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9

Arousal, sensation seeking and frequency of gambling in off-course horse racing bettors

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Heart rate was recorded in a sample of 32 off-course horse racing bettors before, during and after the gambling process, together with sensation seeking and information regarding frequency and expenditure on gambling. Importantly, the present study controlled for the confounding effects of movement on heart rate present in previous studies. Significant differences within subjects were found for heart rate at different points in the gambling process, but no differences were found comparing high- and low-frequency gamblers or gamblers that chase with those that don't chase. These findings are discussed in relation to the theoretical role of arousal and sensation seeking in the explanation of gambling behaviour.

Subjective excitement has been noted as one of the main features of continued gambling behaviour (see Coventry & Brown, 1993 for a review) but only recently has arousal been measured physiologically during gambling. Originally Anderson & Brown (1984) found heart rate (HR) increases of up to 58 beats/minute for frequent gamblers during casino blackjack play. Similar increases have been found with poker machine players (Leary & Dickerson, 1985) and fruit machine players (Griffiths, 1993), although laboratory studies have failed to find similar arousal increases (Anderson & Brown, 1984; Rule & Fischer, 1970; Rule, Nutler & Fischer, 1971), suggesting that arousal is not easily amenable to laboratory investigation (Dickerson, 1986).

Problems with the use of HR as a measure of arousal

Despite the assumption that the existence of arousal increases in gambling has been established (e.g. Brown, 1986; Coventry & Brown, 1993; Griffiths, 1993), methods used in the relevant studies leave cause for concern. While HR can be a useful measure of arousal, HR fluctuates greatly as a function of motor activity, relaxation and acclimatization to experimental conditions (Obrist, 1981; Smith, Guyton, Manning & White, 1976). Significant changes in HR over non-movement controls have been found for both isometric hand and foot exercises (Lynch, Schuri & D'Anna, 1976) and for handgrips, free speech and 100 watt exercise (Fahrenberg, Foerster & Wilmers, 1992). In the studies by Anderson & Brown (1984), Leary &

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Dickerson (1985) and Griffiths (1993) baselines were taken during a period of relaxation prior to participants' involvement with the gambling task and/or when participants were stationary. As most forms of gambling involve motor activity (e.g. placing bets or pressing buttons), these results may well be confounded.

A second set of problems involves the frequency of HR readings taken in the studies of Coulombe, Ladouceur, Desharnais & Jobin, (1992), Leary & Dickerson (1985) and Griffiths (1993). Griffiths (1993), for example, recorded HR every five seconds during fruit machine play, which is about the length of an individual trial. Not only is averaging across a few HR measures unreliable, but the average taken from a session of play cannot possibly separate out different periods of play, such as button-pressing and waiting for the wheels to come to rest.

The present study aims to rectify the possible confounding effects of motor activity with the establishment of a reliable baseline which involves movement. Off-course horse racing was the form chosen for this purpose as each trial lasts an appreciable length of time allowing reliable HR averages to be taken, and additionally HR has not been measured during this form before. This form also allows an examination of the claim that arousal can act as a reinforcer on a fixed interval schedule (Dickerson, 1977, 1979; Saunders, 1981). For Dickerson (1977, 1979) and Brown (1986) there are a series of arousal increases at fixed points in the gambling process (such as bet placement) which may play a role in the explanation of continued gambling. Furthermore, it has been claimed (Brown, 1986; Dickerson & Adcock, 1987) that high-frequency gamblers get more aroused during gambling than low-frequency gamblers,[1] but the evidence for this hypothesis is controversial. Leary & Dickerson (1985) found significantly greater HR increases during poker machine play in high-frequency versus low-frequency players. However, Dickerson, Hinchy, Legg England, Fabre & Cunningham (1992), Coulombe *et al.* (1992) and Griffiths (1993) did not replicate these findings, although Griffiths does report preliminary evidence for the tolerance[2] phenomenon—the HRs of regular gamblers decreased significantly after play whereas those of non-regular gamblers did not. The evidence for this hypothesis is therefore inconclusive, and remains so until the methodological problems noted above have been corrected.

A second theoretical position on the role of arousal in gambling comes in the form of Zuckerman's theory of sensation seeking. Zuckerman (1979, 1983) originally suggested a relationship between sensation seeking and gambling in which 'individuals entertain the risk of monetary loss for the positive reinforcement produced by states of high arousal during the periods of uncertainty, as well as the positive arousal produced by winning' (Zuckerman, 1979, p. 211). However, this hypothesis has received little support (Anderson & Brown, 1984; Blaszczynski, Wilson & McConaghy, 1989; Dickerson, Hinchy & Fabre, 1987; Kuley & Jacobs, 1987), and contrary to Zuckerman's hypothesis that gamblers should be higher sensation seekers than non-gamblers and population norms, Coventry & Brown

[1] The explanation for this finding is open to interpretation. Either frequent gamblers have experienced greater arousal early on than non-frequent gamblers, causing them to gamble more frequently, or alternatively individuals may differ in the extent to which they respond to the gambling environment over time.

[2] The tolerance phenomenon is when individuals need increasing levels of a substance/experience in order to achieve the same levels of excitement/pleasure.

(1993) found that those who bet in the off-course betting office alone are lower sensation seekers than non-gamblers and general population norms (as measured by Zuckerman's Sensation Seeking Scale). However, those who bet on several gambling forms and/or in the casino are higher sensation seekers than the population figures and non-gambling controls. These findings support the view that there is a difference between gambling form 'selection' and 'use' (Cornish, 1978), suggesting that gambling cannot be viewed as a homogeneous activity (Dickerson, 1993; Fisher, 1993). Additionally, Coventry & Brown (1993) found that sensation seeking in off-course bettors correlated with subjective arousal, bet size, expenditure on betting and loss of control, supporting the findings of Anderson & Brown (1984) and Dickerson *et al.* (1987) that sensation seeking may be a predisposing factor to loss of control.

The present study therefore measured HR, sensation seeking and loss of control during off-course betting, while controlling for factors that may be serious confounds in pervious HR studies.

Method

Participants

Ninety-eight potential participants were approached in two off-course betting offices. Of these, 32 (33%) agreed to participate and completed the experiment. All were male, and the mean age was 25 years (SD = 9.27).

Materials

A small ambulatory HR monitor (TYPE TP-200) was used to monitor HR at 30-second intervals before, during and after the gambling process. This monitor employed a photo-plethysmograph clipped to the participant's earlobe, and provided a beat-to-beat output display. Artifactual readings were indicated by the recorder (via a red error signal) as those that are outside the upper and lower HR limits. In particular, errors are produced as a result of sudden movements and changes in light. The baseline involved monitoring HR for a period of five minutes while the gambler walked (at a moderate pace) to the off-course betting office. This baseline therefore reflected a lot of motor movement, much more than that involved during off-course gambling, and therefore can be regarded, if anything, as too stringent a control. In addition to measures taken every 30 seconds, some single readings were also taken. These included the end of the race, bet placement and when the horse was positioned in the top three places. Readings when the horse was in the top three places were taken every 30 seconds and averaged so that this could be compared with periods during the race when the horse was not placed.

A questionnaire was also administered to each gambler comprising:

(*a*) The Thrill and Adventure Seeking (TAS) subscale of the Sensation Seeking Scale (SSS) Form V (Zuckerman, 1979). This was used rather than the full scale to cut down completion times for participants and therefore to reduce the likelihood of a high refusal rate. The TAS portion was chosen as it has been shown to separate out gamblers in terms of type and number of forms participated in more effectively than the other subscales (Coventry & Brown, 1993).

(*b*) A question concerning chasing, 'If you are losing do you increase your bet size to win back your losses?'

(*c*) A question concerning loss of control of betting behaviour, 'Do you think you have a problem controlling your level of gambling?' (as used by DSM–IV, American Psychiatric Association, 1994; Dickerson, 1977, 1979, 1984; Dickerson *et al.*, 1987; Kuley & Jacobs, 1987).

(*d*) Questions relating to frequency of betting behaviour and the number and types of gambling forms participated in aside from off-course betting (adapted from Coventry & Brown, 1993).

Bet size placed by each gambler and the position of the horse in the race (when in the top three places) were also recorded.

Procedure

Participants were recruited from two large chain off-course betting agencies in England (both employing televisual presentation of races). Times of recording were systematically chosen to ensure that a variety of customers and races were sampled. Gamblers were never approached during or just before a race, and the experimenter frequented the office for two weeks prior to commencing the study to further heighten unobtrusiveness. Each participant was asked if he would mind having his HR monitored during a race on which a bet would be placed (using the participant's own money). On agreement, he was taken for a walk outside the office in order to establish a baseline. The baseline recordings were taken out of sight of the office, and participants were also requested to refrain from smoking or sitting down during the recording. Readings were noted down by the experimenter every 30 seconds, and at salient points in the gambling process (when entering the office, bet placement, start of the race, change of horse position in the race to within top three, finish of race, and leaving the office). When artifactual readings were indicated by the monitor, the next non-artifactual reading was taken. Throughout the session the experimenter stood a few feet away from the participant, and at no times were participants able to see the HR readouts. The monitor was held so that it was not clearly visible by others gambling in the office at the same time. Participants were instructed to behave as they normally would during the session. As conversation in off-course betting offices is at a minimum, this entailed no communication between the experimenter and participant during recordings. After recording, the questionnaire was completed by the participant in the presence of the experimenter while still in the office.

Results

Altogether, 72 per cent of participants ($N = 23$) reported betting more than once a week, 28 per cent ($N = 9$) reported chasing and 19 per cent ($N = 6$) admitted to having a problem controlling their level of gambling. A measure of frequency of gambling was calculated by multiplying the average number of days per week spent gambling by the average number of races bet on in one day. The mean frequency was 9.63 (SD = 13.54; range = 1–50).

Table 1 illustrates the relationship between the TAS, arousal and questions relating to loss of control. A significant correlation was found between problem gambling and chasing ($r_s = .41$, $p < .05$, two-tailed) and between frequency of gambling and bet size ($r = .48$, $p < .01$). Spearman rank order correlations revealed significant correlations between number of gambling forms participated in and frequency of gambling ($r_s = .36$, $p < .05$), having a problem ($r_s = .40$, $p < .05$), the TAS ($r_s = .35$, $p < .05$) and arousal at the end of the race ($r_s = .41$, $p < .05$). The mean score for the TAS subscale of the Sensation Seeking Scale was 7.03 (SD = 2.34; range = 2–10). A one-way analysis of variance comparing those participating on different numbers of forms was non-significant ($F(3, 28) = 1.74$, $p > .05$), although the results were in the predicted direction. A t test was also performed comparing those who gamble in the casino with those who don't. This approached significance, again in the expected direction ($t = 1.78$, $p = .08$), with those gambling in the casino (mean TAS score = 8.23, SD = 1.82) scoring higher than those who don't (mean TAS score = 7.03, SD = 2.35).

The mean HR measures for different points before, during and after the gambling process are displayed in Fig. 1. Given that only six gamblers in the sample admitted

Table 1. Pearson product moment correlations/Spearman rank order correlations[a]

Variable	TAS	Frequency of gambling	Problem?	Chasing	No. of forms	Bet size	Arousal baseline	Arousal during bet placement	Arousal at start of race	Arousal during race	Arousal at end of race (last 30 s)	Arousal after the race
Frequency of gambling	−.35											
Problem?	_−.01_	_.23_										
Chasing	_−.05_	_.31_	_.41*_									
No. of forms participated in	_.35*_	_.36*_	_.40*_	_.31_								
Bet size	−.21	.48**	_−.26_	_−.08_	_−.01_							
Arousal baseline	−.04	−.04	_−.21_	_−.17_	_−.11_	−.03						
Arousal during bet placement	−.33	.26	_.11_	_.17_	_.14_	.13	−.18					
Arousal at start of race	.35	.01	_−.06_	_−.20_	_.19_	.01	−.24	.36				
Arousal during race	.20	.24	_.08_	_.07_	_.27_	.22	−.29	.47**	.72***			
Arousal at end of race	.09	.17	_.25_	_.27_	_.41*_	.22	−.21	.40*	.38*	.81***		
Arousal after race	.13	.12	_.05_	_.06_	_.22_	.07	−.10	.22	.37*	.65***	.68***	
Arousal after leaving the office	−.02	.04	_−.23_	_.01_	_.11_	.09	−.05	.21	.46*	.45*	.32	.36

$* p < .05$; $** p < .01$; $*** p < .001$.

[a]Spearman correlations were used for the data which involved measurement not on an interval scale and are in italic.

directly to having a problem controlling their level of gambling behaviour, chasing was used as an index of problem gambling because chasing is significantly correlated with having a problem in the present study, and has been associated as a characteristic of problem gambling in previous studies and existing diagnostic tools (DSM–IV, American Psychiatric Association, 1994; Coventry & Brown, 1993; Dickerson, 1993; Dickerson *et al.*, 1987; Lesieur & Bloom, 1987).

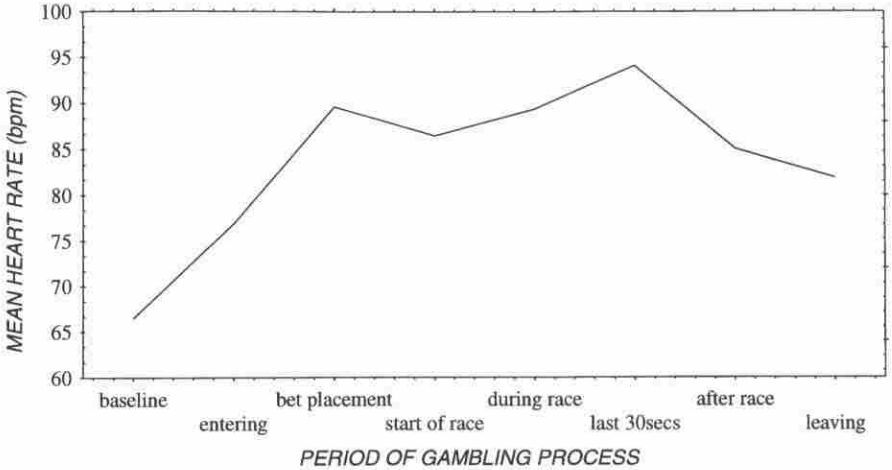

Figure 1. Heart rate at periods during the gambling process.

Participants were partitioned into those who chase and those who don't. A two-way analysis of variance was conducted on the HR data. The between-subjects factor was chasing (two levels), and the within-subjects factor was period during the gambling process (eight levels).There was no main effect of the between-groups factor, chasing versus non-chasing ($F(1,30) = 0.34$, $p > .05$), but a main effect of period was found ($F(7,210) = 23.09$, $p < .001$). No significant interaction between the factors was found ($F(7,210) = 0.77$, $p > .05$).

Follow-up analysis using Tukey's HSD tests revealed significant differences between periods of the gambling process as depicted in Table 2. These affirm that some periods of the gambling process are more arousing than others, and that all periods are more arousing than the baseline.

Participants were also partitioned into high- and low-frequency gamblers. High-frequency gamblers were selected as those scoring higher than 12 on the frequency of gambling index. The resultant means for the two groups were 1.95 (SD = 2.62) for the low-frequency group and 24.27 (SD = 13.97) for the high-frequency group. A two-way analysis of variance was conducted on the HR data. The between-subjects factor was frequency (two levels), and the within-subjects factor was period during the gambling process (eight levels). The findings were almost identical to those for the chase/don't chase analysis above. There was no main effect of frequency ($F(1, 30) = 0.87, p > .05$), a main effect of period was found ($F(7,210) = 24.33, p < .001$), and no significant interaction between the factors was found ($F(7,210) = 1.13$, $p > .05$).

Table 2. Results of Tukey's (HSD) *post hoc* tests on mean heart rates at periods during the gambling process (probabilities reported)

	Baseline	Entering	Bet placement	Start of race	During race	Last 30 s	After race
Entering	.000095*						
Bet placement	.000032*	.000039*					
Start of race	.000032*	.016948*	.654891				
During race	.000032*	.000046*	1.000000	.739540			
Last 30 s	.000032*	.000032*	.467436	.004070*	.381457		
After race	.000032*	.047048*	.433564	.999983	.522614	.001122*	
Leaving	.000032*	.649593	.017402*	.739872	.026710*	.000034*	.901109

* Significant at $p < .05$.

Fourteen participants had their horse positioned in the top three places at some point during the race. The HRs at these points were compared to periods during the race where the horse was not in the top three places (within subjects). The mean when the horse was in the top three was 92.44 (SD = 12.88) versus 84.33 (SD = 10.68) when not in the top three places. A related t test revealed that this was significant ($t = 2.82$, $p < .01$, two-tailed).

Finally, 10 participants won their races, and their HRs were compared to those who didn't at the end of the race, after the race and when leaving the off-course betting office, using a two-way analysis of variance (with success or not as the between-subjects factor and period as the within-subjects factor). The means are displayed in Fig. 2. Again, there was a main effect of period ($F(2, 54) = 19.18$, $p < .001$), but no significant effects of winning/losing ($F(1, 27) = 3.27$, $p = .08$), or interaction between factors ($F(2, 54) = 2.5$, $p = .09$), although in both cases the results approach significance. Comparing individual periods between groups, the only significant difference in HR between groups was in the last 30 seconds ($t = 2.83$, $p < .05$).

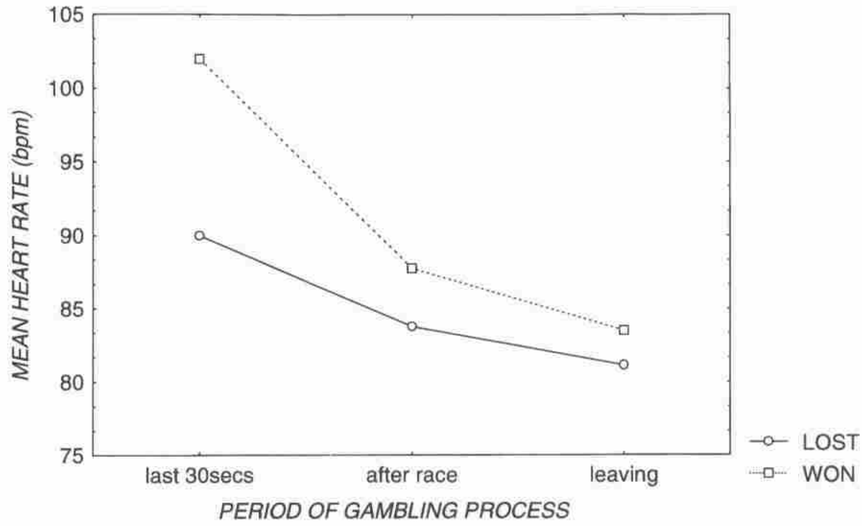

Figure 2. Heart rate during the gambling process and winning.

Discussion

The establishment of a baseline controlling for motor activity leads to a reliable affirmation of the existence of HR increases during gambling, and provides the first evidence for significant HR increases during horse racing gambling in particular. Increases in mean HR of up to 52 beats per minute were found (from the baseline). In addition there were significant differences *between* periods within the gambling process itself, with HR peaks during bet placement, and especially towards the end of a race, suggesting that certain periods in the gambling process may be particularly rewarding.

There is also evidence for the effects of horse position on levels of excitement. When the horse is positioned in the top three places, or wins the race, HR is significantly greater than when the horse does not figure in the race, but this effect is short-lived. No significant differences in HR were found between those who won and those who didn't after the race or when leaving the office. This finding is not consonant with the view that gambling leaves the gambler in a pleasant high state of arousal for quite some time after the race.

Partitioning participants into those who chase and those who don't and into high- and low-frequency gamblers allows one to evaluate the relative merits of the arousal theories noted earlier. The two-way analyses of variance on the HRs at different points during the gambling process revealed no significant differences in HR between gamblers who chase and those who don't, or between high- versus low-frequency gamblers. These data not only fail to support the claims of Leary & Dickerson (1985), but provide no evidence for the tolerance phenomenon reported by Griffiths (1993). However, the methods used to identify loss of control and frequency of gambling in this study (and in the others cited) remain somewhat limited, and future studies should employ more stringent indicators.

A number of caveats should be mentioned regarding the method used to measure HR in the study. While the use of photo-plethysmography is less accurate than other methods of measuring HR, it did not appear to interfere with the normal pattern of behaviour of the participants during the gambling process. As several minutes were allowed outside the office for each participant to acclimatize himself to experimental conditions, when recording started participants did not notice that readings were being taken. Therefore, while less accurate than other methods, unobtrusiveness of use was high. However, arousal changes were monitored throughout only one race per participant. Future research may well benefit from following the same gambler through a number of races.

The role of sensation seeking in the explanation of choice of form(s) for gamblers (Coventry & Brown, 1993) is partly supported in the present study. A significant correlation between the TAS and number of gambling forms participated in was found, although analyses of variance for number of forms and casino/non-casino did not reach significance. The distribution of results looks very similar to those found by Coventry & Brown (1993), with those gambling on three or more forms and in the casino scoring higher than those gambling on few forms. However, TAS scores did not correlate with bet size as Coventry & Brown found, or with arousal as Zuckerman (1979, 1983) originally predicted. Given that off-course gambling involves periods of high arousal, it may be the case that the Sensation Seeking Scale measures the variety of activities that an individual is likely to participate in, rather than the desire for high states of arousal. If the present data are reliable, sensation seeking may not have much utility in the explanation of impaired control of gambling given the lack of replication of previous findings, and the lack of a link between sensation seeking and HR, but the use of the TAS subscale alone suggests that this conclusion may be premature.

Overall, these results point to the serious shortcomings of objective arousal as an explanation of continued gambling behaviour when it is considered as a unitary concept. Increases in arousal, while apparent during gambling, can be caused by a range of factors, and may be the result of anticipation of future events rather than as a response to immediate events. Arousal can also be interpreted in different ways, and provides no direct indication of hedonic tone (see Thayer, 1989). During gambling activity, arousal is likely to be a by-product of an interaction between a decision-making strategy (the beliefs and cognitive strategies the gambler employs) and the information from the setting itself. According to this view, arousal can increase for two different types of reasons. In terms of the input itself, the more exciting the race actually is, the greater the arousal will be experienced by the gambler. For example, if one's horse is performing well, the race is more arousing than if the horse is not doing so well. Clearly, for a race to be maximally exciting for the gambler requires that the gambler remains interested throughout.

A second factor which is likely to determine the amount of arousal experienced resides in the beliefs of the gambler. A number of studies have found that the majority of gambler's verbalizations are erroneous during gambling (Gaboury & Ladouceur, 1989; Gaboury, Ladouceur, Beauvais, Marchand & Martineau, 1988; Griffiths, 1994; Ladouceur, Gaboury, Dumont & Rochette, 1988), and correlations have been found between the number of erroneous verbalizations produced and arousal during video poker play (Coulombe *et al.*, 1992). Further work is needed to identify the determinants of arousal as experienced during gambling and to investigate exactly what role arousal plays in the maintenance of gambling behaviour.

References

American Psychiatric Association (1994). *Diagnostic and Statistical Manual of Mental Disorders*, 1st ed. (DSM–IV). Washington, DC, American Psychiatric Association.

Anderson, G. & Brown, R. I. F. (1984). Real and laboratory gambling, sensation-seeking and arousal. *British Journal of Psychology*, **75**, 401–410.

Blaszczynski, A. P., Wilson, S. W. & McConaghy, N. (1986). Sensation seeking and pathological gambling. *British Journal of Addiction*, **81**, 113–117.

Brown, R. I. F. (1986). Arousal and sensation-seeking components in the general explanation of gambling and gambling addictions. *International Journal of the Addictions*, **21**, 1001–1016.

Cornish, D. B. (1978). Gambling: A review of the literature and its implications for policy and research. *Home Office Research Study, No. 42.* London: HMSO.

Coulombe, A., Ladouceur, R., Desharnais, R. & Jobin, J. (1992). Erroneous perceptions and arousal among regular and occasional video poker players. *Journal of Gambling Studies*, **8**, 235–244.

Coventry, K. R. & Brown, R. I. F. (1993). Sensation seeking, gambling and gambling addictions. *Addiction*, **88**, 541–554.

Dickerson, M. G. (1977). The role of the betting office environment in the training of compulsive gamblers. *Behavioural Psychotherapy*, **1**, 24–29.

Dickerson, M. G. (1979). FI schedules and persistence at gambling in the UK betting office. *Journal of Applied Behavioural Analysis*, **12**, 315–323.

Dickerson, M. G. (1984). *Compulsive Gamblers.* London: Longman.

Dickerson, M. G. (1986). The importance of a field study approach to gambling research. In J. McMillen (Ed.), *Gambling in the 80's.* Brisbane: National Association for Gambling Studies.

Dickerson, M. G. (1993). Internal and external determinants of persistent gambling: Problems in generalising from one form of gambling to another. *Journal of Gambling Studies*, **9**, 225–245.

Dickerson, M. G. & Adcock, S. G. (1987). Mood, arousal and cognitions in persistent gambling: Preliminary investigation of a theoretical model. *Journal of Gambling Behaviour*, **82**, 673–680.

Dickerson, M. G., Hinchy, J. & Fabre, J. (1987). Chasing, arousal and sensation seeking in off-course gamblers. *British Journal of Addiction*, **82**, 673–680.

Dickerson, M. G., Hinchy, J., Legg England, S., Fabre, J. & Cunningham, R. (1992). On the determinants of persistent gambling behaviours. I. High-frequency poker machine players. *British Journal of Psychology*, **83**, 237–248.

Fahrenberg, J., Foerster, F. & Wilmers, F. (1993). Cardiovascular response to mental and physical tasks as predictors of ambulatory measurements. *Journal of Psychophysiology*, **7**, 275–289.

Fisher, S. (1993). The pull of the fruit machine: A sociological typology of young players. *Sociological Review*, **42**, 446–474.

Gaboury, A. & Ladouceur, R. (1989). Erroneous perceptions and gambling. *Journal of Social Behavior and Personality*, **4**, 411–420.

Gaboury, A., Ladouceur, R., Beauvais, G., Marchand, L. & Martineau, Y. (1988). Dimensions cognitives et comportementales chez les joueurs réguliers et occasionnels au blackjack. *International Journal of Psychology*, **23**, 283–291.

Griffiths, M. D. (1993). Tolerance in gambling: An objective measure using the psychophysiological analysis of male fruit machine gamblers. *Addictive Behaviors*, **18**, 365–372.

Griffiths, M. D. (1994). The role of cognitive bias and skill in fruit machine gambling. *British Journal of Psychology*, **85**, 351–369.

Kuley, N. B. & Jacobs, D. E. (1987). The relationship between dissociative-like experiences and sensation seeking among social and problem gamblers. *Journal of Gambling Behaviour*, **4**, 197–207.

Ladouceur, R., Gaboury, A., Dumont, M. & Rochette, P. (1988). Gambling: Relationship between the frequency of wins and irrational thinking. *Journal of Psychology*, **122**, 409–414.

Leary, K. & Dickerson, M. G. (1985). Levels of arousal in high and low frequency gamblers. *Behavioural Research and Therapy*, **23**, 197–207.

Lesieur, H. R. & Bloom, S. B. (1987). The Souths Oaks Gambling Screen (Sogs): A new instrument for the identification of pathological gamblers. *American Journal of Psychiatry*, **144**, 1184–1188.

Lynch, W. C., Schuri, U. & D'Anna, J. (1976). Effects of isometric muscle tension on vasomotor activity and heart rate. *Psychophysiology*, **13**, 222–230.

Obrist, P. A. (1981). *Cardiovascular Psychophysiology. A Perspective*. New York/London: Plenum.

Rule, B. G. & Fischer, D. G. (1970). Impulsivity, subjective probability, cardiac response and risk taking: Correlates and factors. *Personality*, **1**, 251–260.

Rule, B. G., Nutler, R. W. & Fischer, D. G. (1971). The effect of arousal on risk taking. *Personality*, **2**, 239–247.

Saunders, D. M. (1981). The late betting phenomenon in relation to type of bet and type of race. *Behavioural Psychotherapy*, **9**, 330–337.

Smith, E. E., Guyton, A. C., Manning, R. D. & White, R. J. (1976). Integrating mechanisms of cardiovascular response and control during exercise in the normal human. *Progress in Cardiovascular Disease*, **18**, 421–443.

Thayer, R. E. (1989). *The Biopsychology of Mood and Arousal*. New York: Oxford University Press.

Zuckerman, M. (1979). *Sensation Seeking: Beyond the Optimal Level of Arousal*. Hillsdale, NJ: Erlbaum.

Zuckerman, M. (Ed.) (1983). *Biological Bases of Sensation Seeking*. Hillsdale, NJ: Erlbaum.

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