, Soc+*S*s grossly impaired performance. Rammsayer *et al.* (1993) found no effects of haloperidol × extraversion on RT; the present findings confirm this result, but suggests that learning, not RT measures are sensitive to haloperidol × extraversion interactions.

GENERAL DISCUSSION

Results from both experiments show meaningful relationships between Soc/Imp and haloperidol-induced under-arousal effects on critical flicker/fusion frequency and procedural learning. These results complement the findings of Corr *et al.* (1995), who reported on interaction of Soc and caffeine-induced arousal on the same performance measures. Both sets of experiments attest to the importance of Soc in arousal effects, but the present study suggests that both Soc and Imp mediate arousal in an additive manner. This conclusion may provide a partial resolution to the Soc vs Imp debate discussed in the Introduction.

This study is the first to show a significant relationship between attenuated dopaminergic arousal, by a neuroleptic drug, and extraversion. These findings support the theoretical link made by Stelmack and Pivik (1996); the association of brain regions rich in dopamine terminals and introversion–extraversion difference (Fischer *et al.*, 1996); the empirical association between dopamine and positive emotionality (Depue *et al.*, 1994); and the dopamine basis of ARAS arousal (Le Moal & Simon, 1991). The extent to which these dopamine findings reflect a general effect on arousal or specific dopaminergic effect, needs further investigation. What is clear is that even with an important psychiatric drug such as haloperidol, the moderating influence of extraversion is important; indeed, as with the effects of caffeine, ignoring the moderating role of extraversion, leads to inconsistent data (e.g. King & Henry, 1992; Parrott & Hindmarch, 1975).

Consistent with Corr *et al.* (1995), Soc mediated the effects of arousal on procedural learning; however, inconsistent with this previous report was the finding of a significant Drug × Soc × Imp on CFF [previously, Corr *et al.* reported a strong effect of Soc, and only a weak effect of Imp on CFF (re-analysis of Corr *et al.*'s data did not show a caffeine × Soc × Imp)].

The Soc × Imp effect on CFF was largely attributable to the Soc−/Imp− group: this group of putatively highly aroused *S*s showed a strong recovery in performance under haloperidol as compared with placebo, where their performance declined over the task (Fig. 1). Assuming that these *S*s were relatively over-aroused in placebo, the reduction in arousal afforded by haloperidol should be expected to improve performance. The experimental environment might have been perceived by introverts to be stimulating or threatening because of its medical context. Perhaps Soc−/Imp− *S*s were especially sensitive to this putative arousing effect. Procedural learning findings were highly consistent with Corr *et al.*, although once again it must be assumed that Soc− *S*s were over-aroused in placebo.

The 'redundant trait hypothesis', which assumes that Soc may sometimes mediate arousal by virtue of overlapping Imp variance, is not supported by Corr *et al.* (1995), which showed a caffeine × Soc effect after partialling out the effects of Imp, or Experiment 1 of the present study, which showed additive effects of Soc and Imp (along with a theoretically less interesting drug × Imp effect). In Experiment 2, Imp was unimportant in mediating the effects of haloperidol on procedural learning. These data seem to demand the conclusion that Soc mediates arousal, and Imp sometimes adds unique predictive variance. Therefore, the 'additive trait hypothesis', which assumes that Soc and Imp represent lower-order traits of a higher-order general arousal factor (e.g. Eysenck & Eysenck, 1985), seems a sensible interpretation of the present effects. Studies that show strong effects of Imp, and not Soc (e.g. Revelle *et al.*, 1980) may have missed possible Imp × Soc interactions.

Support for the 'additive trait hypothesis' implies that EPI extraversion (Eysenck & Eysenck,

1964) provides the best personality measure of arousal effects. However, in experimental designs, it may be more appropriate to treat Soc and Imp as relatively separate lower-order traits of extraversion in order to further explore their unique influences in arousal-mediated performance. This recommendation is demanded by the fact that, in both experiments, Soc and Imp were weakly correlated. However, a weak Soc/Imp correlation does not necessarily imply that both factors are not related to a common arousal mechanism.

The emergence of Soc as the more important measure of extraversion in the present study and in Corr *et al.* (1995) could, in part, be related to a design feature shared by these experiments: *Ss* were not required to abstain from caffeine-related products. Experiments that show strong Imp effects often require *Ss* to abstain from caffeine products immediately prior to testing (see Revelle, 1987); this is often seen as a desirable design feature in extraversion–arousal studies. But the abolition of arousal modulation effects by forced caffeine abstinence has theoretical importance for the relationship between personality, arousal and behaviour, including sociopsychiatric behaviours that are thought to be influenced by extraversion × arousal interactions. If Imp effects are found only when *Ss* are prevented from modulating basal arousal, then how can such evidence be used to explain the development and maintenance of sociopsychiatric states when *Ss* are free to modulate arousal levels? If Imp effects appear only under these artificially constrained parameters, then their relevance for natural situations in which *Ss* can modulate arousal *ad lib* must be thrown into considerable doubt.

Further work is needed to delineate both the relative contributions of Soc and Imp in arousal-mediated performance and the experimental conditions and task parameters under which differing Soc/Imp and arousal interactions are found. The effects of basal arousal, resulting from *ad lib* arousal modulation and forced abstinence on tonic levels of arousal would be a good starting point to address these issues. In addition, it is also important to assess the comparability of results with different manipulations of arousal (e.g. noise, stimulus intensity and drugs).

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