Reversals in Chess: Right or Wrong

Kevin J. O'Connell

1997

Report of original research
submitted in partial fulfilment
of the requirements for the degree of
MSc in Sports Science (Fitness and Health)
Department of Biological and Chemical Sciences
University of Essex

Contents

Abstract

Elite chess players (n=28) completed self-report forms for competitive games (n=44). It was hypothesised that it would be possible to demonstrate that psychological reversals between the telic and paratelic states occur during competitive play and that these could be precisely located within the game's time-line. It was further hypothesised that errors committed by the subjects in the games examined would be closely associated with the reversals. Such reversals are demonstrated (n=123) and are shown to be independent of outcome. This is an important first for the psychological theory of reversals, although it may be necessary to replicate the research (desirable in any case) because of doubts about the precise wording used on the CHEAS (chess history, evaluation, arousal and state) form. Strong supporting evidence for an associative link between reversals and error is also presented.

Key words:

arousal, chess, error, phenomenology, psychology, reversal theory, sport, stress

Abbreviations

ANS	Autonomic nervous system
CHEAS	Chess History, Evaluation, Arousal and State
FIDE	Fédération Internationale des Echecs
GEMS	Generic error-modelling system
KB	Knowledge-based (error)
Ra	Rating average
RB	Rule-based (error)
SB	Skill-based (error)
TDS	Telic Dominance Scale

Introduction

The psychology of chess playing, the psychological theory of reversals and the investigation of human error and its causes are three fields, each of which has its own extensive literature. The basic objective of the research upon which this paper is based was to investigate possible interactions of the latter two with specific reference to the sport of chess.

Chess

Many psychologists have been involved in research in the field of chess since Binet (1894) produced his ground-breaking work on what makes chess players tick. In the current century chess has been much used by researchers, not only in psychology and sports science but other fields as well, most notably in computer science and the quest for artificial intelligence, in which latter field chess soon came to be regarded as its "drosophila melanogaster" (fruit fly), especially for the tantalising possibilities that it might help in the search for much-needed global strategies for solving general problems of any kind (Michie, 1980; McCarthy, 1990).

The most frequently cited work on how chess players think is that of de Groot (1946, 1965). His research involved 22 chess players of various playing abilities, from two holders of the world champion title down to average club players with the sample skewed heavily towards the upper end of that range, accomplishing 'thinking-aloud' protocols for 34 chess positions of varying character. In writing up that work, he pointed out that the chess errors in his protocols could not be ascribed to 'non-task-connected reproduction tendencies', as predicted by Selz's "dynamic laws of thought in the framework of a closed theory" (Selz, 1913 and 1924), but rather they resulted from 'solution trials' where there was only a partial correspondence between what is required and the faulty solution. However, attention to error, and the causes thereof, was only touched upon in de Groot's work and the only concrete outcome was that chess players operate a dual mode of thinking which might best be described as either looking at moves (calculating) or looking at the position (possibly a transitional phase, providing some rest from calculation which might now be described as 'refocusing'). De Groot found that if concentration is unduly 'tense' then the attempts to withdraw from calculational details in order to 'look at the position' is sometimes unsuccessful and that the consequences are often severe: "blunders generally result from 'overlooking' things one should 'see'." (de Groot, 1965, p. 292)

Krogius (1976) examined 'blunders' in a sample of 1500 games, associated these occurrences with the ages at which the players concerned had learned to play and found a strong effect, later starters making roughly twice as many 'blunders' as the early starters. Krogius did not define what he meant by a 'blunder' (the nearest he came to this was when he stated that a 'blunder' is the same as a 'mistake'). A 'blunder' in chess would normally be defined as a 'big' mistake where 'big' would represent a shift of two or more categories across the positional evaluation scale (see below).

Fatigue is generally, and unsurprisingly, believed to be a significant factor in causing error on the chess board. Certainly, sleep deprivation has been demonstrated to affect chess performance. Wilkinson (1964) deprived a group of subjects from sleeping for 60 hours.

This group was paired with another in which the subjects slept normally. After a week of experimentation the two groups changed places and the experimental tasks of serial reaction, vigilance, decision-taking, card-sorting, table tennis, darts and chess were repeated. There were 12 chess players in the sample, split evenly between the two groups and each game played paired one player from each group. In five of the six pairs, the player most recently deprived of sleep lost a majority of the games. The number of games won, on average, by the sleep-deprived group was 51% of their own performance when in the rested group.

Making even occasional errors is sufficient to lower a player's rating considerably (Holding, 1985). The international rating system provides a measure of the ability of a player (ranging from 2000, the threshold of the international list to 2820, the highest rating ever achieved, while national rating systems commence at about 600 points, the level of a raw beginner) and can also be used, thanks to its secure statistical basis (Elo, 1978; Elo & Talacko, 1966), as a predictor of outcome between two players. Holding drew attention to the need for a classification of types of error and a study of the players who make, and the situations that provoke, different numbers and types of error. Various formulations have been produced over the years to try and assist chess players to avoid gross blunders (Purdy, 1931; Kotov, 1971; O'Connell 1997b). If your general principles are sufficiently effective, then the errors will be rare and that will make the individual concerned a genuinely strong player, but unfortunately some blunders are 'natural' and 'positional' players will tend to err with moves that are good positionally but poor tactically, while 'tactical' players will tend to err with moves that are good tactically but poor positionally (Levitt, 1997).

Research work using chess as the task environment has been made practical by the special nature of chess notation, effectively a separate language (but a universal one, the Roman lower-case letters, a-h, used for the geographical co-ordinates of the chessboard are the same the world over, irrespective of whether the initials used to represent the chess pieces are written in the Roman, Cyrillic, Arabic, Chinese, or any other alphabet) which permits a chess game to be recorded (compulsory for all chess tournaments and matches) precisely and subsequently replayed (without any vagaries of tempo or interpretation as with the repetition of a piece of music) by anyone familiar with the notation. The oldest recorded game is more than a thousand years old and almost every significant game played since the last major rule changes (ca. 1485) has been recorded (see, for example, Levy & O'Connell, 1981) and with the advent of computer and database technology it is now possible, and normal, for professional players to carry with them a notebook computer containing a database of between one and two million games - effectively every significant game ever played (O'Connell, 1995, 1997a). Extensions to that notation also permit players to provide precise evaluations (on a seven-point Likert scale ranging from 'winning for White' to 'winning for Black') to any chess position and there are now many computer programs which can do the same more or less reliably (O'Connell, 1996a).

A virtually unexplored issue is that of chess playing as an emotional activity (Charness, 1991). One of the author's main tasks as a chess coach is to help developing players control the emotional arousal which builds up through the course of a game, especially on being surprised by a move. Tikhomirov & Vinogradov (1970) did some work in this area. This provides a clear link into the area of reversal theory and its explanation of emotion.

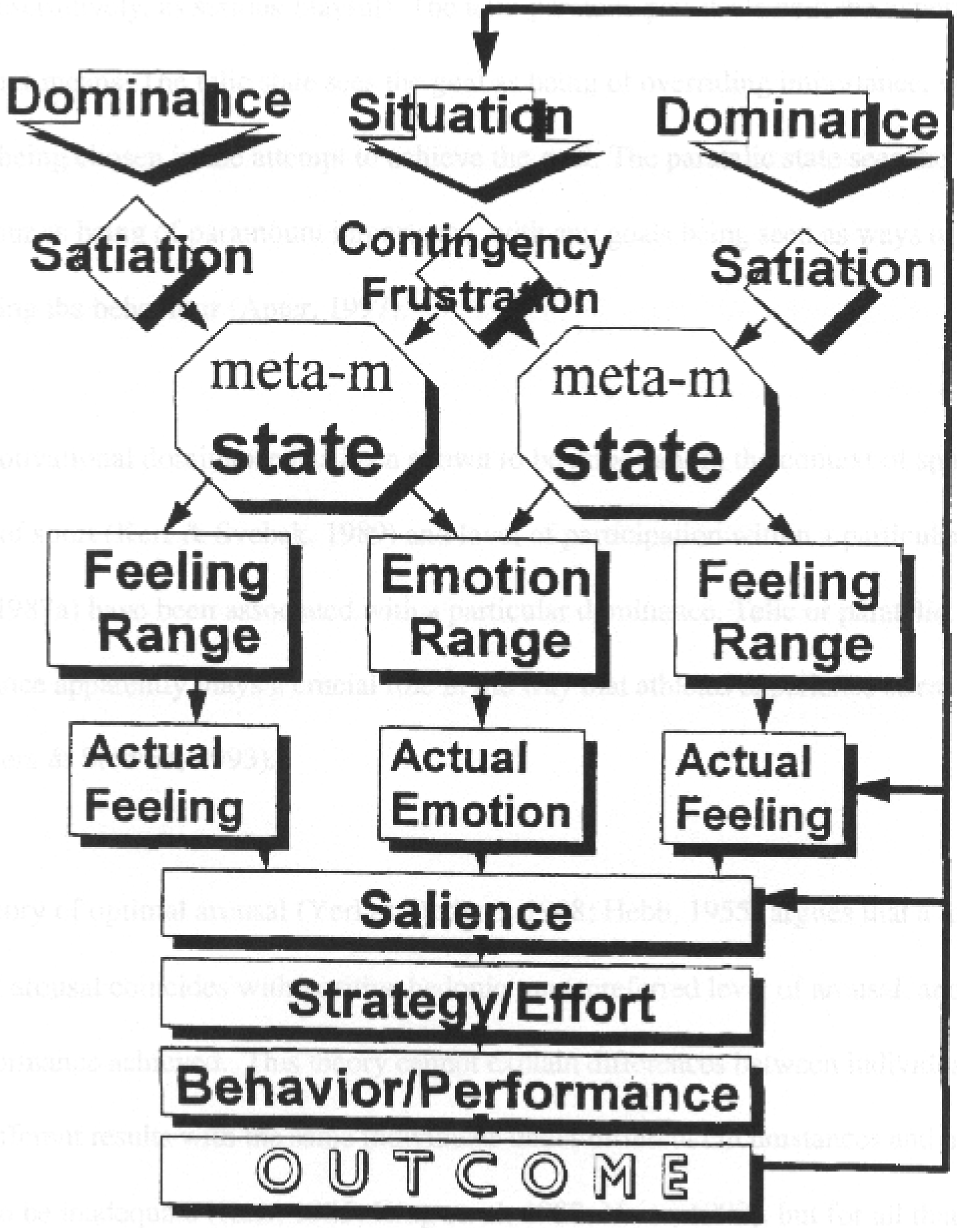
Reversal Theory

Reversal theory (Apter, 1982, 1989) is a general psychological theory dealing with, and attempting to explain, motivation, emotion, personality and psychopathology. Among the best general descriptions of the theory, aside from those by Apter himself, are Griffin (1994) and Frey (1997).

The central phenomenological tenet of reversal theory is that an individual experiences 16 primary emotions (boredom, relaxation, excitement, anxiety, sullenness, placidity, "anger", anger, humiliation, modesty, pride, shame, resentment, virtue, gratitude and guilt) by way of eight bistable states (serious-playful, compliant-defiant, power-oriented--affection-oriented, self-oriented--other oriented) which reverse from one to another. The theory is 'phenomenological' because it is concerned with subjective experience (Apter, 1989); the way in which individuals see themselves, the world, what they want and, above all, whether what they are experiencing matches what they wish to be experiencing at that time. It is the reversals between the pairs of metamotivational states that, the theory argues, forms the basis of human personality and motivation (Kerr, 1997).

Circumstances that bring about, or tend to induce, a reversal include: environmental events and situations (as experienced by the individual) which may also serve to maintain current states, frustration in achieving the preferred levels of the relevant variables (low/high arousal, for example), and processes of satiation (Apter, 1997). The framework is shown by the accompanying figure 1.

Figure 1: The conceptual framework of Reversal Theory



It is postulated that some individuals are predisposed to spend more time in one or other of a pair of metamotivational states and a number of psychometric instruments have been developed to measure such dominance, the best known of which is the Telic Dominance Scale (TDS; Murgatroyd et. al, 1978; see Appendix A). The TDS measures an individual's predisposition to be in the telic state of the telic-paratelic pair (referred to above, perhaps more descriptively, as serious-playful). The telic-paratelic pair deals with the experience of goals-and-means. The telic state sees the goal as being of overriding importance, with the means being chosen in the attempt to achieve the goal. The paratelic state sees the ongoing behaviour as being of paramount importance, with any goals being seen as ways of enhancing the behaviour (Apter, 1997).

Metamotivational dominance has been shown to be important in the context of sport. Both choice of sport (Kerr & Svebak, 1989) and level of participation within a particular sport (Kerr, 1987a) have been associated with a particular dominance. Telic or paratelic dominance apparently plays a crucial role in the way that athletes experience stress (Summers & Stewart, 1993).

The theory of optimal arousal (Yerkes-Dodson, 1908; Hebb, 1955) argues that a moderate level of arousal coincides with positive hedonic tone, preferred level of arousal, and level of performance achieved. This theory cannot explain differences between individuals or even different results with the same individuals under different circumstances and has been found to be inadequate (Kerr, 1985; King et. al, 1987; Neiss, 1990), but for all that it continues in widespread use in sports periodicals and coaching manuals. In high contrast, reversal theory specifically caters for individual differences in respect of: (i) dominance in relation to each metamotivational pair of states, (ii) lability (ease with which reversal occurs), (iii) relative salience which they tend to experience for each pair of states, and (iv) specific strategies adopted, and levels of effort invested, in the pursuit of high positive hedonic tone in relation to each metamotivational state when it is active (Apter, 1997).

Reversal theory looks quite differently at the relationship between arousal and hedonic tone (the pleasurable or unpleasurable perception of a state of being) and this is especially important, in the context of the present study, for the telic-paratelic bistable pair. Figure 2 (Apter, 1989; Kerr 1997) graphically shows the relationship and how pleasant feelings of excitement, emanating from high arousal in the paratelic state, can, following a reversal, be experienced as unpleasant feelings of anxiety in the telic state. Reversals, should they occur, involve flipping from one of the four emotions depicted at the corners of the figure to one of the two adjacent, while a simultaneous change in both arousal and hedonic tone will not result in a reversal, simply a switch to the emotion diagonally opposite.

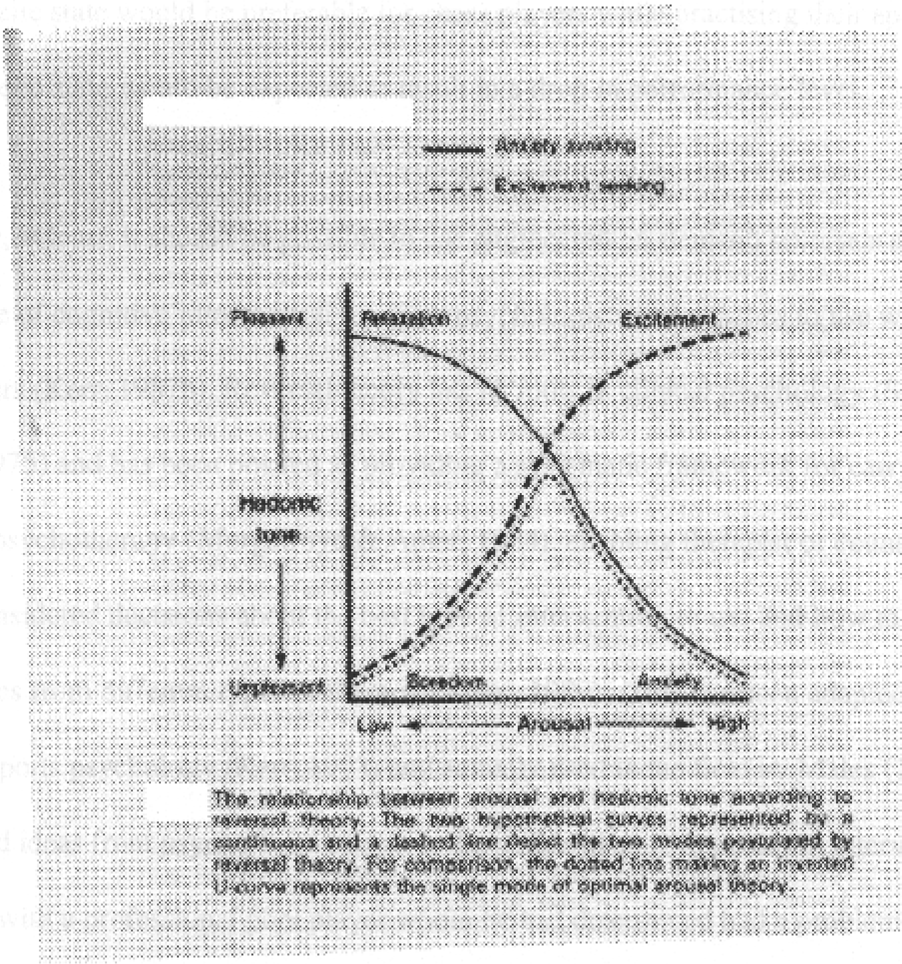


Figure 2: The experience of arousal

It would be hard to over-emphasize the importance of this in the field of sport. Apter (1989) found that when under severe pressure, paratelic subjects placed their emphasis on intensity of action while telic subjects concentrated on 'tightness of control', which is likely to prove disadvantageous for the more telic-minded (c.f. Gallwey, 1975). The same individuals, when in different metamotivational states, may think or process information quite differently (Frey, 1997). Gallwey's work was apparently inspired by the principles of Zen Buddhism and there are many similarities to and parallels with reversal theory, especially the telic and paratelic states (Fontana, 1981, 1991). Gallwey's comments that "concentration is fascination of mind", not *trying* to concentrate (p.92) and that "conscious trying often produces negative results" (p.19) point clearly to the distinct possibility that the paratelic state would be preferable for chess players while practising their sport and that the telic state would be expected to result in a drop in performance level.

In theory, at least, it should be possible to use engineered on-demand reversals as a technique of cognitive intervention for sport psychologists and coaches to use with elite performers (Kerr, 1987b). Reversal theory has its roots in clinical psychology (Smith & Apter, 1975) and has been posited as providing a systematic framework for carrying out eclectic psychotherapy (Murgatroyd & Apter, 1984), enabling therapist or counsellor to make considered decisions about the best type of intervention to use and how to combine techniques from different types of therapy (Apter, 1989). This has been adapted to the field of sports psychology (Kerr, 1993) and actually used in the field by Males (1995) who combined ideas from psycho-synthesis with the notion of state reversals in intervention sessions with a professional pool player whom he had determined had a problem with negative self-talk, the source of which lay in inappropriate reversals between telic and paratelic states during play (Kerr, 1997).

Most research in the field of reversal theory has concentrated on the notion of metamotivational dominance. Although there has been a trend, evident in recent years, to move towards working with metamotivational state, several criticisms of the theory have been made and one particularly important problem remained to be addressed - a demonstration that reversals do actually occur, thus allowing the theory to be tested "by assessing whether the relationship between why, when and how reversals occur is congruent with the theory" (Griffin, 1994).

Human Error

There has been a great deal of study devoted to the field of human error. It seems self-evident that it is a field of major importance, but in case that is not so one might mention instances of human error such as Bhopal 1984, Chernobyl 1986, King's Cross 1987, and Piper Alpha 1988, to name but a few fairly recent instances that have had a major impact on human existence.

The odds against error-free performance seem overwhelmingly high, with usually only one way (at best a few) of performing a task correctly, while there exists a myriad of unintended or inappropriate pathways along which we could stray (Reason, 1990). Errors are, however, rarer than correct actions and they take only a limited number of forms. Reason (1990) identified three main categories of error and related them to Rasmussen's (Rasmussen & Jensen, 1974; Rasmussen, 1981) performance levels, producing the categories of skill-based slips and lapses (SB), rule-based mistakes (RB) and knowledge-based mistakes (KB). The distinctions between them are summarized in Table 1 (Reason, 1990).

Table 1: "Summarising the distinctions between skill-based, rule-based and knowledge-based errors" (Reason, 1990)

DIMENSION	SKILL-BASED ERRORS	RULE-BASED ERRORS	KNOWLEDGE-BASED ERRORS
TYPE OF ACTIVITY	Routine actions	Problem-solving activities	
FOCUS OF ATTENTION	On something other than the task in hand	Directed at problem-related issues	
CONTROL MODE	Mainly by automatic processors (schemata)	(stored rules)	Limited, conscious processes
PREDICTABILITY OF ERROR TYPES	Largely predictable "strong-but-wrong" errors (actions)	(rules)	Variable
RATIO OF ERROR TO OPPORTUNITY FOR ERROR	Though absolute numbers may be high, these constitute a small proportion of the total number of opportunities for error		Absolute numbers small, but opportunity ratio high
INFLUENCE OF SITUATIONAL FACTORS	Low to moderate; intrinsic factors (frequency of prior use) likely to exert the dominant influence		Extrinsic factors likely to dominate
EASE OF DETECTION	Detection usually fairly rapid and effective	Difficult, and often only achieved through external intervention	
RELATIONSHIP TO CHANGE	Knowledge of change not accessed at proper time	When and how anticipated change will occur unknown	Changes not prepared for or anticipated

All of Reason's categories can be readily identified in chess, although the other side of the coin (allotting a specific erroneous move in a chess game to a specific category is a more challenging task). The most common SB error in chess is the 'automatic' response of recapturing. Player A captures something and player B recaptures, immediately, on the same square, a piece of equivalent value. One of the first things in chess which most people learn, or are taught, is that one must not lose material (since it will 'invariably' lead to defeat) and, although there are many exceptions to this, the teaching is so dogmatic that recapturing becomes a habitual, though frequently inappropriate response. An attentional check, to see if there is anything more important to be done than effect the recapture, is essential at this point.

Rule-based errors are, perhaps, the most common in chess, at least as played by non-professionals. There are many useful 'rules' which players gradually acquire with experience and many writers have referred to the pattern-matching and 'chunking' (Chase & Simon, 1973) abilities of experienced chess players. Typically, the errors occur as a result of applying a 'bad' rule or misapplication of a 'good' rule.

Chess is such a difficult sport that even the most highly-skilled players are frequently at the mercy of KB errors as they work in totally uncharted waters where even their extensive network of rules, patterns and chunks is no longer effective.

Reason (1990) further proposes a generic error-modelling system (GEMS) which shows the relationship between the three types of error and an overall structure within which they may operate (Fig.3).

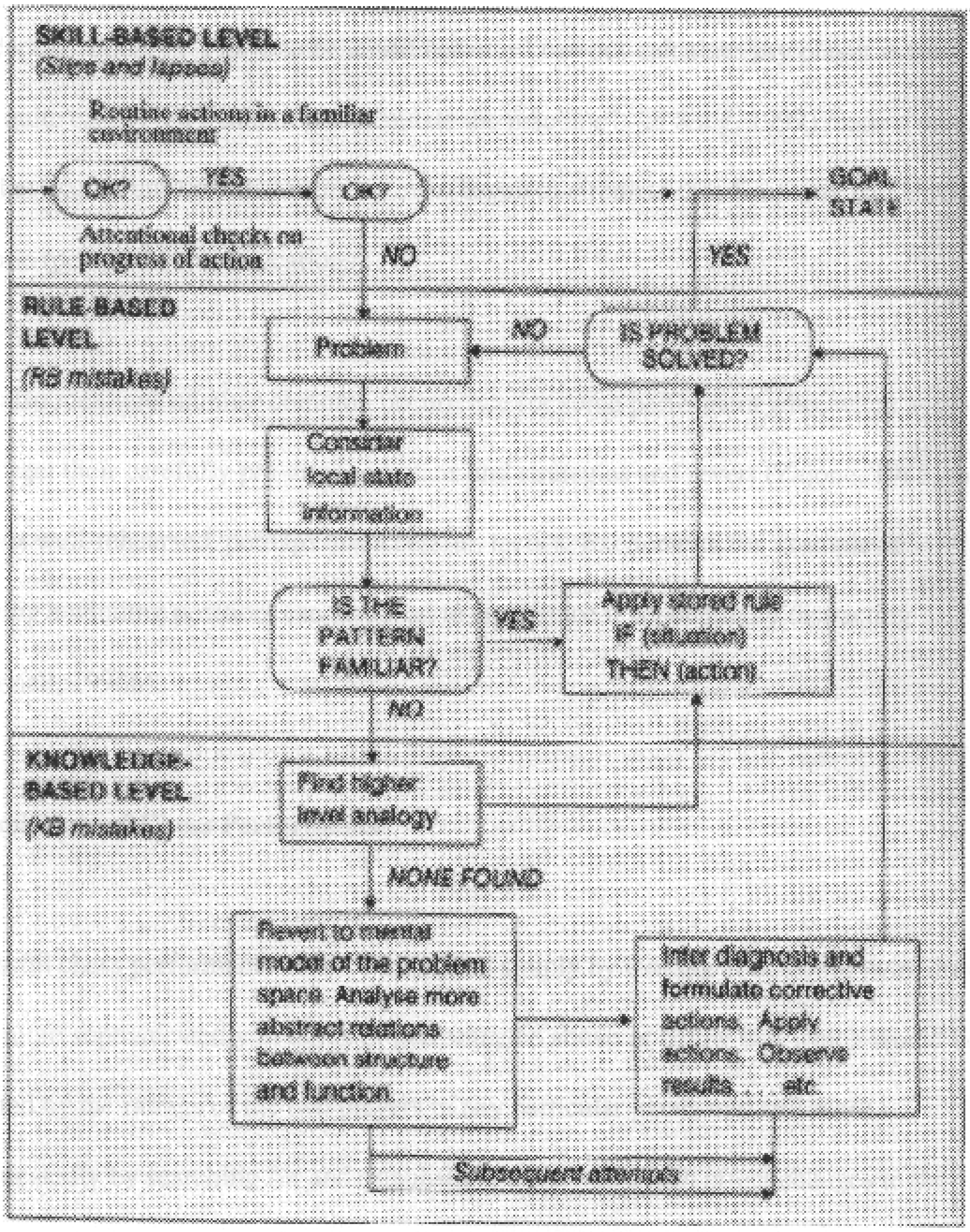


Figure 3:
Reason's (1990) outline of the dynamics of GEMS, a generic error-modelling system

Judgement can be severely affected by anxiety and this may lead to inappropriate decisions and unforced errors (Jones, 1991). Perhaps the very best example of this is the sixth and final game of the 1997 match between the world's best human chess player and the world's best non-human (Kasparov-Deeper Blue, New York) in which Kasparov, in a state of considerable anxiety ("I have to be afraid because I can out-calculate any player in the world quite easily, but I cannot out-calculate the machine" - in King, 1997) made a mistake (SB) that was so unlikely that rumours even began to circulate that Kasparov had 'thrown' the game (personal communications).

Jones also mentions another common occurrence for some performers who, when anxious, may forget their carefully pre-arranged plans and strategies and revert (Zajonc, 1965) to previous well-rehearsed, perhaps unsuccessful, tactics. Excitement, for example at achieving a winning position, can also lead to error since it is potentially distracting (O'Connell, 1996b).

Determinants of Chess Performance

Successful chess performance may be measured simply by looking at outcome (win, draw, loss), more sophisticatedly in terms of performance above or below that which would be predicted by the ratings of the two players in any particular game, and still more sophisticatedly by searching for and establishing the errors which effect changes to the positional evaluation and, ultimately, determine the outcome of any game (aside from agreed draws, usually of short duration).

The factors which influence performance appear to be of two types which work independently but may also combine. These are of a domain-specific nature (what is often called talent or expertise but which appears to be a combination of information-processing rate and knowledge - c.f. Holding, 1985; Levitt, 1997) and of a more universal kind, relating to the ways in which individuals cope with competitive stress and performance anxiety in an attempt to minimize the occurrence of error (O'Connell, 1996b).

Although calculation does play its part (especially in the field of computer chess), it is only a small part. The sheer magnitude of the task confronting a 'calculator' makes it obvious that something is required to cut down the size of the search field (this is true also for computer chess). Take, for instance, a 'typical' hypothetical position in which each player will have an overall mean estimate of 32 moves available. To examine exhaustively such a position just 5-ply deep would require the calculation and assessment of something approaching 33,554,432 positions (it is somewhat less because of 'move transpositions' - different sequences of moves leading to the same position, e.g. red-black-blue-green and red-blue-black-green both reach the same 'position').

Hypotheses to be tested

An unstated hypothesis underlies the research and much of the literature; that is that chess performance is determined by error or lack thereof ("The player who wins is the one who makes the mistake before the last" frequently attributed to Tartakower, but without a specific reference, and *erro ergo sum*, actually "Ich mache Fehler - also ich existiere!", Tartakower, 1924).

Two basic hypotheses were posited at the start of the research: (1) that reversals between the telic and paratelic states would occur during chess games and that these reversals could, in the case of elite players, be measured and located precisely within the time-frame of the game, (2) that unforced errors would most frequently occur after a reversal (probably from the paratelic to the telic state).

Materials and Methods

The research was designed to test the ideas that reversals occur and that there is a link between them and the occurrence of error. Elite chess players filled out specially designed questionnaires shortly after finishing competitive games in one of a dozen major international tournaments (including the strongest-ever tournament - Las Palmas 1996 - the 1996 Chess Olympiad and the 1996 World Under-14 Championship) in 1996/1997.

Subject Group

The 28 subjects, all elite chess players, are summarized in Table 2. Details of age and rating are as of 1997.07.01 (FIDE, 1997). Note that one of the amateur players is currently unrated ($), two of them are of unknown age (*) and two of the juniors (#) have yet to achieve an international rating.

SUBJECTS	Professional	Amateur	Junior	Total
n=	17	6	5	28
male-female	16-1	4-2	5-0	25-3
age: mean	31	32	14	28
range	22-42	29-34*	13-16	13-42
rating: mean	2627	2248	2186	2498
range	2375-2765	2100-2370$	2090-2240#	2090-2765

Table 2: Subjects

The 28 subjects completed a total of 44 specially designed protocols and 26 of them also completed the Telic Dominance Scale (TDS). Three of the juniors completed four protocols each, the other two juniors and five of the professionals (all presently or formerly in the world top 10) each completed two protocols.

Protocol and Questionnaire design

Two self-report questionnaires were utilized. One of these was a standard, the other had to be specially developed.

The TDS was developed by Murgatroyd et. al (1978). It is a scale which measures the dominance of subjects in relation to telic and paratelic states (Apter, 1982). The TDS, and its scoring, will be found as Appendix A. Although one can produce an overall score of telic dominance, the TDS contains three sub-scales (serious-mindedness, planning-orientation and arousal-avoidance) and it is the serious-mindedness sub-scale which is seen as the defining scale (Apter, 1989).

The TDS has been widely used by researchers in the field of Reversal Theory and was used in this study primarily because research (Svebak & Murgatroyd, 1985) has suggested that there are biological differences between telic and paratelic dominant subjects which may contribute to the likelihood of error (Lacey, 1959, and Andreassi, 1995).

A special Chess History Evaluation Arousal and State (CHEAS) form was developed and modified, following a small pilot trial during the summer of 1996. A copy of the CHEAS form as used can be found as Appendix B. The form records a complete game, together with a detailed record of positional evaluation, self-reported arousal level and self-reported hedonic tone for each ply.

The condensed wording used on the CHEAS form was developed after consulting several sources for the measurement of self-reported stress and arousal (Mackay et. al, 1978; Cox & Mackay, 1985) and for measuring telic state (Svebak & Murgatroyd, 1985), especially in the sport context (Kerr's SOMIFA). There are still some problems with this form because of the wording (see the Discussion).

Interview

Each interview was conducted by the author, who avoided examining the TDS forms until shortly before writing this paper, and so had no direct knowledge of that TDS data. It transpired that the respondents were fairly evenly split between telic dominant (n=14) and paratelic dominant (n=12), with two respondents not completing the TDS.

The subjects filled in a CHEAS for one or more games that they had played. The subjects normally did this within 24 hours of the end of the game. The games concerned were competitive ones in major international events. The subjects were asked to draw a line down each of the three Likert scale columns, passing through the appropriate box (representing a point on the Likert scale) for each move. On the final sheet of the CHEAS form (only 11 games were of 30 moves or less, while 6 went to more than 60 moves, and hence a third sheet) the respondent marked a five point Likert scale indicating how well they felt they had performed in that particular game compared with their average level of performance.

Data Collection, Preparation, Entry and Disaster Recovery

The basic strategy for data collection was to exploit (hopefully not excessively) the author's special relationship with the subject group. That worked well. However, the author's professional duties during the tournaments at which he was conducting the interviews made it difficult to get as many questionnaires completed as would have been desirable. Nonetheless, the size of the sample is considered to be sufficient.

It soon became apparent that the CHEAS protocols were particularly valuable and irreplaceable. The principal disaster recovery strategy adopted was to ensure that at least one complete set of photocopies of that material was maintained in a separate location from the originals. Additionally, of course, once the data entry, analysis and report stage was reached, duplicate copies of all computerised data were stored.

Data preparation involved preparing a chess database file of the games. These were prepared in a standard format (ChessBase) so that they could readily be passed to and from other specialist chess applications. The reigning World Computer Champion (Fritz4) was extensively used, running from CD-ROM on the author's computers, to corroborate the human assessment (both by player and by author) of error in all of the games.

The CHEAS forms were carefully checked and marked up. The marking up involved indicating, directly on the forms, errors and points at which either arousal or hedonic tone moved from one end of the scale to the other (reversed). Then coding information was marked directly on the right-hand margin of the forms in order to facilitate (and hopefully minimize error in) the process of data entry.

Statistical analysis was conducted using SPSS 4.01 running on a variety of different computers, most usefully on a Hewlett Packard 200LX 'palmtop' computer which can be carried in a good-size pocket. Statistical measures of significance used were Chi-square (for 2x2 crosstabulations) and PHI/Cramers V (for larger crosstabulations).

Results

A preliminary precis of these results (40 protocols of 26 subjects) was presented at the 8th International Conference on Reversal Theory (Griffin & O'Connell, 1997).

The basic assumption of this research, that the outcome of chess games is determined by the occurrence of error, was supported by the data. Table 3 shows the expected association ($p<.00001$) between outcome and the occurrence of error (each bar is shown as a percentage of the whole sample of 44 games).

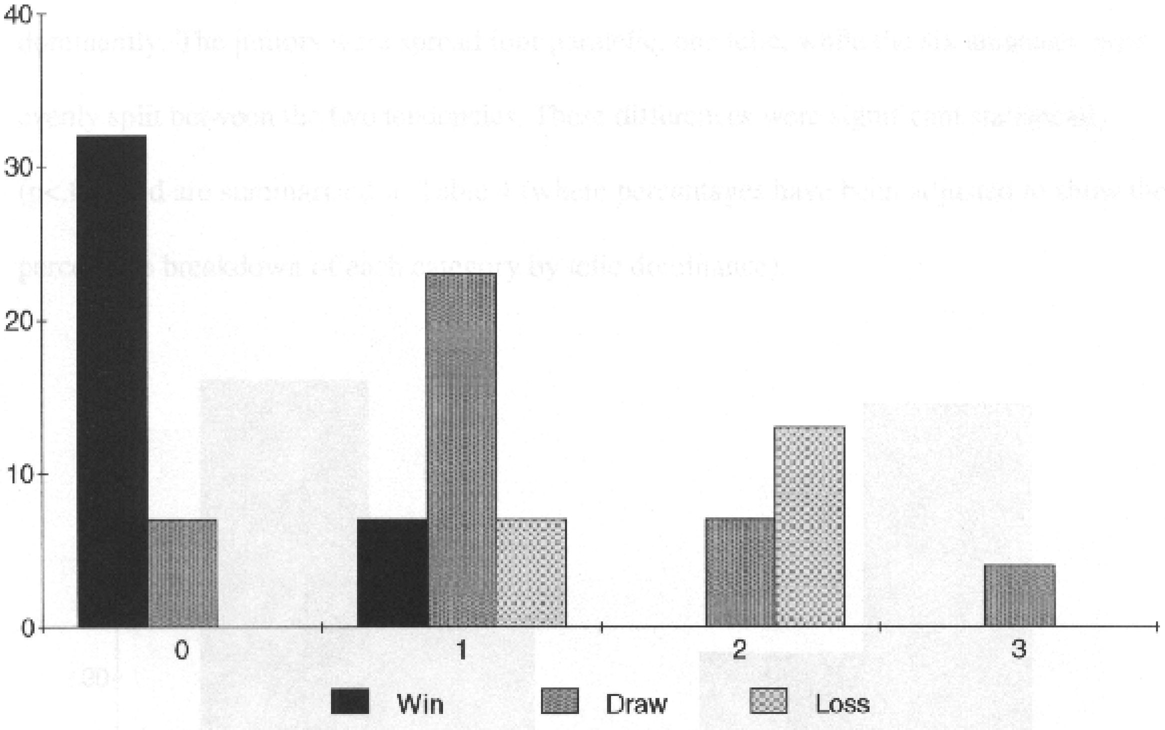


Table 3: Percentage results for subject error by quantity (0-3)

For the rest of the results, a significance level of $p<.05$ has generally been considered to be an acceptable indication of dependency (de Vaus, 1996).

Telic Dominance

26 of the 28 subjects completed the TDS (see Appendix A). 12 of the subjects produced scores tending to paratelic dominance, while 14 of them scored towards the telic dominant end of the defining serious-minded sub-scale. Although the single most paratelic score was registered by a player currently in the world top ten, six of the eight players who are or who have featured among the top ten in the world scored as telic dominant (equally divided between those who are in the top ten and those who have previously been).

Of the 17 professional players (including those in the top 10), two thirds scored telic dominantly. The juniors were spread four paratelic, one telic, while the six amateurs were evenly split between the two tendencies. These differences were significant statistically ($p<.02$) and are summarized in Table 4 (where percentages have been adjusted to show the percentage breakdown of each category by telic dominance).

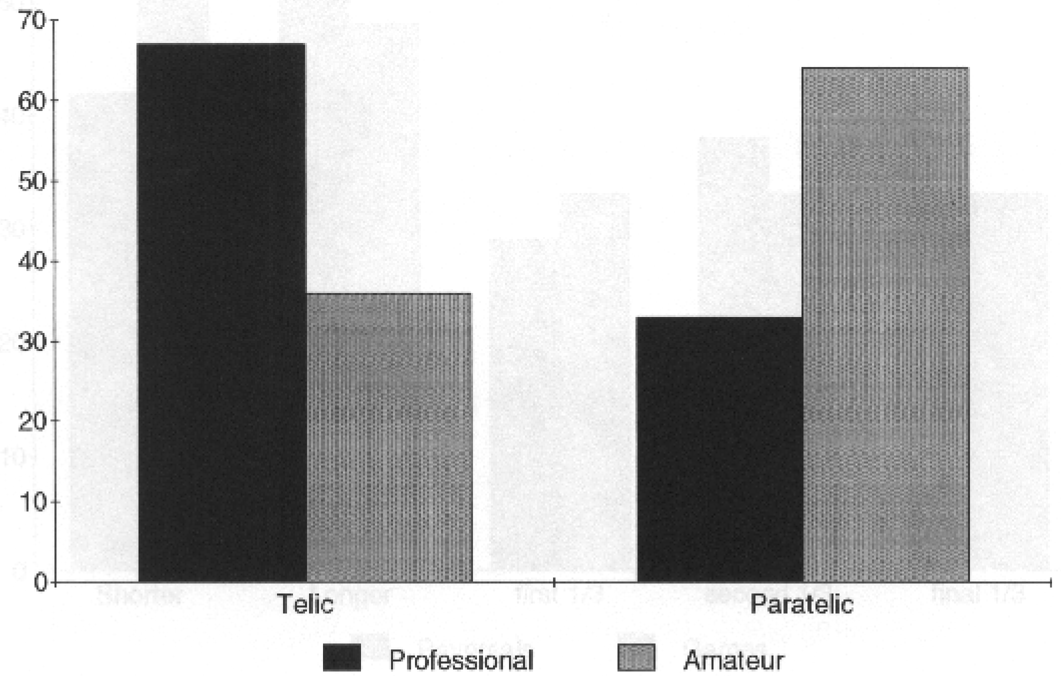


Table 4: Telic dominance

Detailed individual TDS scores (identified only by Professional or Amateur) can be found as part of Appendix A.

Reversals

Reversals were observed in 36 (82%) of the games. The number of reversals in those 36 games ranged from 1 to 7 (respectively n= 4, 9, 8, 6, 4, 2, 3), a total of 123 reversals. The reversals which occurred were not restricted to any particular phase of the game, as is shown by Table 5. The table is designed to show the proportion of reversals which occurred in games of shorter/longer duration and in which third of the game they occurred (so Reversals x Shorter/Longer = 100%, as do Games x Shorter/Longer) and thus graphically illustrate any divergence from a normal distribution.

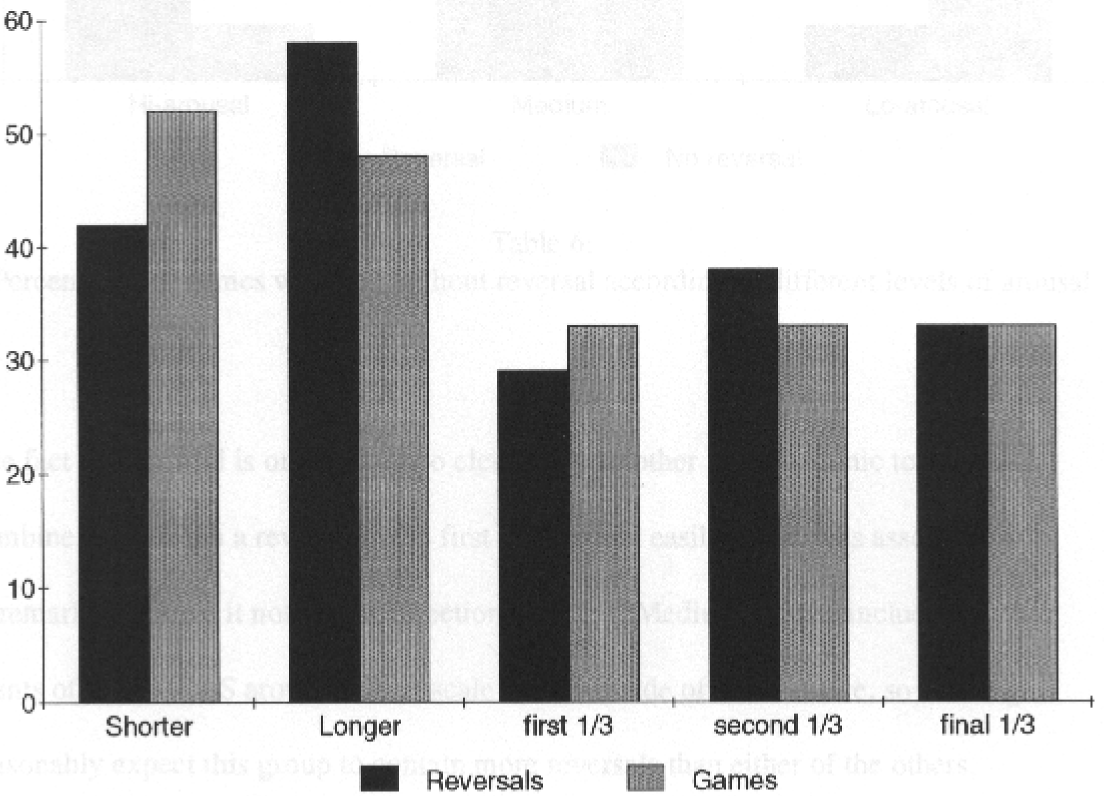


Table 5: Percentages of reversals occurring by game length and by game period compared with percentages of games

Few of the crosstabulations suggested any link between reversals and other variables, and so the great bulk of these have been consigned to Appendix C. However, level of arousal was closely associated with the observed reversals ($p < .03$), as shown in Table 6.

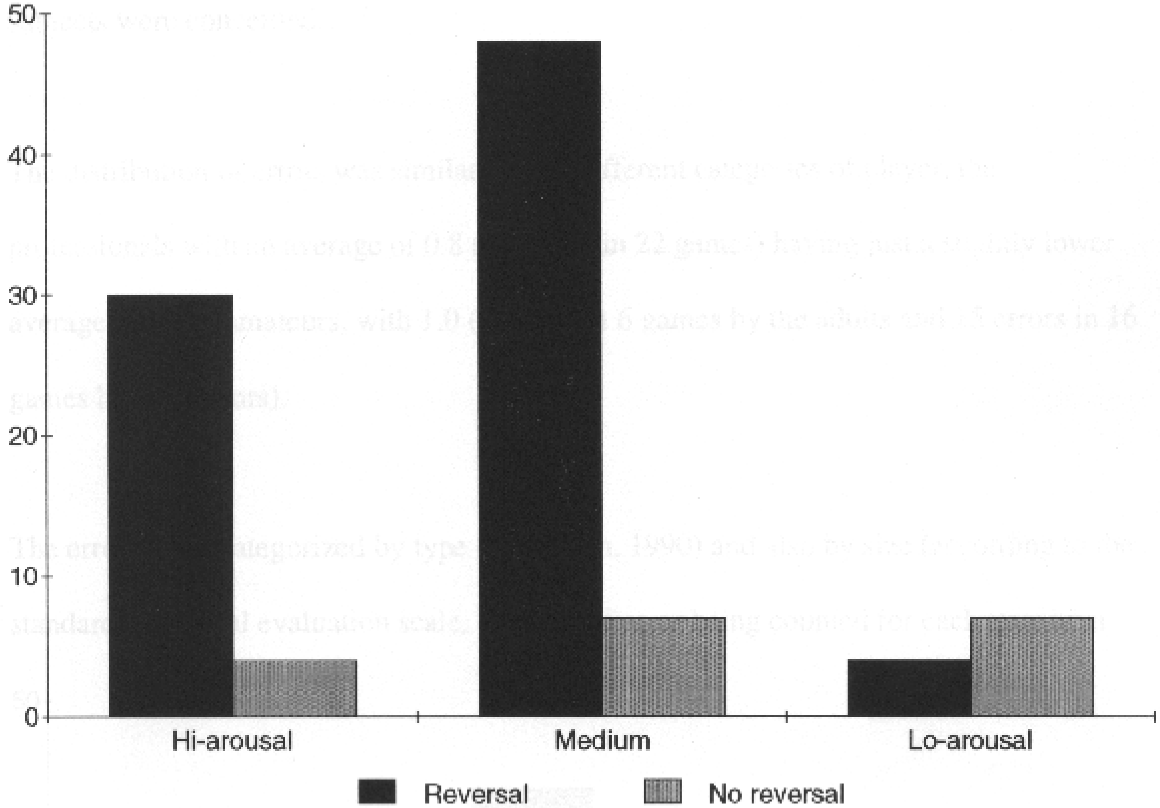


Table 6:
Percentages of games with and without reversal according to different levels of arousal

The fact that arousal is one of the two elements (the other being hedonic tone) which combine to establish a reversal in the first place could easily render this association unremarkable, were it not for the directionality of it. Medium arousal includes the two points of the CHEAS arousal Likert-scale on either side of the mid-line, so one might reasonably expect this group to contain more reversals than either of the others.

Error

A total of 44 errors (committed by research subjects, those by their opponents being ignored) were noted in 27 games (61%), 17 of the games being error-free as far as the subjects were concerned.

The distribution of errors was similar for the different categories of player, the professionals with an average of 0.8 (18 errors in 22 games) having just a slightly lower average than the amateurs, with 1.0 (7 errors in 6 games by the adults and 15 errors in 16 games by the juniors).

The errors were categorized by type (cf Reason, 1990) and also by size (according to the standard positional evaluation scale, one unit of error being counted for each transition

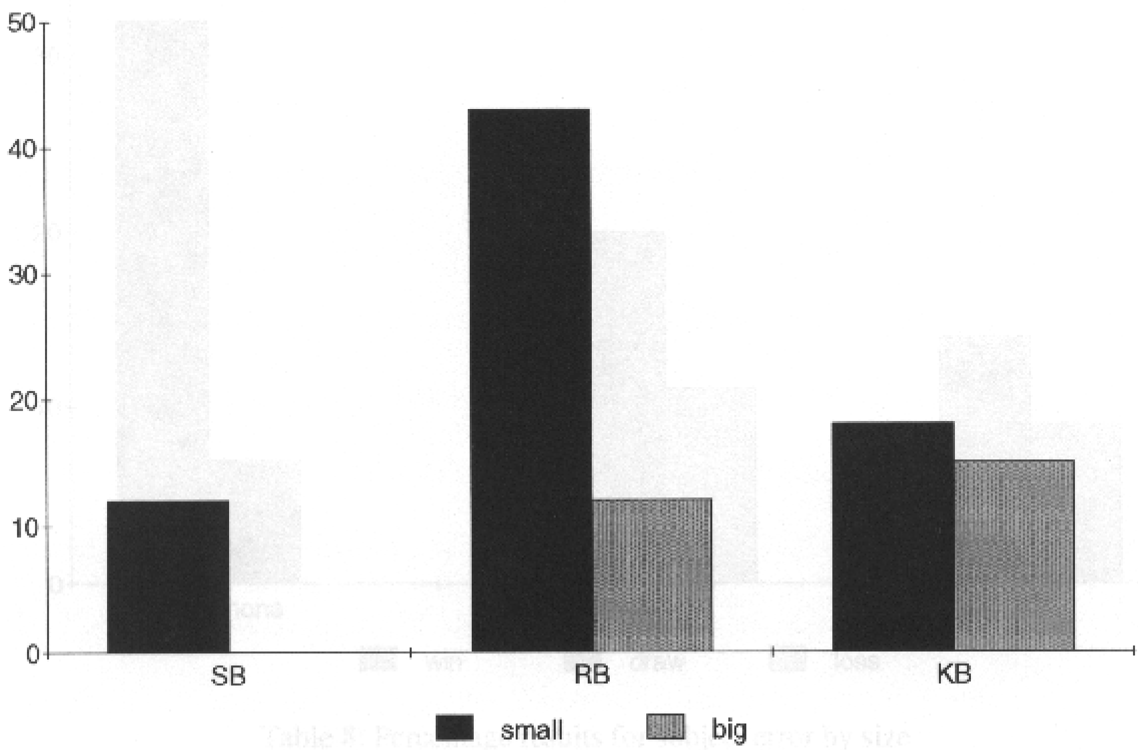


Table 7: Frequency of error type categorized by size of error

along the Likert-scale, and then condensed into 'small' errors of one unit and 'big' errors of two or more units). All types and all sizes of error were found in the sample. These categorizations (n.s.) are summarized in Table 7.

The results were analysed to see whether either the type or size of error had a significant effect upon outcome. These results are shown in Table 8. Type of error had no statistically significant effect upon outcome, which seems surprising given the apparent 'shape' of the crosstabulation of result by type (only p<.54). The 'self-evident' idea that big errors should have a more deleterious effect on outcome than smaller ones is illustrated in Table 8 (p<.00008). The original crosstabulations (RESxSIZE and RESxTYPE) are in Appendix C.

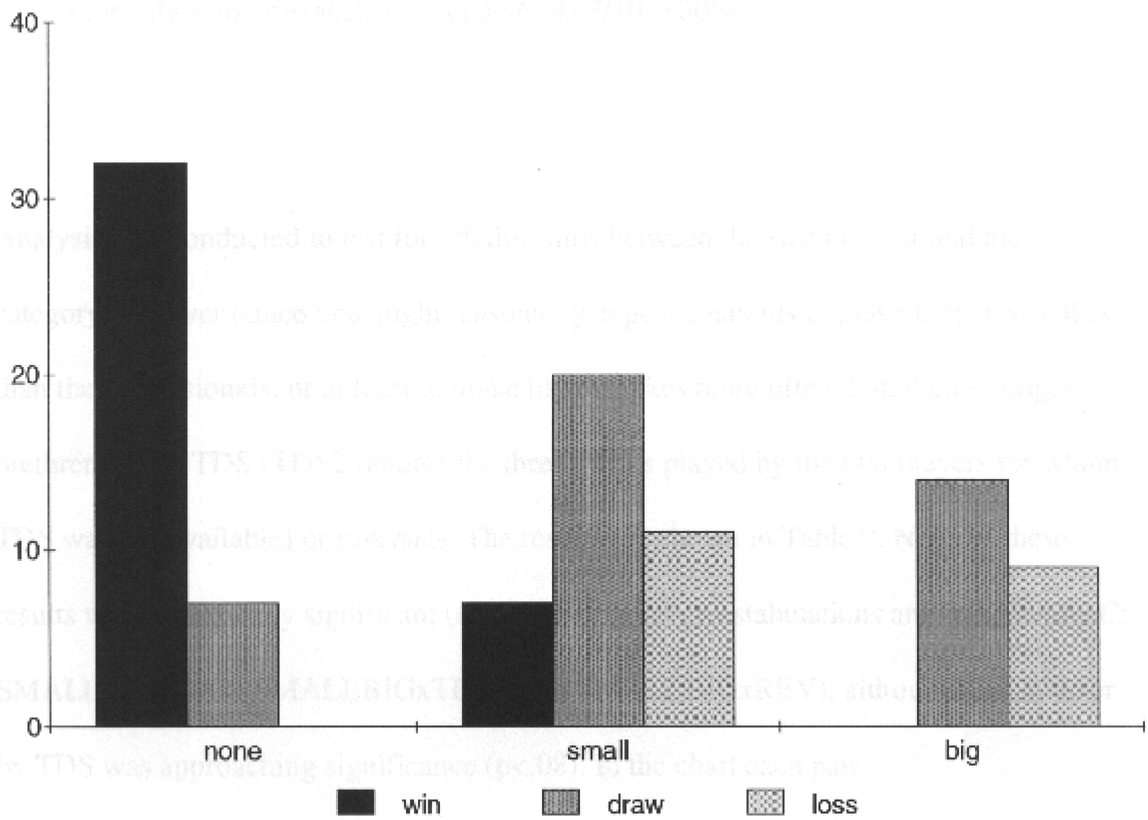


Table 8: Percentage results for subject error by size

This information can be rendered even more 'graphically' (to chess players at least, who are accustomed to keeping track of performance in a tournament according to the 'plus/minus' calculation of the number by which a player's total wins exceed the total number of his/her losses) by rendering it in the following form: games without error ('plus 11' undefeated), games with only small errors ('minus2') and games with big errors or 'blunders' ('minus 4' without a win).

Details of the scores:

overall score	(+17 =18 -9) 26/44 = 59%
score after small mistake(s)	(+3 =9 -5) 7.5/17 = 44%
score after big mistake(s)	(+0 =6 -4) 3/10 = 30%

Analysis was conducted to test for relationships between the size of error and the category of player (since one might reasonably expect amateurs to make bigger mistakes than the professionals, or at least to make big mistakes more often than their stronger brethren), their TDS (TDS2 ignores the three games played by the two players for whom TDS was not available) or reversals. The results are shown in Table 9. None of these results were statistically significant (again the original crosstabulations are in Appendix C: SMALLBIGxCAT, SMALLBIGxTDS2, and SMALLBIGxREV), although size of error by TDS was approaching significance ($p<.08$). In the chart each pair (Professional/Amateur, Telic/Paratelic, Reversal/No Reversal) sums to 100%.

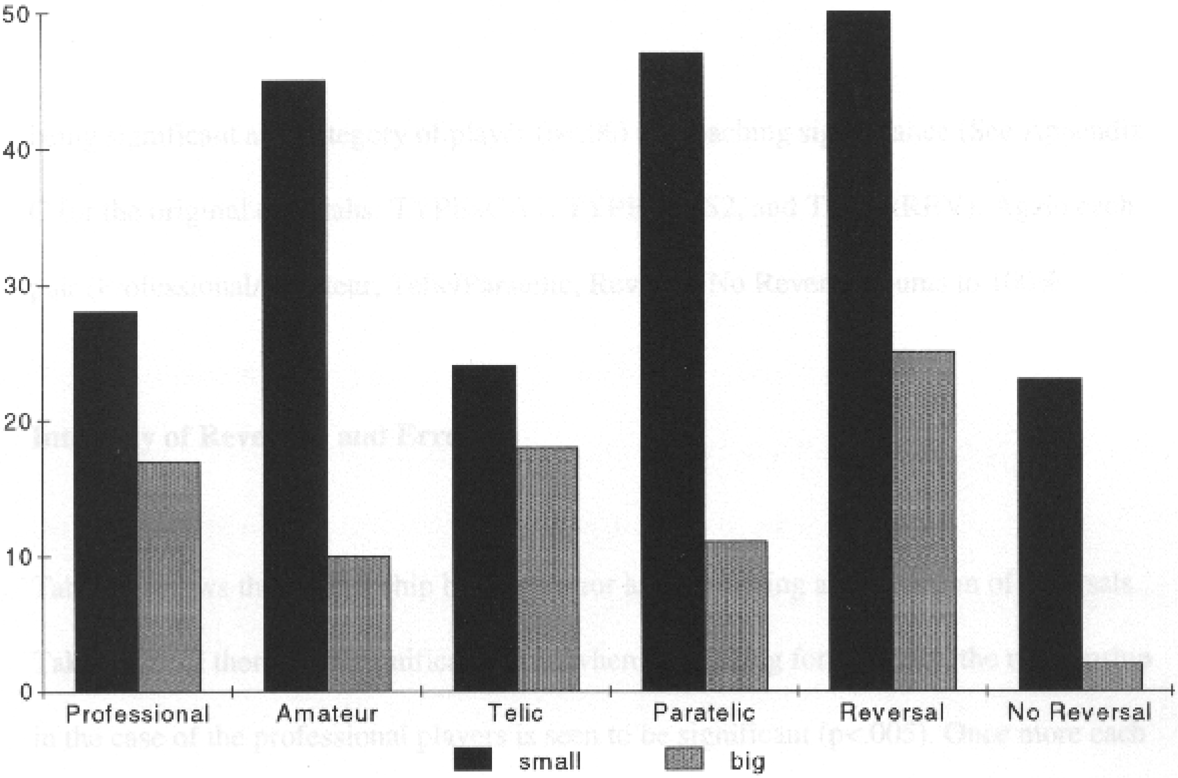


Table 9: Size of error related to three pairs of variables

Type of error was also investigated to see whether it might be influenced by the category of player, their TDS or reversals. The results are shown in Table 10. Error type seems to be more clearly influenced by other variables, presence or absence of reversal (p<.006)

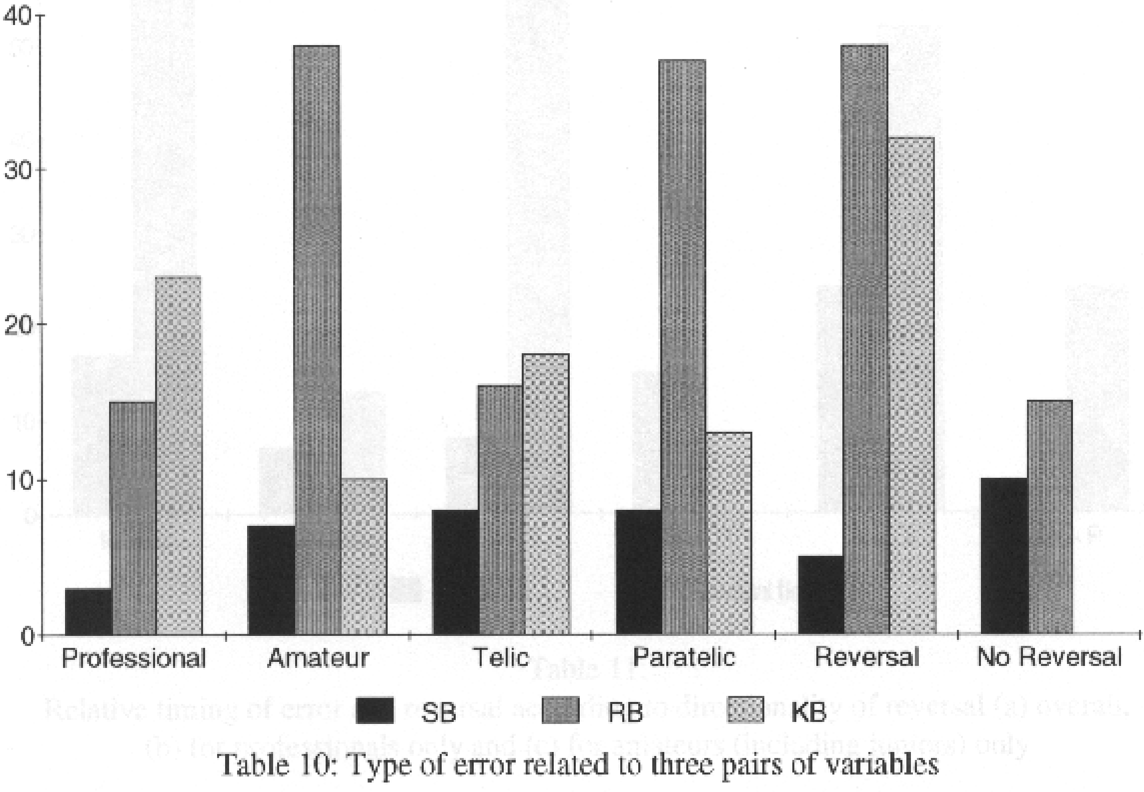


Table 10: Type of error related to three pairs of variables

being significant and category of player ($p<.06$) approaching significance (See Appendix C for the original crosstabs: TYPExCAT, TYPExTDS2, and TYPExREV). Again each pair (Professional/Amateur, Telic/Paratelic, Reversal/No Reversal) sums to 100%.

Interplay of Reversals and Error

Table 11 shows the relationship between error and the timing and direction of reversals. Taken overall there is no significance, but when controlling for category, the relationship in the case of the professional players is seen to be significant ($p<.005$). Once more each pair (to Telic/to Paratelic, Pro-T/Pro-P, Am-T/Am-P) sums to 100%.

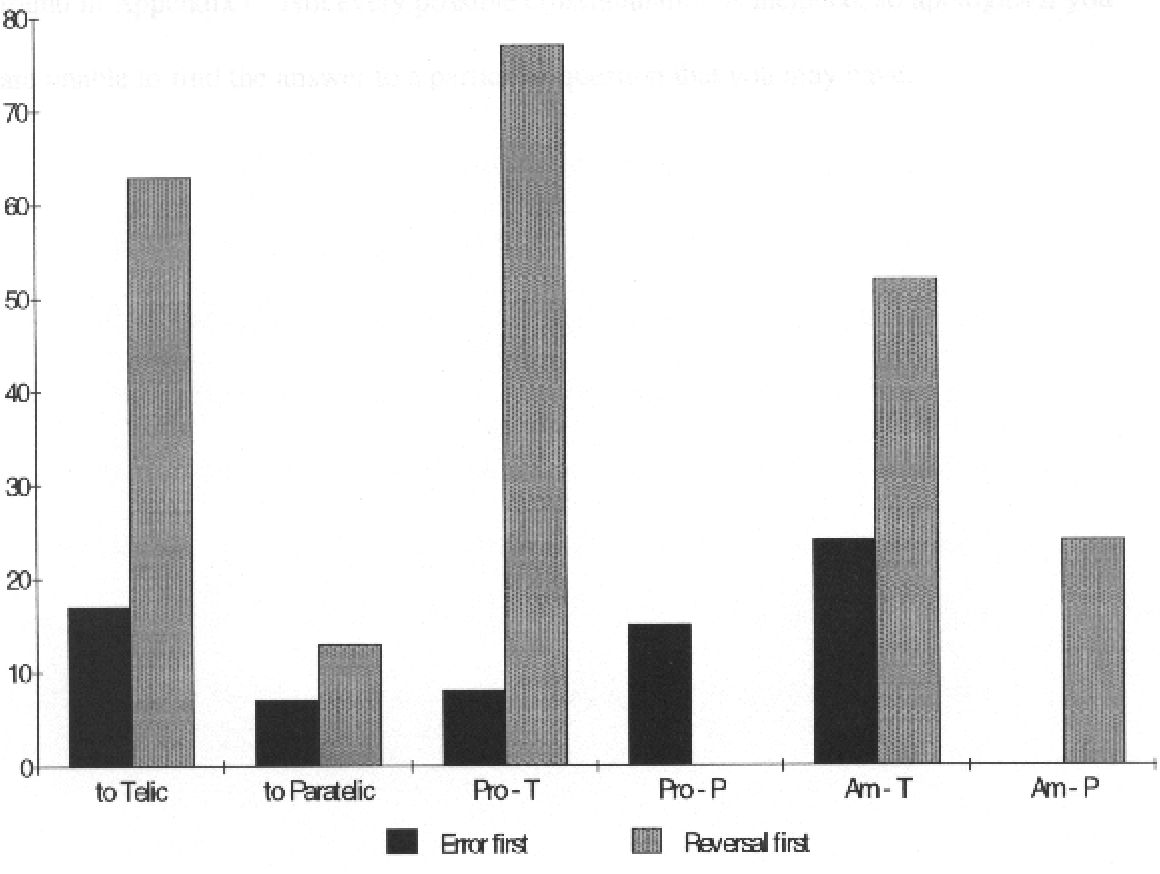


Table 11:
Relative timing of error and reversal according to directionality of reversal (a) overall, (b) for professionals only and (c) for amateurs (including juniors) only

Summary

The results provide strong support for the two basic hypotheses:

(1) reversals between the telic and paratelic states occur during chess games and they can be measured and located precisely within the time-frame of a game;

(2) errors do occur most frequently following a reversal from the paratelic to the telic state.

The results presented here have been selected as being the most relevant. More can be found in Appendix C. Not every possible crosstabulation is included, so apologies if you are unable to find the answer to a particular question that you may have.

Discussion

Design

One aspect of the design which it is especially important to address is the concept and validity of the post-game self-report questionnaire. Certain fields of human endeavour apparently impose a useful compartmentalized template, enabling experts in that domain, with greater or lesser precision, to identify and pinpoint particular occurrences, including changes in physiological and psychological state. For instance, if you were to ask a London taxi-cab driver to map out precisely the route he had travelled the previous day, it is quite likely that he would be able to do so with a high degree of accuracy.

Chess players specifically train themselves to recall, in great detail, what they were thinking during a game and elite players have a remarkable ability to recall enormous amounts of data, neatly compartmentalized in ply 'boxes'. The entire literature is full of examples of this. Thus it will come as no surprise, at least to elite chess players, that they have been able, retrospectively, to identify reversals. Such ability is greatest in the stratospheric reaches of ability and may account for the differences in Table 11 above. Those differences may be genuine or merely an artefact of the comparative inability of the elite amateur to be sufficiently precise in their recollections, thus leading to a blurring of the effects.

In an ideal experiment the players' assessments of arousal and hedonic tone would be recorded after each and every move during the game. This is not possible in the competitive situation. At least in the author's opinion (benefiting from his experience as an elite chess player) the post-game self-report design utilized here loses little in accuracy and nothing in validity in comparison with the 'ideal'.

Subjects

The subjects in this study are all elite chess players. "Elite" in the sports context means widely and sometimes wildly different things to different researchers. The author's definition of elite was that for inclusion a player had to be, at the very least, ranked in the top 10 in their country or, in the case of juniors, ranked in the top 100 in the world for their age group. Adults ranked among the top 100 in the world were particularly sought. The 28 subjects (m=25 f=3), from 15 countries, form, within the limits of the above definition of elite, quite a representative sample.

There are just over 20,000 players in the world with an international ranking. Of these 81% are from Europe, 11% from the Americas, 7% from Asia and 1% from Africa. The subjects in the study matched this distribution quite well: Europe 86%, Americas 7%, Asia 7%. Also the sex of the participants turned out to be a perfect match with the international distribution of just under 10% of all players being female. The only obvious mismatch was that the majority (61%) of the sample had English as their first language.

Looking at the sample subjects in more detail, 17 of them are professional players, more than half of whom are or have been ranked among the top ten in the world, plus 6 amateurs and 5 juniors. The full list of players will be found under Acknowledgements.

The 15 countries represented (number of subjects in brackets when >1) are: Australia, Barbados (2), Bielorussia, Bosnia & Herzegovina, Bulgaria, Croatia, England (10), Germany, India, Ireland (3), Moldova, Netherlands, Russia, Scotland (2) and Spain. England, current European Champion country, is ranked second in the world (behind Russia) but had a disproportionately large number of players in the sample for two principal reasons: all five juniors are English because, in this category, the author wanted to use exclusively players whom he coaches, while the number of Russians included was greater than it appears since four of the players listed under other countries were born in the Soviet Union.

Subject participation

Sportsmen and women are known to be reluctant to participate in research studies, the completion of psychological instruments being at worst impossible and at best intrusive during competitive events. Kerr (1997) reviews several attempts to get around this difficulty, referring to the researcher's option "to re-create the natural conditions of real-life sports situations under controlled conditions in field experiments," but the natural conditions are those imposed by the competition. The author's approach to the problem has been somewhat different. As an elite chess player (comfortably meeting the conditions specified in the materials and methods section above), the author was aware of the fact that such players (a) recall every move of a competitive game for at least a few days, and usually a few weeks afterwards (in some cases permanently retaining in memory every move of every game they have ever played), (b) can recall most of their thoughts and feelings during a game, and (c) that the latter are neatly compartmentalized by the framework of the game (mean number of half-moves, or 'ply', per game covered by this research =84). Thus the author was certain that players would be able retrospectively to identify changes in arousal and hedonic tone and that these recollections, being compartmentalized, would probably be independent of outcome.

Because of the chess rating scale and the way in which games are recorded, chess offers psychologists an ideal task environment in which to study skilled performance. However, as noted by Charness (1991), chess does have its limitations as a model environment because of the difficulty of obtaining skilled chess players for research projects; the highly skilled practitioner is a rare commodity, a problem shared with other skill domains. In the present instance, this difficulty was fairly readily overcome by the author's unique combination of circumstances, being well-known to the leading players (as administrator, author, coach and player) and having ready access to them at many of the world's most important chess events through his professional involvement in chess (providing special chess display equipment, in the form of tournament quality wooden chess boards and sets which contain hidden electronics enabling the current board position to be displayed on screens in the playing hall, press room, and to be transmitted directly to internet sites).

State dominance

Since elite chess players have to endure very high levels of stress (Hollinsky et. al, 1997) and various studies (as reported by Kerr, 1990) have shown that paratelic dominant individuals were adversely affected by the absence of stressors in their everyday lives and actually thrived on moderate amounts of stress, one might expect to find a preponderance of paratelic dominant individuals in the upper reaches of the chess rating list. In fact the results (see Table 4) pointed (albeit without statistical significance) in the opposite direction, two thirds of professional players being telic dominant, while it was the amateurs, also by a majority of approximately 2-1, who demonstrated paratelic dominance. This was unexpected. The author hopes to pursue this research further and, gradually increasing the sample size, establish whether there is any significance in this initial finding.

Reversals

The data strongly supports the first hypothesis (that reversals between the telic and paratelic states would occur during chess games and that these reversals could, in the case of elite players, be measured and located precisely within the time-frame of the game). One might even say that the data confirmed the existence of reversals, were it not for the fact that some members of the Reversal Theory community have expressed doubts about the wording of the CHEAS form, especially use of 'calm' (which has strong telic associations and so is not entirely appropriate as a cue for hedonic tone). Both author and supervisor are of the opinion that this did not make any significant difference to the results obtained, but the fact that it could have done means that the data (on reversals) must be considered even more carefully than might otherwise have been the case. It is hoped that future research, with a modified form (currently under development), will confirm the results obtained, or perhaps clarify them, for it seems probable that any 'wording-induced reversals' would merely have muddied the waters.

Those results recorded no fewer than 123 reversals (more than enough to establish their existence, even if a few of them were 'wording-induced'), and these were independent of outcome and almost all other variables. Reversals, as predicted by the theory, could (and did) occur in all stages of games, whether of short or long duration. It is unsurprising that rather more (but not statistically significant) reversals should occur in longer games than in shorter ones, especially since the majority of these games were played in front of an audience as one of a number of games going on at the same time and the longer the game, the more likely it is to become the sole object of attention (as the other games finish) for all of the spectators, which social impact theory would predict to place comparatively more pressure on the remaining players (Latané, 1981).

If one accepts that reversals do, indeed, occur, the next questions to be addressed are why?, when? and how? Examination of the data suggests some tendencies and lines for further research.

Almost three quarters of the reversals recorded were 'triggered' by a change in hedonic tone (rather than by a change in level of arousal). It is in this way that Reversal Theory provides a neat theoretical model for what happens in the course of a chess game. Players, typically, spend most of the game in a state of high arousal, constantly scanning the board position for signs of danger. If the course of the game is satisfactory (or better) then a player will, normally, be enjoying an emotional high (excitement). This state may be unaffected even by the emergence of dangers on the board, provided that they have been foreseen. Suddenly, a previously unsuspected danger is perceived and the player's way of looking at the world changes, and what had been a very pleasant emotional high reverses into a state of anxiety (c.f. Jones, 1991, as mentioned in the Introduction). See below for a consideration of a physiologically-based interpretation of this which may still fit in with the theory.

Performance

Of the performance determinants (information-processing rate, expertise and error commission/avoidance under competitive stress), only that of error commission was measured by this research. Since the whole of this research is based upon the assumption (established in the literature, but never previously demonstrated) that the outcome of chess games is determined by the occurrence of error (in move choice and even, occasionally, in implementation of a chosen move), it was comforting to find that the data entirely supported this view (Table 3 above). In particular the data provides support for the view that if a player does not make a mistake then it is not possible to lose (O'Connell, 1997b). The very similar view, that a player who makes a large mistake will almost certainly not win, and is likely to lose (although a game can degenerate into a contest of errors, with only the last being decisive for outcome), is also strongly supported by the data (c.f. Tartakower, 1924).

Analysis of error

When looking for errors it is important to use multiple checking systems. Woods (1984) reviewed data from 99 test scenarios in which experienced nuclear power plant operators were exposed to a number of simulated plant failures. Nearly two-thirds of all errors went undetected, being corrected only through the intervention of some external agent. Although the subjects were asked to indicate errors on the response form at the time of interview, all games were subsequently independently checked for error both by human and by machine (Fritz 4, winner of the 1995 World Computer Championship ahead of IBM's Deep Blue, assisted work on this project by checking all games for errors). The machine, in particular, and as expected, proved adept at revealing unsuspected errors.

The definition of error, for this research, is a move which changes the assessment of the position by at least one interval along the Likert-like positional evaluation scale (in purely material terms, equivalent to something between 0.5 and 0.9 of a pawn).

Types of error

All three categories of error (SB=5, RB=22, KB=13) were present in the data. There are good theoretical reasons for expecting that the data should follow a particular pattern.

Serious players, especially those that have received any coaching (and this would apply probably to every one of the professional players, and most of the amateurs as well), use a variety of attentional checks to minimize the occurrence of SB errors (O'Connell, 1997b). As would be expected, the quantity of SB errors was small. Those errors were also evenly distributed between professionals and amateurs.

RB errors, on the other hand, were largely concentrated (almost 3-1) in the hands of the amateurs. This, also, would be expected from what is known about how chess players achieve and then demonstrate their skill, their expertise being enshrined largely in a highly developed set of move sequences and, especially, 'rules' and patterns. It is by having access to these 'rules' that players are able both to eliminate much of the calculation conducted by chess-playing computer programs and also to enable accurate assessment of those positions which are calculated. All previous research work in the field (since de Groot, 1946) has demonstrated that professionals have a better developed set of these 'rules' than do amateurs.

More than twice as many KB errors were committed by professionals than by amateurs (9-4). This data also sits comfortably with Reason's GEMS model. Amateurs comparatively rarely proceed past the point at which (correctly-applied) stored rules are adequate to solve a problem and into the area of uncharted waters where KB mistakes take over.

Size of error

Determining the size of an error in chess is relatively easy and may be accurately measured on the chess position evaluation scale. Not only does the objectivity appeal, in comparison with at least some subjective information required to establish the category of each case, but the measurements can readily be verified independently, both by human and by machine (as was done in this research).

It was hardly surprising that the results showed a highly statistically significant link between the size of error and outcome. Given a free choice any player would choose not to make any error at all and, failing that, to keep both size and frequency to a minimum, thus maximizing performance.

Causes of error

It has been suggested that working memory may be considered to be a set of specialized short term memory systems (articulatory loop and visuospatial sketchpad), coordinated by a central executive (Baddeley, 1986). Several studies have shown that it is possible to dissociate and disrupt different components of working memory (Baddeley & Hitch, 1974; Baddeley, 1986). A recent study (Robbins et. al, 1996) involved three experiments to compare the effects of blocking the auditory loop, the visuospatial sketchpad and the central executive on memory for briefly exposed chess positions. This is one possibility for the cause of the errors which occurred (most likely SB and RB mistakes) but does not readily fit in with the apparent dependence of error upon reversal.

Very high levels of heart rate (220/min and more) and large increases in the secretion of noradrenaline (200% and more) have been correlated with elementary errors made by semi-elite players (Ra 2159) in competitive play (Hollinsky et. al, 1997). Although the precise mechanism is unknown, it is possible to combine Hollinsky et. al's findings with those of Ruggiero & Feinstein (1996), into a speculative hypothesis that high levels of noradrenaline (the ganglionic neurotransmitter in the sympathetic nervous system) excite the cardiac muscle to increase blood flow and that the feed-back to the hierarchic regulation of the ANS (especially the neurons involved in complex panmodal afferent processing, which include those encoding conscious perceptions such as self-awareness and patterns of emotional expression) could thereby effect changes in perception, which might equate to the very change in hedonic tone which triggers three quarters of the reversals associated with error in professional players (at least as represented by the data in this research).

Conclusion

Although the results obtained clearly support both stated hypotheses, the research needs to be re-confirmed using a CHEAS form, the wording of which would not be open to criticism. It would also be desirable to have independent verification of the self-reported levels of arousal, an objective which, with modern telemetric technology, should soon be achievable even within the very strict confines of what professional players consider to be acceptable.

Since the data suggests that errors are more likely to occur following a reversal from paratelic to telic, perhaps it would be beneficial to reverse back as quickly as possible. Chess players and coaches might find it profitable to investigate the possibilities for using cognitive intervention methods to enable players to monitor state and to engineer reversals as appropriate during the course of a game.

Acknowledgements

I owe the greatest debt to my subjects, many of whom I am delighted to say remain my friends despite having been invited to fill in the protocols, while the rest remain friendly acquaintances. The full list of the "invitees" is, in alphabetical order: Michael Adams, Viswanathan Anand, Evgenny Bareev, Victor Bologan, Suzanne Connolly, Kevin Denny, Terence Farley, Boris Gelfand, Mark Heidenfeld, Artur Jussupow, Bogdan Lalic, Susan Lalic, Steve Mannion, Paul Motwani, Predrag Nikolic, Mairead Ni Siochru (now Mairead King), John Nunn, Nicholas Pert, Richard Pert, Jeroen Piket, Edmund Player, Ian Rogers, Alexei Shirov, Nigel Short, Jonathan Speelman, Veselin Topalov, Jack Waller and Laurie Waller.

I am also indebted to my supervisor, Dr Murray Griffin, for introducing me to the world of Reversal Theory and its father and grandfather, Professor Michael Apter and Dr K.C.P. Smith respectively.

References

Andreassi, J.I. (1995). *Psychophysiology: Human Behavior and Physiological Response*, 3rd ed. (p. 346). Hillsdale, N.J.: Lawrence Erlbaum Associates.

Apter, M.J. (1982). *The Experience of Motivation: The Theory of Psychological Reversals.* London: Academic Press.

Apter, M.J. (1989). *Reversal Theory: Motivation, Emotion and Personality.* London and New York: Routledge.

Apter, M.J. (1997). *Reversal Theory as a Set of Propositions.* Keynote address to the Eighth International Conference on Reversal Theory, University of East London.

Binet, A. (1894). *Psychologie des grands calculateurs et joueurs d'échecs.* Geneva, Paris: Slatkine (1981 reproduction).

Charness, N. (1991). Expertise in chess: the balance between knowledge and search. In K.A. Ericsson & J. Smith (Eds.), *Toward a General Theory of Expertise: Prospects and Limits.* Cambridge: Cambridge University Press.

Chase, W.G. & Simon, H.A. (1973). Perception in chess. In *Cognitive Psychology, 4*: 55-81.

Cox, T., & Mackay, C. (1985). The measurement of self-reported stress and arousal. In *British Journal of Psychology*, 76: 183-186.

De Groot, Adriaan D (1946). *Het denken van den Schaker*. Amsterdam: North-Holland.

De Groot, Adriaan D (1965). *Thought and Choice in Chess*. The Hague and Paris: Mouton.

de Vaus, D.A. (1996). *Surveys in Social Research*, 4th ed. London: UCL Press.

Elo, A.E. (1978). *The Rating of Chessplayers, Past and Present*. London: Batsford.

Elo, A.E. & Talacko, J. (1966). *Use of the Standard Sigmoid and Logistic Curves in Pairwise Comparisons*. Paper presented at Symposium on Biomedical Engineering, Marquette University, Milwaukee.

FIDE (1997). *International FIDE Rating List, July 1997*. Lausanne: Fédération Internationale des Echecs.

Fontana, D. (1981). Reversal theory, the paratelic state, and Zen. In *European Journal of Humanistic Psychology*, 9: 229-236.

Fontana, D. (1991). Reversals and the Eastern religious mind. In J.H. Kerr & M.J. Apter (Eds.), *Adult play: a reversal theory approach* (pp. 141-150). Amsterdam: Swets &

Zeitlinger.

Frey, K.P. (1997). About reversal theory. In S. Svebak & M.J. Apter (Eds.) *Stress & Health: A Reversal Theory Perspective.* Washington, D.C. & London: Taylor & Francis.

Gallwey, W.T. (1975). *The Inner Game of Tennis.* London: Jonathan Cape.

Griffin, M. (1994). An analysis of social facilitation phenomena: the role of reversal theory and inferred monitoring. PhD thesis, University of London Goldsmiths' College.

Griffin, M. & O'Connell, K.J. (1997). *Evidence for Metamotivational Reversals in Elite Chess Players.* Paper presented at Eighth International Conference on Reversal Theory, University of East London.

Hebb, D.O. (1955). Drives and the C.N.S. (conceptual nervous system). In *Psychological Review*, 62: 243-254.

Holding, D.H. (1985). *The Psychology of Chess Skill.* Hillsdale, N.J.: Lawrence Erlbaum Associates.

Hollinsky, C., Maresch, G., Hiller, M., Kohlberger, P., & Biegelmayer, C. (1997). An investigation into the influence of physical fitness on the performance of league-ranking chess players. In *FIDE Forum*, 11, 3: 15-19.

Jones, (J.) G. (1991). Stress and Anxiety. In Bull, S.J. (ed.) *Sport Psychology: A Self-Help Guide*. Ramsbury, Wilts: The Crowood Press.

Kerr, J.H. (1985). The experience of arousal: a new basis for studying arousal effects in sport. In *Journal of Sports Sciences*, 3: 169-179.

Kerr, J.H. (1987a). Differences in the motivational characteristics of "professional", "serious amateur" and "recreational" sports performers. In *Perceptual and Motor Skills*, 64: 379-382.

Kerr, J.H. (1987b). Cognitive intervention with elite performers: reversal theory. In *British Journal of Sports Medicine*, 21, 2: 29-33.

Kerr, J.H. (1990). Stress and sport: reversal theory. In G. Jones and L. Hardy (Eds.), *Stress and Performance in Sport*. Chichester: Wiley.

Kerr, J.H. (1993). An eclectic approach to psychological interventions in sport: Reversal theory. In *The Sport Psychologist*, 7: 400-418.

Kerr, J.H. (1997). *Motivation and Emotion in Sport: Reversal Theory*. Hove: Psychology Press.

Kerr, J.H. & Svebak, S. (1989). Motivational aspects of preference for, and participation in, 'risk' and 'safe' sports. In *Personality and Individual Differences*, 10,7: 797-800.

King, D. (1997). *Kasparov v Deeper Blue.* London: B.T. Batsford.

King, M., Stanley, G. & Burrows, G. (1987). *Stress: Theory and Practice.* London: Grune and Stratton.

Kotov, A. (1971). *Think Like a Grandmaster.* London: Batsford.

Lacey, J.I. (1959). Psychophysiological approaches to the evaluation of psychotherapeutic processes and outcome. In E.A. Rubinstein & M.B. Parloff (Eds.), *Research in psychotherapy* (pp. 173-192). Washington, D.C.: American Psychological Association.

Latané, B. (1981). Psychology of social impact. In *American Psychologist*, 36: 343-356.

Levitt, J. (1997). *Genius in Chess: Discover and develop your talent.* London: Batsford.

Levy, D. & O'Connell, K. (1981). *Oxford Encyclopedia of Chess Games: Volume 1, 1485-1866.* Oxford: Oxford University Press.

Mackay, C., Cox, T., Burrows, G., & Lazzerini, T. (1978). An inventory for the measurement of self-reported stress and arousal. In *British Journal of Social and Clinical Psychology*, 17: 283-284.

Males, J.R. (1995). *Helping athletes perform: Integrating reversal theory and* *psychosynthesis in applied sport psychology.* Paper presented at the 7th International Conference on Reversal Theory, Melbourne, Australia.

McCarthy, J. (1990). Chess as the drosophila of AI. In T,A. Marsland & J. Schaeffer (Eds.) *Computers, Chess and Cognition.* New York: Springer-Verlag.

Michie, D. (1980). Chess with computers. In *Interdisciplinary Science Reviews,* 5, 3: 215-227.

Murgatroyd, S. & Apter, M.J. (1984). Eclectic psychotherapy: a structural phenomenological approach. In W. Dryden (Ed.), *Individual Psychotherapy in Britain,* pp.389-414. London: Harper & Row.

Murgatroyd, S., Rushton, C., Apter, M.J., & Ray, C. (1978). The development of the Telic Dominance Scale. In: *Journal of Personality Assessment, 42:* 519-528.

Neiss, R. (1990). Ending arousal's reign of error: A reply to Anderson. In *Psychological Bulletin*, 107, 1: 101-105.

O'Connell, K.J. (1995). ChessBase pour Windows. In *Europe Echecs*, 439: 32-34.

O'Connell, K.J. (1996a). Fritz4. In *Europe Echecs*, 449: 16-17.

O'Connell, K.J. (1996b). Performance Anxiety an Important Part of Sport. MSc paper, University of Essex.

O'Connell, K.J. (1997a). Vive les échecs multimédia. In *Europe Echecs,* 454: 8-9.

O'Connell, K.J. (1997b). Avoiding error. In *East Anglian Daily Times*, 29 July 1997.

Purdy, C.J.S. (1931). A system to reduce errors. In *The Australasian Chess Review,* reprinted in J. Hammond & R. Jamieson (Eds.), *C.J.S. Purdy: His Life, his Games and his Writings*, Melbourne: John Hammond, 1982.

Rasmussen, J. (1981). Models of mental strategies in process plant diagnosis. In J. Rasmussen & W. Rouse (Eds.), *Human Detection and Diagnosis of System Failures.* New York: Plenum.

Rasmussen, J., & Jensen, A. (1974). Mental procedures in real-life tasks: A case study of electronic troubleshooting. In *Ergonomics,* 17: 293-307.

Reason, J. (1990). *Human Error.* Cambridge: Cambridge University Press.

Ruggiero, D.A., & Feinstein, D.L. (1996). The autonomic nervous system. In S. Mraovitch & R. Sercombe (Eds.) *Neurophysiological Basis of Cerebral Blood Flow Control.* London: John Libbey.

Smith, K.C.P. & Apter, M.J. (1975). *A Theory of Psychological Reversals.* Chippenham:

Picton Publishing.

Summers, J. & Stewart, E. (1993). The arousal performance relationship: Examining different conceptions. In S. Serpa, J. Alves, V. Ferriera, & A. Paula-Brito (Eds.), *Proceedings of the VIII World Congress of Sport Psychology* (pp. 229-232). Lisbon: International Society of Sport Psychology.

Svebak, S., & Murgatroyd, S. (1985). Metamotivational dominance: a multimethod validation of reversal theory constructs. In: *Journal of Personality and Social Psychology, 48, 1:* 107-116.

Tartakower, S.G. (1924). *Die Hypermoderne Schachpartie.* Vienna: Wiener Schachzeitung.

Tikhomirov, O.K., & Vinogradov, Y.E. (1970). Emotions in the heuristic function. In *Soviet Psychology*, 8: 198-203.

Wilkinson, R.T. (1964). Effects of up to 60 hours' sleep deprivation on different types of work. *Ergonomics,* 7: 175-186.

Woods, D.D. (1984). Some results on operator performance in emergency events. In *Institute of Chemical Engineers Symposium Series,* 90: 21-31.

Yerkes, R.M. & Dodson, J.D. (1908). The relation of strength of stimulus to rapidity of habit formation. In *Journal of Comparative Neurology of Psychology*, 18: 459-482.

Zajonc, R.B. (1965). Social Facilitation. In *Science*, 149: 269-274.

Appendix A

TDS

The TDS form itself is shown on pages 56-59. Here is a brief description of the scoring mechanism.

The Seriousmindedness (defining) scale measures how frequently a subject is in a state oriented towards serious ends (telic) rather than paratelic ones (playful enjoyment of ongoing sensations or skills). Specific questions, with the telic answer indicated (a not sure counts .5) relate to the three subscales in the following manner:

Seriousmindedness:

13 b	14 b	16 b	17 a	22 b	23 b	24 b
28 a	29 b	31 a	33 b	37 a	38 b	39 a

Planning orientation:

1 a	2 a	4 b	6 a	7 a	8 a	10 a
20 b	25 a	26 a	27 b	32 b	41 a	42 a

Arousal avoidance:

3 b	5 b	9 a	11 a	12 a	15 b	18 b
19 a	21 a	30 b	34 a	35 a	36 a	40 b

The survey subjects scores on the TDS are given in Table 12 overleaf.

	Professionals					Amateurs		
Serious	Planning	Arousal	Total		Serious	Planning	Arousal	Total
0.5	2.5	10	13		2	6.5	5	13.5
2	5	4.5	11.5		3.5	5	5.5	14
4	8	8	20		4.5	8	5	17.5
4.5	3	4.5	12		4.5	7.5	4.5	16.5
5	6	5.5	16.5		5	8	7	20
6	7	6	19		5.5	8.5	9	23
6	6	8.5	20.5		7.5	11	8.5	27
6.5	4	2	12.5		7.5	8	7	22.5
7	6.5	6	19.5		9.5	10	6.5	26
7	8	7	22		5	6	3.5	14.5
7	9.5	10	26.5		4	6	5.5	15.5
8	7.5	6	21.5					
9	7	7	23					
9	8.5	9.5	27					
11	8	11	30					

Table 12: scores of the 26 players who completed the TDS

Confidential

THE TELIC DOMINANCE SCALE (TDS)

FORM A3

NAME .... SEX ....

OCCUPATION .... AGE ....

Instructions

Here are some short questions. If you have an open choice, which of the following alternatives would you usually prefer. Please complete **all** the items by putting a cross in the circle corresponding to your choice, making one choice for each numbered item. Only if you are not able to make a choice should you put a cross in the circle corresponding to 'Not sure'. Try to answer all of the items by putting a cross in one of the circles for each item, using the 'Not sure' choice as little as you can. Work quickly and do not spend too much time on any one item: it is your first reaction we want.

Now turn over the page and start. This is not a test of intelligence or ability and there are no right or wrong answers.

For further information about this scale, contact:

Dr. M.J. Apter
Psychology Department,
University College, Cardiff,
P.O. Box 78,
Cardiff CF1 1XL,
Wales, U.K.

Do not write in this space

S = [ ] P = [ ] A = [ ]

Total: [ ]

1. Compile a short dictionary for financial reward ○
Write a short story for fun ○
Not sure ○

2. Going to evening class to improve your qualifications ○
Going to evening class for fun ○
Not sure ○

3. Leisure activities which are just exciting ○
Leisure activities which have a purpose ○
Not sure ○

4. Improving a sporting skill by playing a game ○
Improving it through systematic practice ○
Not sure ○

5. Spending one's life in many different places ○
Spending most of one's life in one place ○
Not sure ○

6. Work that earns promotion ○
Work that you enjoy doing ○
Not sure ○

7. Planning your leisure ○
Doing things on the spur of the moment ○
Not sure ○

8. Going to formal evening meetings ○
Watching television for entertainment ○
Not sure ○

9. Having your tasks set for you ○
Choosing your own activities ○
Not sure ○

10. Investing money in a long term insurance/ pension scheme ○
Buying an expensive car ○
Not sure ○

11. Staying in one job ○
Having many changes of job ○
Not sure ○

12. Seldom doing things "for kicks" ○
Often doing things "for kicks" ○
Not sure ○

13. Going to a party ○
Going to a meeting ○
Not sure ○

14. Leisure activities ○
Work activities ○
Not sure ○

15. Taking holidays in many different places ○
Taking holidays always in the same place ○
Not sure ○

16. Going away on holiday for two weeks ○
Given two weeks of free time finishing a needed improvement at home ○
Not sure ○

17. Taking life seriously
    - Treating life light-heartedly
    - Not sure

18. Frequently trying strange foods
    - Always eating familiar foods
    - Not sure

19. Recounting an incident accurately
    - Exaggerating for effect
    - Not sure

20. Spending £100 having an enjoyable weekend
    - Spending £100 on repaying a loan
    - Not sure

21. Having continuity in the place where you live
    - Having frequent moves of house
    - Not sure

22. Going to an art gallery to enjoy the exhibits
    - To learn about the exhibits
    - Not sure

23. Watching a game
    - Refereeing a game
    - Not sure

24. Eating special things because you enjoy them
    - Eating special things because they are good for your health
    - Not sure

25. Fixing long-term life ambitions
    - Living life as it comes
    - Not sure

26. Always trying to finish your work before you enjoy yourself
    - Frequently going out for enjoyment before all your work is finished
    - Not sure

27. Not needing to explain your behaviour
    - Having purposes for your behaviour
    - Not sure

28. Climbing a mountain to try to save someone
    - Climbing a mountain for pleasure
    - Not sure

29. Happy to waste time
    - Always having to be busy
    - Not sure

30. Taking risks
    - Going through life safely
    - Not sure

31. Watching a crucial match between two ordinary sides
    - Watching an exhibition game with star performers
    - Not sure

32. Playing a game . . . . ○
Organising a game . . . . ○
Not sure . . . . ○

33. Glancing at pictures in a book . . . . . . ○
Reading a biography . . . . ○
Not sure . . . . ○

34. Winning a game easily . . . . ○
Playing a game with the scores very close . . ○
Not sure . . . . ○

35. Steady routine in life . . . . ○
Continual unexpectedness or surprise . . . ○
Not sure . . . . ○

36. Working in the garden . . . . ○
Picking wild fruit . . . . ○
Not sure . . . . ○

37. Reading for information . . . . ○
Reading for fun . . . . ○
Not sure . . . . ○

38. Arguing for fun . . . . ○
Arguing with others seriously to change their opinions. . . . . ○
Not sure . . . . ○

39. Winning a game . . . . ○
Playing the game for fun . . . . ○
Not sure . . . . ○

40. Travelling a great deal in one's job . . . . . ○
Working in one office or workshop . . . . . ○
Not sure . . . . ○

41. Planning ahead . . . . ○
Taking each day as it comes . . . . ○
Not sure . . . . ○

42. Planning a holiday . . . . ○
Being on holiday . . . . ○
Not sure . . . . ○

PLEASE MAKE SURE
YOU HAVE ANSWERED ALL THE QUESTIONS

Appendix B
The CHEAS Form

The basic outline of the CHEAS form (shown on p.62) consists of four columns.

The first column has numbered lines ready for the insertion of the white and black (n ...) moves of a chess game. Every significant chess game ever played has been recorded using a form of standard chess notation.

The second column is essentially a seven point Likert scale for the positional evaluation of the game. Read from left to right the seven positional symbols (familiar to any serious chess player) indicate a winning advantage for White, a large advantage for White, a small advantage for White, approximate equality, a small advantage for Black, a large advantage for Black, and a winning advantage for Black. Elite chess players are not only familiar with such symbols, they are also accustomed to assessing each and every position that arises on the chess board (and also the many hundreds or thousands of positions that do not actually arise on the board but which are visualized in the course of a game).

The third and fourth columns are for the measurement of reversal theory constructs. Originally seven point Likert scales (as illustrated on p.62), they were changed, following the pilot study, to six point Likert scales to make it essentially impossible for the respondents to choose the mid-point on the scale; this was important because, for coding purposes, it was essential to determine on which side of the mid-point the respondent was for any given move. The third column is for the measurement of arousal, from high (energetic, wide awake) to low (tired, sleepy). The fourth column is intended to measure hedonic tone, either pleasant (calm, comfortable) or unpleasant (emotional, uncomfortable). The outcomes of the third and fourth columns of the form can then be plotted against the standard telic/paratelic model (Fig.2 above) to determine state for any particular move.

Table 13: The CHEAS form

								energised						flat	happy						sad
	++-	+-	+=	=	=+	-+	-++	charged up			=			tired	comfortable			=	uncomfortable		
1																					
1...																					
2																					
2...																					
3																					
3...																					
4																					
4...																					
5																					
5...																					
6																					
6...																					
7																					
7...																					
8																					
8...																					
9																					
9...																					
10																					
10...																					
11																					
11...																					
12																					
12...																					
13																					
13...																					
14																					
14...																					
15																					
15...																					
16																					
16...																					
17																					
17...																					
18																					
18...																					
19																					
19...																					
20																					
20...																					
21																					
21...																					
22																					
22...																					
23																					
23...																					
24																					
24...																					
25																					
25...																					
26																					
26...																					
27																					
27...																					
28																					
28...																					
29																					
29...																					
30																					
30...																					

How well do you consider you performed by your own standards?
(Please circle the appropriate point on the scale below - where average means *your* average)

well below average | below average | average | above average | well above average

Appendix C
Statistics (original crosstabulations)

Index of variables in the following tables:

AROUSAL	Level of arousal	1 Hi	2 Medium	3 Lo
CAT	Category of player	1 Professional	2 Amateur (inc. junior)	
DIR	Direction of reversal	1 to telic	2 to paratelic	
ERR	Error	number		
ERRLOHI	Error	0 none	1 one	2 two or more
MODE	Modal state	1 telic	2 paratelic	
RES	Outcome	1 win	2 draw	3 loss
REV	Reversal	1 yes	2 no	
SIZE	Size of error	0 none	1 small	2 big
SMALLBIG	Size of error (exc.0)	1 small	2 big	
START	Start state	1 telic	2 paratelic	
TDS	Telic dominance	1 telic	2 paratelic	9 unknown
TDS2	TDS (exc. unknown)	1 telic	2 paratelic	
TRIGGER	Trigger of reversal	1 arousal	2 hedonic tone	
TYPE	Type of error	1 SB	2 RB	3 KB
WHEN	When do errors occur?	1 error before reversal	2 error after reversal	

Table 14:
CAT by TDS

CAT \ TDS (Count)	1.00	2.00	Row Total
1.00	10	5	15 57.7
2.00	4	7	11 42.3
Column Total	14 53.8	12 46.2	26 100.0

- Chi-Square	Value	DF	Significance
Pearson	2.34488	1	.12570

Table 15
RES by ERR

RES	none	1	2	3	Total
Win	32	7			
Draw	7	23	7	4	
Loss		7	13		

100% (n=44; p<.00001)

Table 16
RES by SIZE

SIZE Page 1 of 1

RES (Count)	.00	1.00	2.00	Row Total
1.00	14	3		17
				38.6
2.00	3	9	6	18
				40.9
3.00		5	4	9
				20.5
Column	17	17	10	44
Total	38.6	38.6	22.7	100.0

Phi	.73800	.00008
Cramer's V	.52184	.00008

Table 17

SMALLBIG by TYPE

TYPE — Page 1 of 1

SMALLBIG (Count)	TYPE 1.00	TYPE 2.00	TYPE 3.00	Row Total
1.00	5	17	7	29 72.5
2.00		5	6	11 27.5
Column Total	5 12.5	22 55.0	13 32.5	40 100.0

Phi	.33229	.10988 *1
Cramer's V	.33229	.10988 *1

Table 18

RES by TYPE

TYPE — Page 1 of 1

RES (Count)	TYPE 1.00	TYPE 2.00	TYPE 3.00	Row Total
1.00	1	1	1	3 7.5
2.00	2	14	6	22 55.0
3.00	3	6	6	15 37.5
Column Total	6 15.0	21 52.5	13 32.5	40 100.0

Phi	.27639	.54856 *1
Cramer's V	.19544	.54856 *1

Table 19
REV by AROUSAL

REV \ AROUSAL (Count)	1.00	2.00	3.00	Row Total
1.00	13	21	2	36 81.8
2.00	2	3	3	8 18.2
Column Total	15 34.1	24 54.5	5 11.4	44 100.0

Page 1 of 1

Phi	.38834	.03623 *1
Cramer's V	.38834	.03623 *1

Table 20
DIR by TRIGGER
Controlling for..
TDS Value = 1.00

DIR \ TRIGGER (Count)	1.00	2.00	Row Total
1.00	6	24	30 50.8
2.00	11	18	29 49.2
Column Total	17 28.8	42 71.2	59 100.0

Page 1 of 1

Chi-Square	Value	DF	Significance
Pearson	2.31145	1	.12842

Table 21
DIR by TRIGGER
Controlling for..
TDS Value = 2.00

DIR \ TRIGGER (Count)	1.00	2.00	Row Total
1.00	9	24	33 51.6
2.00	9	22	31 48.4
Column Total	18 28.1	46 71.9	64 100.0

Page 1 of 1

Chi-Square	Value	DF	Significance
Pearson	.02448	1	.87567

Table 22
REV by TDS

Count	TDS 1.00	TDS 2.00	TDS 9.00	Row Total
REV 1.00	16	17	3	36
				81.8
REV 2.00	4	4		8
				18.2
Column Total	20	21	3	44
	45.5	47.7	6.8	100.0

Page 1 of 1

Statistic	Value	ASE1	T-value	Approximate Significance
Phi	.12807			.69709 *1
Cramer's V	.12807			.69709 *1

*1 Pearson chi-square probability

Table 23
REV by CAT

Count	CAT 1.00	CAT 2.00	Row Total
REV 1.00	18	18	36
			81.8
REV 2.00	4	4	8
			18.2
Column Total	22	22	44
	50.0	50.0	100.0

Page 1 of 1

Chi-Square	Value	DF	Significance
Pearson	.00000	1	1.00000

Table 24
REV by START

Count	START 1.00	START 2.00	Row Total
REV 1.00	14	22	36
			81.8
REV 2.00	2	6	8
			18.2
Column Total	16	28	44
	36.4	63.6	100.0

Page 1 of 1

Chi-Square	Value	DF	Significance
Pearson	.54563	1	.46011

Table 25
REV by ERR

ERR — Page 1 of 1

REV (Count)	.00	1.00	2.00	3.00	Row Total
1.00	16	11	8	1	36 81.8
2.00	1	5	1	1	8 18.2
Column Total	17 38.6	16 36.4	9 20.5	2 4.5	44 100.0

Chi-Square	Value	DF	Significance
Pearson	5.22914	3	.15577

Table 26
REV by MODE

MODE — Page 1 of 1

REV (Count)	1.00	2.00	Row Total
1.00	13	23	36 81.8
2.00	2	6	8 18.2
Column Total	15 34.1	29 65.9	44 100.0

Chi-Square	Value	DF	Significance
Pearson	.35964	1	.54870

Table 27
REV by ERRLOHI

ERRLOHI — Page 1 of 1

REV (Count)	.00	1.00	2.00	Row Total
1.00	16	11	9	36 81.8
2.00	1	5	2	8 18.2
Column Total	17 38.6	16 36.4	11 25.0	44 100.0

Statistic	Value	ASE1	T-value	Approximate Significance
Phi	.28467			.16817 *1
Cramer's V	.28467			.16817 *1

Table 28
SMALLBIG by CAT

Count	CAT 1.00	2.00	Row Total
SMALLBIG 1.00	11	18	29 72.5
2.00	7	4	11 27.5
Column Total	18 45.0	22 55.0	40 100.0

Page 1 of 1

.14452

Table 29
SMALLBIG by TDS2

Count	TDS2 1.00	2.00	Row Total
SMALLBIG 1.00	9	18	27 71.1
2.00	7	4	11 28.9
Column Total	16 42.1	22 57.9	38 100.0

Page 1 of 1

Pearson	2.94421	1	.08619

Table 30
SMALLBIG by REV

Count	REV 1.00	2.00	Row Total
SMALLBIG 1.00	20	9	29 72.5
2.00	10	1	11 27.5
Column Total	30 75.0	10 25.0	40 100.0

Page 1 of 1

Pearson	2.04807	1	.15240

Table 31
TYPE by CAT

TYPE	CAT: 1.00	2.00	Row Total
1.00	3	3	6
			15.0
2.00	6	15	21
			52.5
3.00	9	4	13
			32.5
Column Total	18	22	40
	45.0	55.0	100.0

Count; Page 1 of 1

Phi	.36860	.06605 *1
Cramer's V	.36860	.06605 *1

Table 32
TYPE by TDS2

TYPE	TDS2: 1.00	2.00	Row Total
1.00	3	3	6
			15.8
2.00	6	14	20
			52.6
3.00	7	5	12
			31.6
Column Total	16	22	38
	42.1	57.9	100.0

Count; Page 1 of 1

Phi	.26418	.26553 *1
Cramer's V	.26418	.26553 *1

Table 33
TYPE by REV

TYPE	REV: 1.00	2.00	Row Total
1.00	2	4	6
			15.0
2.00	15	6	21
			52.5
3.00	13		13
			32.5
Column Total	30	10	40
	75.0	25.0	100.0

Count; Page 1 of 1

Phi	.50079	.00663 *1
Cramer's V	.50079	.00663 *1

Table 34
WHEN by DIR

WHEN \ DIR	>T	>P
Err before Rev	17	7
Err after Rev	63	13

100% (n=30; p<.51731)

Table 35
WHEN by DIR
Controlling for CAT = Professional

WHEN \ DIR	>T	>P
Err before Rev	8	15
Err after Rev	77	

100% (n=13; p<.00500)

Table 36
WHEN by DIR
Controlling for CAT = Amateur

WHEN \ DIR	>T	>P
Err before Rev	24	
Err after Rev	52	24

100% (n=17; p<.20457)