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Using signal detection theory in the analysis of emotional sensitivity of male recidivist offenders

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ABSTRACT

Background *Study of emotional responses of antisocial individuals has produced inconsistent findings. Some studies report emotional deficits, while others find no differences between people with and without antisocial behaviours.*

Aims *Our aim was to apply signal detection theory methods to compare the sensitivity of antisocial and control participants to emotional stimuli. We hypothesised that offenders would show lower ability to discriminate changes in the level of arousal and valence of emotional stimuli relative to the controls.*

Methods *Signal detection theory was applied to study the sensitivity of recidivist offenders in prison to emotional arousal and valence induced by pictures. This approach, novel in this context, provides a departure from the usual reliance on self-report.*

Results *Offenders reported higher arousal than controls but showed lower sensitivity to changes between different levels of arousal (whereas no differences were found for valence). Also, offenders showed increased response bias for changes in the levels of arousal, as well as in the higher levels of valence.*

Conclusions *Our findings show that direct observations of emotional arousal, but not valence, discriminate between recidivist offenders with antisocial personality disorder and non-offending controls. Use of such approaches is likely to provide more valid data than self-reports and may prove particularly useful in studies of intervention for recidivists or in assessment of their readiness for release.*

Introduction

The core feature of antisocial personality disorder is a persistent pattern of disregard for, and violation of, the rights of others (American Psychiatric Association, 2000), often leading to criminal acts (e.g. Mendez, 2009). One main explanation for persistent antisocial behaviour patterns relies on the assumption that antisocial individuals have reduced capacity to process and experience emotional stimuli. Emotional responsiveness in these circumstances has been studied since the 1950s (Hare, 1965; Fowles, 1988; 1993; Patrick, 1994; Ishikawa and Raine, 2002; Verona et al., 2004). Such studies frequently include direct self-report measures of emotional processing (e.g. Patrick et al., 1993; Patrick et al., 1994). While some demonstrate that antisocial individuals report less emotional loading than normal controls (Pham et al., 2000; Eisenbarth et al., 2008; Hastings et al., 2008), others show identical emotional response patterns to the same stimuli (Patrick et al., 1994; Levenston et al., 2000; Pastor et al., 2003; Müller et al., 2008).

This inconsistency, where studies rely on self-report measures, is at odds with psychophysiological data that show that emotional stimuli do not produce the same brain and somatic states in individuals with and without such personality difficulties (for a review, see Ishikawa and Raine, 2002). Self-report may, however, be the problem here, as study participants do not seem to have been able to provide reliable self-reports of their emotional state (see Kroner et al., 2005). Some can report emotions convincingly, without experiencing them (Kiehl and Buckholtz, 2010; Pham et al., 2010), some perhaps attempting to conform to perceived expectations of the experimenters (Kroner and Forth, 1995). As explained by Snowden et al. (2013), methods in which participants have to report experienced emotions in a forced choice format fail to distinguish between sensitivity to the affective information and a bias in reporting it. In our study, therefore, we attempted to improve on methodological shortcomings of previous research of emotional loading by analysing self-report measures using methods from signal detection theory (SDT). We used SDT indices to compare the discriminative ability of recidivist offenders and controls for affective arousal and valence.

Several methodological paradigms have emerged from SDT (Green and Swets, 1966; Macmillan and Creelman, 1991), providing effective solutions to differentiate individual response tendencies from the ability to detect and discriminate environmental information (e.g. Windman and Krüger, 1998; Li, 2002), including information with emotional content (e.g. Perez-Lopez and Woody, 2001; Pessoa et al., 2005). Our basic assumption is that even if individuals tend to alter their response criteria to conform to perceived expectations, as seems to be the case with antisocial participants (Kroner and Forth, 1995), use of SDT allows estimation of their response bias and their discriminative ability for emotional information. SDT provides methods that allow examination not only of the extent of difference between groups in perception of the same stimuli but also the extent of similarities (Marques-Teixeira et al., 2009).

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Our aim was to apply SDT-based methods to compare the sensitivity of antisocial and healthy control participants to emotional stimuli. We hypothesised that male recidivist offenders would show a pattern of low discriminative ability for different levels of arousal and valence of emotional stimuli relative to controls.

Method

The samples

The recidivist offenders were recruited from two local prisons for men. Based on prison records, all recidivist offenders were invited to take part in the study. First-time offenders, offenders with a past history of substance dependence, mental or neurological illness or with evidence of sensory dysfunction that might interfere with task performance were excluded. Control participants who reported having no history of offending were recruited from prison staff, university staff or their friends.

The General Directorate of the Prison Services authorised this research. All participants signed informed consent to participate in the study.

Test materials

Participants were shown 120 pictures from the International Affective Picture System (IAPS,[1] Lang et al., 1997), which contains 480 pictures rated on a nine-point scale for each of the emotional dimensions: arousal and valence. This subset of 120 pictures was selected according to normative values of arousal and valence (Spanish norms by Vila et al., 2001) and organised in six levels of arousal and six levels of valence, as described in the following.

Because arousal values are not homogeneously distributed across valence values and vice versa, every effort was made to select pictures so that the final distribution would respect the distribution of each dimension across the other in the original IAPS set. More precisely, effort was made to force orthogonality across the arousal and valence dimensions while respecting IAPS structure, so that when comparing two adjacent arousal levels, valence would not differ

[1]The final stimulus set was composed by pictures 1070, 1090, 1110, 1111, 1113, 1200, 1201, 1220, 1230, 1270, 1274, 1280, 1301, 1310, 1650, 1660, 1670, 1710, 1740, 1811, 1910, 1920, 1931, 2020, 2030, 2120, 2130, 2150, 2160, 2170, 2200, 2210, 2340, 2410, 2520, 2620, 2650, 2661, 2691, 2791, 2840, 3010, 3160, 3180, 3210, 3220, 3230, 3300, 4100, 4220, 4230, 4250, 4290, 4606, 4607, 4611, 4640, 4650, 4652, 4659, 4664, 4770, 5270, 5623, 5890, 5900, 5920, 5990, 6150, 6200, 6312, 6370, 6410, 6610, 6930, 7000, 7034, 7090, 7130, 7170, 7190, 7234, 7270, 7280, 7320, 7351, 7360, 7361, 7390, 7450, 7470, 7500, 7550, 7620, 7700, 8010, 8032, 8041, 8160, 8161, 8260, 8470, 8500, 9000, 9001, 9190, 9210, 9220, 9250, 9300, 9401, 9402, 9404, 9500, 9570, 9600, 9620, 9622, 9830 and 9911. Pictures 1040, 1440, 1590, 2070, 2550, 3102, 3400, 4002, 7233 and 7400 were used as training trials.

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between them and vice versa. In doing so, comparisons between levels of one dimension were minimally contaminated by the effects of the other dimension. As advised by Marques-Teixeira et al. (2009), the normative values for arousal and valence for the 480 IAPS pictures were converted to *z*-scores, and we then constituted the six levels for each of the two dimensions (arousal and valence) by grouping pictures rated <1.0; [−1.0; −0.5]; [−0.5; 0.0], [0.0; 0.5], [0.5; 1.0], and >1.0 standard deviation (SD) from the mean. By crossing the six levels of arousal and valence, we obtained a 36-cell matrix where the 480 IAPS pictures were distributed. We then selected images from each cell to obtain 20 images for each level of arousal and valence, in a way that was proportional to the original IAPS data. For example, we selected nine images from a cell with 56 images and four images from a cell with 25 images. This procedure ensures that the selected stimuli are representative of the original IAPS structure. The full details of the picture selection are described by Marques-Teixeira et al. (2009). Given the status of the prisoner participants, none of the pictures had male sexuality, drug or prison-related content.

Stimuli were presented with E-Prime 1.2 (2002, Psychology Software Tools Inc., Pittsburgh, PA, USA) on a laptop computer with a 15.4-inch screen, located approximately 75 cm from the participant. Ratings for each picture were obtained using an external numerical keypad with a computerised version of the Self-Assessment Manikin (SAM), developed by Lang (1980). The SAM is a nine-point pictorial rating device that allows obtaining self-reports of the experienced valence and arousal. As this is a non-verbal assessment instrument, it is suitable for participants of practically any age or educational background.

Procedure

Participants were asked to sit on a chair, read the instructions and, if content to participate, to give written consent. They were instructed to pay attention to each picture and to rate it using the SAM on a nine-point scale for arousal (from 1, lower to 9 and higher) or valence (from 1, more unpleasant to 9 and more pleasant). There were 15 training trials. The training pictures covered the entire scope of valence and arousal values and combinations, ensuring that participants comprehended the response system. Each picture was then presented for 4 seconds, and immediately after, participants rated the induced arousal or valence using the SAM. There was a 7-seconds rating period with no inter-stimulus interval. Order effects were controlled by randomising the presentation of pictures. Also, the order of the dimensions to which participants responded was counterbalanced, so that half of the sample was instructed to rate the pictures on emotional arousal on a first experimental array and valence on the second and the other half was instructed to rate valence first and then arousal.

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Data analysis

Firstly, ratings of arousal and valence were compared across levels and groups. A 6 × 2 mixed factor plan was used with arousal level as a within-subject variable and group (recidivist or control) as between-subjects variable. A similar analysis was conducted for valence. Secondly, self-report ratings were treated according to SDT methodology (Macmillan and Creelman, 1991) separately for arousal and valence. For simplicity, we will describe the analysis for arousal, but the same was carried out for valence.

Receiver operator characteristics (ROC) curves and corresponding sensitivity indices were estimated to discriminate between each of the two levels of arousal (e.g. arousal 1 from arousal 2 and arousal 2 from 3) from each of the individual criteria points (i.e. the amount of signal, such as physical arousal) the respondent required to change his response from one value to the next (e.g. from reported arousal 1 to reported arousal 2). Initially, the number of responses for each rating of arousal was tabulated for each of the six levels and converted into conditional probability (probability of response '1' to level 1; probability of a response '1' to '2', etc.). Next, the cumulative probabilities for each response were as computed, ranging from 1 to 9. ROC curves and sensitivity indices were estimated from the conditional probabilities of each response to each emotional level. Because there were six arousal levels and a nine-point rating scale, ROC curves and the corresponding sensitivity index were estimated from eight-criterion measures for each of two levels (1–2, 2–3,… 8–9). Sensitivity, response bias and ROC curves were estimated using RSCORE2 (Harvey, 2004). This software uses a maximum-likelihood procedure for the estimation of the ROC curve and the area below it.

As to the sensitivity index, the Az was chosen.[2] This measure has no requirement with respect to the homogeneity of variances of underlying distributions, being less restrictive and yielding accurate ROC curves (Swets, 1986). As shown by Green and Swets (1966), this index is equivalent to the estimate of the proportion of correct answers on a two-alternative forced choice, and it constitutes a robust sensitivity measure, even if homogeneity of variances of the underlying distributions is not met (Swets, 1986). Az varies between 0 and 1, with a value of 0.5 reflecting no discriminative power when comparing two stimuli. Values of Xc were used as criterion measures.[3] This index places the participants' threshold in relation to the first level, allowing the comparison of the groups for response bias,

[2]Az represents the area under the ROC curve (see formula in Green and Swets, 1966).

[3]Xc defines a critical threshold above which the response indexes the presence of a signal. In the present case, the value of Xc for each level of arousal/valence indexes the amount of signal each participant requires to change from one level to another: low values of Xc indicate that participants require little change in signal intensity to change their responses (i.e. their response criterion is 'liberal'), whereas high values of Xc indicate that participants require large changes in signal intensity to change their response (i.e. their response criterion is 'conservative').

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which is the relative tendency to be more liberal or conservative when rating the pictures. Lower Xc values reflect a more liberal response pattern (Macmillan and Creelman, 1991), meaning the respondent requires less signal to change his response. Once obtained, the dependent measures (raw scores, sensitivity and criteria indices for arousal and valence) were analysed using mixed-factors repeated measures analysis of variance, reporting a 0.05 significance level. The Greenhouse–Geisser adjustment was used when necessary for the estimation of the significance of *F* ratios. Epsilon values are presented where appropriate. Reported *p*-values reflect the correction. Given the differences in age between our samples, we repeated all the analyses using age as covariate.

Results

Characteristics of the samples

The mean age of the 38 recidivist male offenders, all Caucasians, was 42.57 years (SD 10.44). All met *Diagnostic and Statistical Manual of Mental Disorders, 4th Edition, Text Revision* criteria for antisocial personality disorder. Their index convictions were as follows: homicide (4), burglary (16), drug trafficking (12), physical offence (2), procuring (1), swindling (2) and drunk driving (1). The 30 Caucasian male controls were younger (mean age 27.93 years; SD 7.12). During the study, two participants left before rating the pictures for arousal and six before rating pictures for valence.

Raw scores

As expected, there was a main effect of arousal level ($F(5, 320)$ 137.88, $p < 0.001$, $\varepsilon = 0.432$). Bonferroni-corrected *post-hoc* analyses showed that participant ratings significantly increased with arousal level (all $p < 0.001$), with the exception of the comparison between levels 4 and 5, which was not significant. There was also a main effect of group, with the recidivist offenders [mean (M) 5.50, SD 0.21] giving the images significantly higher arousal ratings than did the control participants (M 4.64, SD 0.25; $F(1, 64)$ 6.80, $p = 0.011$). There was also a main effect of valence level, with all participants rating increasingly pleasant levels with increasingly positive ratings for valence ($F(5, 300)$ 334.35, $p < 0.001$, $\varepsilon = 0.428$). There were no group effects for valence. Repeating the analysis with age as covariate showed that there were no main effects or interactions according to age.

Sensitivity

Comparison of sensitivity measures for emotional arousal and valence levels between groups revealed a main effect in discriminating all levels of arousal

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(2 to 6) from level 1 ($F(4, 256)$ 49.58, $p < 0.001$, $\varepsilon = 0.557$). As expected, the farther apart stimuli levels were from the lowest arousal level, the higher was the participants' discriminative sensitivity (Table 1). Contrast analysis showed that all sensitivity values differed from each other, with the exception of Az values for levels 4 and 5. There was a significant main effect for group ($F(1, 64)$ 9.84, $p < 0.01$), with recidivist offenders showing lower overall sensitivity values (M 0.68, SD 0.12) than control participants (M 0.76, SD 0.08).

For emotional valence, again it was verified that the further the levels were from 1, the higher was the sensitivity value obtained ($F(4, 244)$ 148.15, $p < 0.001$, $\varepsilon = 0.595$). There were no group effects.

Repeating the analysis with age as covariate showed that there were no main effects or interactions involving this variable.

Response bias

An 8 × 2 mixed-factors analysis of variance was performed, with a cutting point between each level of emotional arousal (1–2, 2–3, 3–4, 4–5, 5–6, 6–7, 7–8 and 8–9) as the within-subjects variable and group as the between-subjects variable and response criterion (Xc) values as the dependent variable. There was a main effect for emotional arousal threshold ($F(7, 448)$ 239.87, $p < 0.001$, $\varepsilon = 0.237$), with the higher Xc values corresponding to the highest cutting points (Table 2). There was an effect for group ($F(1, 64)$ 12.96, $p < 0.01$), with the recidivist offenders being significantly more liberal (i.e. participants require less change in signal intensity to modify their response) in their response pattern than control participants.

The same procedure for emotional valence also yielded a main effect for cutting point ($F(7, 427)$ 146.83, $p < 0.001$, $\varepsilon = 0.279$) and group ($F(1, 61)$ 5.84, $p < 0.05$). There was also a cutting point X group interaction ($F(7, 427)$ 6.21, $p < 0.001$). Further analysis revealed that the groups did not differ for their

Table 1: Mean Az values for the discrimination between level 1 and subsequent levels for arousal and valence

	Arousal		Valence	
Levels	Controls	Offenders	Controls	Offenders
1–2	0.68 (0.10)	0.58 (0.09)	0.60 (0.12)	0.57 (0.13)
1–3	0.69 (0.09)	0.63 (0.13)	0.68 (0.10)	0.64 (0.15)
1–4	0.78 (0.10)	0.71 (0.16)	0.79 (0.08)	0.75 (0.15)
1–5	0.79 (0.08)	0.70 (0.17)	0.86 (0.08)	0.79 (0.15)
1–6	0.86 (0.10)	0.76 (0.20)	0.90 (0.10)	0.85 (0.15)
Total	0.76 (0.08)	0.68 (0.12)		

Note: Standard deviations are presented in parentheses.

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Table 2: Means Xc values for the eight cut-points for arousal and valence

	Arousal		Valence	
Cut-point	Controls	Offenders	Controls	Offenders
1–2	−0.64 (0.97)	−0.94 (1.09)	−0.37 (1.79)	−0.26 (1.38)
2–3	−0.01 (0.94)	−0.41 (0.81)	−0.20 (0.74)	−0.05 (0.94)
3–4	0.36 (0.92)	−0.06 (0.68)	0.20 (0.61)	0.21 (0.79)
4–5	0.68 (0.82)	0.13 (0.67)	0.66 (0.56)	0.42 (0.77)
5–6	1.10 (0.68)	0.50 (0.62)	1.39 (0.49)	0.90 (0.77)
6–7	1.52 (0.66)	0.83 (0.64)	1.84 (0.62)	1.25 (0.64)
7–8	1.96 (0.57)	1.23 (0.73)	2.39 (0.66)	1.60 (0.61)
8–9	2.59 (0.72)	1.80 (0.93)	3.03 (0.63)	2.05 (0.67)

Note: Standard deviations are presented in parentheses.

Xc values on the cutting points, namely 1–2, 2–3, 3–4 or 4–5, but did so for points 5–6, 6–7, 7–8 and 8–9 (all the latter at $p < 0.01$). Thus, recidivist offenders present a more liberal response pattern for higher emotional valence ratings (more positive affect ratings) but not for lower ones.

Again, repeating the analysis with age as covariate showed that there were no main effects or interactions involving this variable.

Receiver operator characteristics curves

As explained earlier, ROC curves for both groups were computed from eight-criterion measures for each level of emotional arousal and valence, always in comparison to level 1. Because no Az differences were found related to valence, only ROC curves of arousal are presented (Figure 1). These show that the recidivist offenders demonstrate lower emotional sensitivity for every arousal level.

Discussion

Our hypothesis was sustained in that the men who were recidivist offenders did show poorer discriminative ability for different levels of arousal and valence of emotional stimuli relative to the controls. This means that in order to obtain identical emotional levels to the controls, it was necessary to present higher level stimuli.

The emotional processing differences may be attributable to the fact that antisocial participants require little change in signal intensity to modify their response (i.e. they present more liberal response criteria), which is particularly evident for higher emotional-inducing stimuli. This finding is unlikely to be due to any participant limitations in understanding the task or the response

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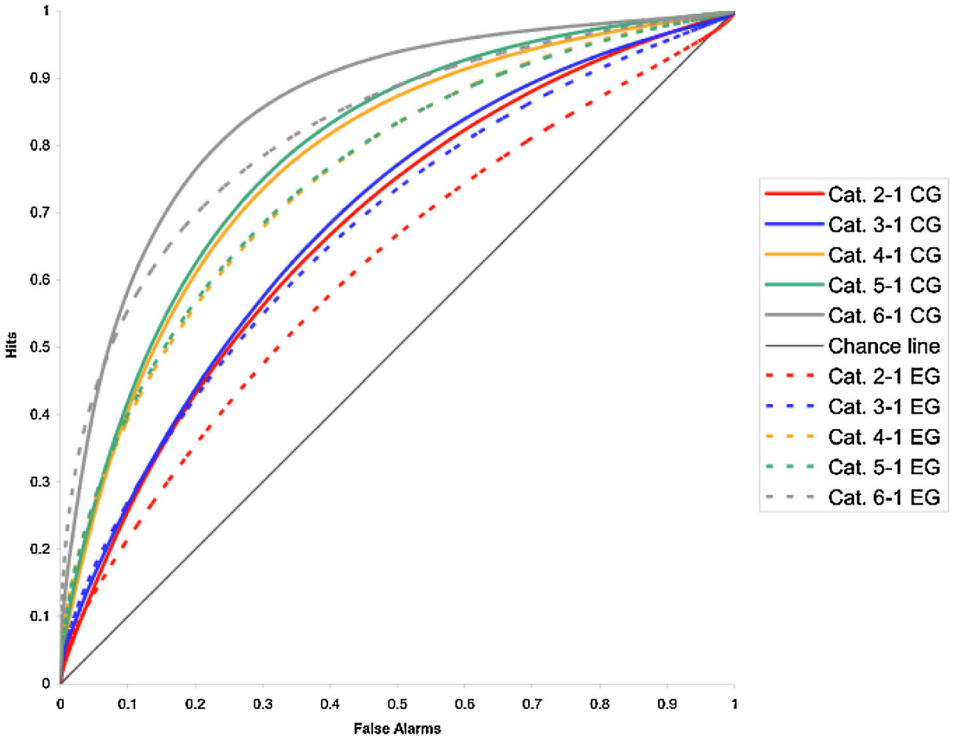

Figure 1: Receiver operator characteristics curves for controls (CG, control group, continuous curves) and recidivist offenders (EG, experimental group, dotted curves) when discriminating stimuli of each level (2–6) of emotional arousal from level 1

system. No between-group differences on ratings of sensitivity values for emotional valence were found, but the expected within-group patterns concerning arousal and valence sensitivity scores were obtained. This indicates that men in the recidivist sample were able to deal with the task and the response scale at a satisfactory level.

Our findings have implications for researchers studying the emotional state of any given sample. In emotional interference studies, for example such as those based on dot-probe tasks (e.g. Kimonis et al., 2006) or affective oddball paradigms (e.g. Cacioppo et al., 1993; Crites and Cacioppo, 1996; Marques-Teixeira and Barbosa, 2005), it has been shown that the emotional content of stimuli affects cognitive performance. Our findings add to this literature by showing that inducing emotional states in criminal and control samples may require stimuli with different emotional intensities to achieve the same effect.

Use of SDT approaches is likely to provide more valid and reliable data than self-reports and may prove useful in the evaluation of antisocial individuals, either for research or for practical, clinical or criminal justice purposes.

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