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Individual differences in chess expertise: A psychometric investigation

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Abstract

Starting from controversies over the role of general individual characteristics (especially intelligence) for the attainment of expert performance levels, a comprehensive psychometric investigation of individual differences in chess expertise is presented. A sample of 90 adult tournament chess players of varying playing strengths (1311–2387 ELO) was screened with tests on intelligence and personality variables; in addition, experience in chess play, tournament participation, and practice activities were assessed. Correlation and regression analyses revealed a clear-cut moderate relationship between general (and in particular numerical) intelligence and the participants' playing strengths, suggesting that expert chess play does not stand in isolation from superior mental abilities. The strongest predictor of the attained expertise level, however, was the participants' chess experience which highlights the relevance of long-term engagement for the development of expertise. Among all analysed personality dimensions, only domain-specific performance motivation and emotion expression control incrementally contributed to the prediction of playing strength. In total, measures of chess experience, current tournament activity, intelligence, and personality accounted for about 55% of variance in chess expertise. The present results suggest that individual differences in chess expertise are multifaceted and cannot be reduced to differences in domain experience.

PsycINFO classification: 3120; 3575; 2343

Keywords: Intelligence; Expertise; Chess; Practice; Personality

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1. Introduction

Chess is frequently called the "drosophila" of cognitive psychology, because it represents the domain in which expert performance has been most intensively studied (Simon & Chase, 1973). Decades of expertise research in chess have piled up an extensive body of empirical evidence concerning the cognitive mechanisms underlying superior chess play and, thus, have strongly contributed to today's theories and understanding of expertise. For instance, it has become a general notion that expert performance in basically all cognitive domains is mediated through a large, elaborate, and flexible knowledge base acquired during extensive domain-specific practice and training (Ericsson, 2005; Ericsson & Lehmann, 1996; Rikers & Paas, 2005; Simon & Chase, 1973). The application of this knowledge base even seems to allow experts to circumvent some general limitations of the human information processing system. As examples, experts can temporarily hold in mind vast amounts of information (e.g., up to 80 digits; Ericsson, Chase, & Faloon, 1980) or simultaneously play up to 50 chess games blindfolded (cf. Holding, 1985).

Despite a wide consensus on the indispensable role of domain-specific knowledge for expert performance, there are, however, controversies concerning the importance of general individual characteristics in moderating the attained performance level and the process of expertise acquisition. Besides the potential significance of various personality factors (for a review, cf. Charness, Tuffiash, & Jastrzembski, 2004), it is heavily discussed whether and to what extent expert performance is also a function of individual differences in intelligence (e.g., Brody, 1992; Ceci & Liker, 1986; Detterman & Ruthsatz, 1999; Ericsson, Krampe, & Tesch-Römer, 1993; Hambrick & Engle, 2002; Hambrick & Oswald, 2005; Masunaga & Horn, 2000; Ruthsatz & Detterman, 2003; Stern, 1994; Walker, 1987). Researchers on the domains of intelligence vs. expertise have often adopted antithetic positions in this context. While authors of prominent textbooks and reviews on expertise state that "IQ is either unrelated or weakly related to performance among experts …; factors reflecting motivation … are much better predictors of improvement" (Ericsson & Lehmann, 1996, p. 280), intelligence researchers point to the extensive corpus of findings demonstrating the high predictive validity of this construct for success in various areas of life (e.g., Jensen, 1998) and sometimes conclude that often-cited studies, in which no relationship between intelligence and expert performance was observed (e.g., in Ceci & Liker, 1986), are "too problematic and too limited in scope to support their far-reaching conclusions" (Brody, 1992, p. 48).

By pursuing a psychometric approach, the present investigation aims at providing new insights into the relationship between general individual characteristics (in particular intelligence), domain-specific variables, and the expertise level in the domain of chess (for another psychometric study, see Van der Maas & Wagenmakers, 2005).

1.1. Intelligence and chess expertise

The debate concerning the importance of intelligence has been particularly vivid in the classic expertise domain of chess because this game obviously places great intellectual demands on the players. Recently, Howard (1999, 2001, 2005) even interpreted the observation that the mean age of world-class chess players is progressively declining in the past decades as real-world evidence that human intelligence is rising (a view that has been severely criticised by Gobet, Campitelli, & Waters, 2002; see also Charness & Gerchak, 1996). In

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contrast to most other expertise domains, chess offers the great advantage of providing an objective and valid indicator of the players' expertise levels, viz. the ELO ranking system (Elo, 1978; see also Charness, 1992; Reynolds, 1992). ELO rankings typically range from 1200 (for a beginner in tournament chess) to the world champion's ranking of about 2800. Every time a player participates in an official tournament and wins against a stronger opponent, his or her ELO ranking slightly increases by a certain number of points (calculated as a difference function between the players' actual game results and the expected game results based on the player's own ELO ranking and those of his or her opponents); in the case of a defeat, the player's ELO ranking decreases. As the ELO ranking changes only marginally over time (in advanced players a change of about 10 points can be observed per tournament period of 6 months), a high ELO ranking reflects consistently achieved high performance, thus, perfectly conforming to common definitions of expertise as a relatively stable characteristic of an individual (Ericsson, 1996; Ericsson & Smith, 1991; Gobet, 2001; Gruber, 2001).

Studies investigating the relation between intelligence components and the attained expertise level in chess have drawn strikingly different pictures in children and in adults. For instance, Frank and D'Hondt (1979) trained adolescents in chess and found that the achieved playing strength could be predicted by the participants' spatial aptitude and numeric ability. Likewise, Horgan and Morgan (1990) observed a correlation (figural matrices) between reasoning performance in 15 child elite chess players and their playing strengths. Finally, testing 33 child tournament players with the Wechsler Intelligence Scale for Children (WISC), Frydman and Lynn (1992) observed scores significantly above average for general intelligence (mean IQ = 121) and the performance IQ (mean IQ = 129) but not for verbal intelligence (mean IQ = 109), and concluded that "high-level chess playing requires a good general intelligence and strong visuo-spatial abilities" (p. 235).

Reviewing the empirical evidence in adults, in contrast, one is tempted to agree with Gobet et al.'s (2002) statement: "Most importantly, we are not aware of a single study that has shown that more skilled chess players outperform less skilled chess players on any psychometric test." (p. 305). In fact, since the first investigation in the late 1920s, this issue was addressed explicitly by only a handful of studies. In their pioneering investigation, Djakow, Petrowski, and Rudik (1927) tested the intellectual abilities of eight grandmasters and found no evidence of above-average concentration ability, visuo-spatial memory or general intelligence in their sample. An unpublished investigation of Lane (mentioned in Cranberg & Albert, 1988, p. 161), who used a sample of players ranging from novices to strong amateurs, also failed to identify an association between chess skill and performance on a non-chess visuo-spatial task. Doll and Mayr (1987) have conducted the only comprehensive investigation of expert chess players' general intellectual abilities using psychometric measures so far. Twenty-seven chess experts (ELO rankings from 2220 to 2425) worked on two intelligence tests: (1) a test based on the Berlin Intelligence Structure Model (BIS; Jäger, 1982, 1984), measuring three content-related abilities (verbal, numerical, figural), four operational abilities (processing speed, memory, creativity, information processing capacity), and, as an integral of the former components, general intelligence; and (2) a part of Cattell's Culture Fair Intelligence Test (CFT-3; Weiss, 1971). Compared with reference samples, the chess players displayed significantly higher IQs for the BIS operational subscales *processing speed* ($M = 115.30$) and *information processing capacity* ($M = 114.20$) as well as for the content subscale *number* ($M = 116.40$). Moreover, the general intelligence scores of the BIS ($M = 106.50$) and the CFT-3 (no IQ scores indicated) were also significantly higher in the sample of chess experts. On the remaining subscales of the BIS (verbal,

$M = 103.60$; figural, $M = 104.50$; creativity, $M = 104.10$; and memory, $M = 100.40$) no significant effects were observed. Doll and Mayr additionally computed correlations between the scores in the intelligence tests and the ELO rankings but failed to find any significant effect which was traced back to the restricted variance in the players' ratings. The participants' superior performance in the information processing capacity scale was interpreted to reflect the skill of forward search (cf. Gobet, 1998; Holding, 1985); their superiority in numerical abilities was attributed to their experience with numerically coded chess positions and moves.

The most recent study of the relation between components of intelligence and chess expertise was conducted by Waters, Gobet, and Leyden (2002). They investigated visual memory ability in a sample of 36 tournament players whose playing strengths ranged from weak club players to strong grandmasters. Participants were presented two types of visual memory tasks: a modified version of the classic chess memory paradigm (requiring the reconstruction of briefly presented chess positions; cf. Chase & Simon, 1973a, 1973b) and a shape memory test, requiring the players to learn a configuration of shapes over 4 min and to recognise groups of learned shapes afterwards. As could be expected, the performance in the chess memory task correlated significantly ($r = .68$) with playing strength; shape memory performance, in contrast, was entirely unrelated to chess skill ($r = .03$). Thus, "at the very least, the data indicate that individuals can become exceptional chess players without having exceptional visual memory abilities." (Waters et al., 2002, p. 563).

1.2. Domain-specific experience and practice

Simon and Chase (1973) noted that nobody attains the level of an international chess master "with less than about a decade's intense preparation with the game" (p. 402). Supported by data from other expertise domains (for an overview, cf. Ericsson & Lehmann, 1996), Simon and Chase's *10-year rule* has become widely accepted as an estimate of the practice period necessary to achieve expert performance. However, an important finding in expertise research is that an investment of time alone does not guarantee expertise (Ericsson & Charness, 1994); instead, the individual has to engage in specific practice activities in order to considerably improve his or her performance.

Ericsson et al. (1993) introduced the term *deliberate practice*, comprising all those practice activities that are most effective in improving performance, highly effortful, and, thus, not inherently enjoyable. In their monotonic benefits assumption, they claim that "the amount of time an individual is engaged in deliberate practice activities is monotonically related to that individuals' acquired performance" (p. 368). Actually, they assume that virtually every individual can attain the level of an international expert in a domain if he or she consequently engages in deliberate practice over a long time. The authors substantiated their assumption by two empirical studies in the musical domain. In one study they assessed current and past levels of deliberate practice in three groups of adult violinists of different expertise (labelled *best violinists*, *good violinists*, and *music teachers*). The participants were required to write down all practice activities in a diary for one week and to rate these activities with regard to (a) their relevance for performance improvement, (b) the amount of effort required to perform them, and (c) how enjoyable the activity is without considering the evaluation of the result of the activity. Amongst all music-related practice activities (playing for fun, taking lessons, listening to music, group performance, etc.), *practising alone* was rated to contribute most strongly to performance improvement, to be very effortful, and to be not very enjoyable. In addition, they asked the participants to estimate how much time (hours per week) they typically had spent on practising alone for each year since they had started practising. Two results of this study are noteworthy: First, they found that the current amount of deliberate practice (practising alone) was significantly higher in the best and good violinists as compared to the music teachers. And, second, the accumulated amount of deliberate practice was monotonically related to the performance level of the violinists.

Recently, Charness, Tuffiash, Krampe, Reingold, and Vasyukova (2005) conducted a similar investigation in two large samples of tournament chess players. In both samples (in total over 300 participants), they found that the current amount of time the players engage in *serious study alone* was correlated with their skill rating between 0.27 and 0.37. Likewise, significant correlations were also reported for the average tournament playing time (0.22), the age at which they had started playing chess (−0.13 to −0.28) and the age at which they had begun serious practice (−0.30 to −0.41). In addition to measures of the current engagement in practice activities, the participating players were requested to estimate the time spent on *serious study alone* for each year beginning from the first year they had learned to play chess. In line with the monotonic benefits assumption, the accumulated hours of deliberate practice were a very strong predictor of the current chess skill (*r*s between 0.48 and 0.54). Subsequent regression analyses revealed that a combination of different practice activities could account for about 40% of the variance in current playing strength.

1.3. Personality variables

Even though the role of cognitive traits (such as intelligence) for the acquisition of expertise has frequently been disclaimed (e.g., Ericsson & Lehmann, 1996; Ericsson et al., 1993), it is assumed "that several 'personality' factors, such as individual differences in activity levels and emotionality may differentially predispose individuals toward deliberate practice as well as allow these individuals to sustain very high levels of it for extended periods" (Ericsson et al., 1993, p. 393). Likewise, Charness, Krampe, and Mayr (1996) include personality variables in their theoretical framework of factors mediating expert performance. In particular, they postulate that the intensity, duration and content of practice – and, eventually, the level of skilled performance – is influenced by the level of internal motivation and the individual's personality characteristics.

First, chess players obviously need a vast amount of intrinsic motivation to gain skills and to persist with practice, also because the latter activity is often not inherently enjoyable. Van der Maas and Wagenmakers (2005) cite early work by Djakow, Petrowski, and Rudik (1926) who concluded based on results in the Rorschach test that chess grand masters have a high "will power". The authors also included a chess motivation questionnaire in their Amsterdam Chess Test (ACT; Van der Maas and Wagenmakers) and indeed found bivariate correlations between ELO ranking and motivation of up to 0.22. In addition, their measure of motivation significantly contributed to the prediction of tournament performance in regression analyses.

Second, there is some evidence of a link between traditional personality dimensions and the attained level of chess mastery. Kelly (1985) administered the Myers-Briggs Type Indicator (Myers, 1962) in a sample of 270 average players and 209 masters and showed that the chess players had significantly higher scores on introversion, intuition and thinking as compared to the general population norms. Moreover, master-level players were even more introverted and intuitive than average players. Avni, Kipper, and Fox (1987) employed selected scales of the Minnesota Multiphasic Personality Inventory (MMPI; Wiggins, 1969) and found that chess players differ from non-players in terms of unconventional thinking and orderliness – characteristics that may be critical to playing a strategic game of chess (Charness et al., 2004). Finally, a recent investigation by Joireman, Fick, and Anderson (2002) revealed a relationship between sensation seeking and involvement in chess. Undergraduate students scoring high on the sensation seeking scale (Zuckerman, 1979) were more likely to have tried chess and to have more experience with the game. More detailed analyses showed that this holds particularly true for the Thrill and Adventure Seeking (TAS) and the Disinhibition (DIS) subscales, suggesting that the primary determinants of involvement in chess are the desire to engage in exciting and oftentimes risky activities and a tendency to act in a disinhibited manner.

1.4. Research questions

The first (and primary) goal of the present study lies in the investigation of the relationship between intelligence components and the attained level of expertise in the domain of chess. In light of the inconsistent findings regarding the association between psychometric intelligence (components) and expertise in adults, a large sample of tournament chess players of varying playing strength is tested with a well-established multidimensional intelligence test. This procedure allows us not only to examine whether general intelligence is associated with expertise (as measured by participants' ELO ranking), but also reveals how different intelligence components are related to chess playing strengths. The latter question is of particular interest, since previous studies have provided conflicting evidence on the role of visuo-spatial or figural ability for expertise in the domain of chess. While studies in children (e.g., Frydman & Lynn, 1992) as well as studies on working memory suppression (e.g., Robbins et al., 1996) point to a central position of this component, psychometric studies in adults (e.g., Doll & Mayr, 1987; Waters et al., 2002) have not reported any evidence of above-average visuo-spatial or figural abilities in chess players.

The second goal of the present investigation addresses the question of the importance of experience in chess play, tournament participation and practice activities for the achieved level of playing strength. In this context we refer to the theoretical framework of deliberate practice put forward by Ericsson et al. (1993) who have described criteria for those practice activities that are assumed to contribute most strongly to performance enhancement. Following their suggested procedure, first, all chess-related activities that might improve performance are rated by the tournament players with regard to the criteria for deliberate practice, and, second, the time they typically spend on the execution of the practice activities is assessed. In addition, biographical data (developmental milestones such as when they joined a chess club) and indicators of the participants' current tournament activity are assessed (see also Cranberg & Albert, 1988). Correlation and regression analyses between these variables and the participants' ELO score should reveal how mere chess playing experience is related to the achieved expertise level, to what extent the participation in tournaments is associated with skill, and whether current deliberate practice activities can predict playing strength.

Finally, the relevance of personality factors for superior chess play is examined. As reviewed above, previous investigations have revealed associations of chess skill with measures of intrinsic motivation and some personality variables. To further elucidate the

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relationship between chess expertise in tournament players and their personality profiles, questionnaires on the classic *big five* personality factors, on emotional competences, on motivational variables, and on chess-related attitudes are administered.

2. Method

2.1. Participants

From August 2003 to June 2004, 98 Austrian tournament chess players were recruited through announcements at Austrian chess clubs and local tournaments, offering the opportunity to obtain information about their intelligence and personality profiles. Eight participants had to be excluded from analyses, because they did not complete the tests or belonged to an age group not appropriate for the psychometric tests applied (i.e., persons under 15 years). The remaining sample of 90 participants comprised 87 males and 3 females whose age ranged from 15 to 65 years ($M = 36.23$, $SD = 13.29$). In contrast to other studies investigating the relationship between general intellectual abilities and chess expertise (e.g., Doll & Mayr, 1987), the sample covers a broad span of playing strength as measured by the national ELO ranking system: ELO rankings[1] ranged between 1311 and 2387 ($M = 1869$, $SD = 247$). With regard to the educational background, the sample consists of participants with the following highest education levels: basic education (6%), apprenticeship (22%), high school without a university entrance diploma (11%), high school with a university entrance diploma (37%) and university degree (24%). Participants' ELO ranking was marginally correlated with age ($r = -0.21$, $p = 0.05$) and significantly associated with educational level ($r = 0.36$, $p < 0.01$).

2.2. Test material

Participants were presented a set of psychometric tests and a questionnaire on chess-related biographical data and attitudes (subsequently referred to as *chess questionnaire*). The test material is described in the following.[2]

2.2.1. Intelligence structure test

For assessing the intelligence profile of the participants, the well-established German intelligence structure test 2000 revised (Intelligenz-Struktur-Test 2000 R, I-S-T 2000 R; Amthauer, Brocke, Liepmann, & Beauducel, 2001) was administered. The I-S-T 2000 R draws on those intelligence components that have consistently been found in different models of intelligence structure (Cattell, 1963, 1987; Thurstone, 1938; Vernon, 1961). In particular, these are (a) verbal intelligence, (b) numerical intelligence, (c) figural intelligence, and, at a more general level as a total score consisting of the three content factors, (d) general intelligence. Each content factor is measured by means of three subscales (each consisting of 20 items): verbal intelligence (sentence completion, verbal analogies, finding

[1] Since the testing of the participants covered a time period of over 1 year and the national ELO ranking list is updated every 6 months (in January and July), the ELO rankings were aggregated over the respective time periods in the present sample (i.e. from July 2003 to July 2004). This indicator of playing strength can be considered more reliable than a singular rating.

[2] The entire test material was in German; therefore, example items in the description of the test material represent rough translations of the original items.

similarities), numerical intelligence (arithmetic problems, number series, arithmetic operators), and figural intelligence (figure selection, cube task, matrices). The total time for the administration of the intelligence test is approximately 90 minutes.

2.2.2. Chess questionnaire

This questionnaire consists of the following parts:

(1) *Chess-related developmental milestones*. For the investigation of the relationship between chess playing experience and playing strength, participants were asked at what age they had started playing chess, and since what age they are a member in a chess club. Time periods, in which they paused playing chess on a regular basis were also enquired for.
(2) *ELO ranking*. Besides assessing the current (national) ELO ranking of the participants in the questionnaire, all available information from the official ELO ranking list was retrieved, covering the ELO rankings, number of tournament games and the tournament results in the period from July 2002 to January 2005.
(3) *Chess-related attitudes*. Seven items drawing on the subjective importance of playing chess (two items: "How much importance do you generally attach to playing chess in your life?", "How much importance do you attach to playing chess in your spare time?"), chess-related practice motivation (two items: "How much deliberate chess practice do you engage in?", "How strong is your motivation to practise chess playing deliberately?"), and performance motivation (two items: "Playing better than others is for me … [*not important–very important*]", "In playing chess, the demands I make on myself are … [*very low–very high*]"), and one item assessing fun in playing chess ("How much do you enjoy playing chess?") were presented (Cronbach's α for all items = 0.82). All items had to be answered on a seven-graded rating scale.
(4) *Practice activities*. Participants were requested to indicate which kinds of practice activities they regularly carry out and to estimate the average number of hours per week they usually spend on them. Seven types of chess-related practice activities emerged in prior talks with tournament chess players and are consistent with investigations in the framework of the deliberate practice theory: (a) practising alone with written material such as chess books, (b) practising alone with computer programmes, (c) practising together with other players, (d) playing chess just for fun (without deliberate practice), (e) giving private lessons in chess, (f) getting private lessons in chess, and (g) watching current tournaments in the media. Additionally, since deliberate practice has been relatively clearly defined by Ericsson et al. (1993) as an activity that is most effective in improving performance, highly effortful, and not inherently enjoyable, the indicated practice activities had to be evaluated by the participants with regard to these three criteria on a 10-graded rating scale. In contrast to Charness et al. (2005) only the current amount of practice is determined and related to playing strength. Therefore, no firm conclusions on the validity of Ericsson et al.'s monotonic benefits assumption can be drawn based on the present data. However, since Ericsson et al. as well as Charness et al. showed that even the current amount of deliberate practice is predictive for expertise, presumably because the amount of practice necessary for the maintenance of expertise is also a positive function of the expertise level, this procedure appears reasonable.
(5) *General performance motivation*. In order to assess participants' general performance motivation (outside the context of chess), two subscales of the "Leistungs-Motivations-

Test" (LMT; Hermans, Peterman, & Zielinski, 1978), measuring (a) performance aspiration (15 items; "Leistungsstreben") and (b) persistency and assiduity (13 items; "Ausdauer und Fleiss") were included in the chess questionnaire.

2.2.3. Personality questionnaire

Participants' personality profile was measured by means of the NEO-Five-Factor-Inventory by Costa and McCrae (1989); German translation by Borkenau and Ostendorf (1993). This questionnaire was chosen because it allows a comprehensive and economical personality assessment in accordance with the currently well-established big five model of personality. Five subscales with 12 items each provide information on participants' level of neuroticism, extraversion, openness to experience, agreeableness and conscientiousness.

2.2.4. Questionnaire on emotional competences

For assessing participants' emotional competences, a recently developed self-report measure ("Fragebogen zur emotionalen Kompetenz"; FEK; cf. Freudenthaler & Neubauer, 2005) was administered. In 49 items, this questionnaire measures self-assessed emotional abilities concerning the following aspects (example items are given in parentheses): perception of one's own emotions ("I often need a lot of time to recognise my true feelings."), perception of the emotions of others ("It is not hard for me to identify dishonest expressions of emotions."), control over the expression of emotions ("In certain situations I cannot suppress my feelings even though I try."), masking of emotions ("If I want I can simulate almost all kinds of feelings."), regulation of one's own emotions ("It is easy for me to change my bad mood."), and regulation of the emotions of others ("I can hardly change the feelings of others."). Responses were scored on a six-graded rating scale ranging from *not true* to *very true*.

2.3. Procedure

Participants were tested in small groups (of 2–14 participants) at the Department of Psychology in Graz, at local tournaments or at local chess clubs. At all sites, testing conditions were uniform in that participants were always tested in quiet rooms by the same number of persons. After a short introduction to the principal aim of the study, participants started working on the intelligence module of the I-S-T 2000 R. To avoid copying of answers in the intelligence test, parallel versions were used in the case that two participants sat together. Then, the remaining questionnaires were administered without time restriction in the following order: chess questionnaire, NEO-FFI, and FEK. The total testing time was about 3 h. For economical reasons, eight participants (from two different test sessions) were asked to finish the three latter questionnaires at home and to return them via mail.

2.4. Data analyses

Prior to statistical analyses, variables were examined for accuracy of data entry and missing values. Unless otherwise noted, all analyses refer to the sample of $N = 90$ participants (one participant has not returned all questionnaires by mail, hence reducing the sample size in some analyses). The assumption of normal distribution was tested for all variables by means of the Kolmogorov–Smirnov Goodness-of-Fit test. Since the vast majority of variables met this criterion, Pearson product-moment correlations are presented. In case the of deviations from normality, additional Spearman rank-order correlations were computed, which, except when otherwise stated, yield the same pattern of results. The probability of a Type I error was maintained at .05 for all subsequent analyses.

3. Results

3.1. Intelligence

The first goal of the present study is to investigate the relationship between different intelligence components and the participants' expertise level. Looking first at the descriptive statistics of the I-S-T 2000 R scores in Table 1, a wide intellectual ability range in both, the general intelligence level and the content factors can be observed, displaying the largest standard deviation for figural intelligence.[3] The tournament players' general intelligence as well as the scores in all intelligence components were significantly higher than in the (age-matched) reference sample (as assessed by means of one-sample t-tests; all $t\text{s}(89) > 3.78$, $p\text{s} < .01$). The highest score emerges for numerical intelligence (about one standard deviation higher than in the reference sample), somewhat lower means for verbal and figural components. Pairwise comparisons by means of t-tests additionally reveal that the players' numerical intelligence is, on average, significantly higher than their verbal and figural intelligence, both $t\text{s}(89) > 6$, $p\text{s} < .01$. The descriptive statistics of the subscales of the intelligence components support this general picture. All three numerical subscales display means above 110, while the verbal and figural subscales lie within the average range between 90 and 110.

More importantly, several significant correlations with playing strength (ELO ranking) were found. Higher playing strength is associated with higher scores in general intelligence, verbal intelligence, and, most strongly pronounced, numerical intelligence (see also Table 1). However, for figural intelligence a completely different result emerges: While the correlations of verbal and numerical intelligence reach statistical significance at the .01 level, figural intelligence turns out to be entirely unrelated to ELO ranking.[4] Two of the figural subscales (figure selection and cube task) even display null-correlations. These two tasks require two-dimensional (figure selection: joining together dissected figures) and three-dimensional (cube task: mental rotation of cubes) visuo-spatial skills, while the matrices focus on inductive reasoning with figural material. Concerning the numerical subscales, the highest correlation appeared for number series, a subscale also drawing on inductive reasoning, though, with numerical material (e.g., "2 5 8 11 14 17 20 ?").

The respective scatterplots of IQ scores and ELO rankings are depicted in Fig. 1. Considering the broad range of the participants' intellectual abilities it appears interesting to look for a potential intelligence threshold, possibly necessary for strong chess play. When a high playing strength is defined as an ELO ranking above 2000 (strong intermediate players, i.e., 33% of the sample), this expertise level can apparently be achieved with verbal and

[3] Two participants had figural intelligence scores below IQ 75 but ELO rankings above 2000. Since the performance in all (three) figural subscales was comparably low for these participants, this result was not attributed to misunderstandings of the instruction.

[4] This null-correlation also remains when excluding the two participants with very low IQ scores but high ELO rankings (see Fig. 1).

Table 1
Correlations with ELO and descriptive statistics of the scores in the I-S-T 2000 R

	r	Min	Max	*M*	SD
General intelligence	.35**	78.87	144.38	113.53	14.05
Verbal intelligence	.38**	72.02	134.09	108.41	13.36
Numerical intelligence	.46**	77.78	135.95	116.41	14.15
Figural intelligence	.02	69.77	140.87	106.14	15.41
Subscales					
Sentence completion[a]	.30**	78.68	131.80	106.77	12.53
Analogies[a]	.28**	70.36	132.05	106.56	12.74
Finding similarities[a]	.30**	70.49	130.79	105.33	13.42
Arithmetic problems[b]	.38**	81.04	136.69	114.23	15.02
Number series[b]	.44**	70.76	131.92	113.27	14.79
Arithmetic operators[b]	.39**	78.70	130.00	115.81	12.54
Figure selection[c]	−.07	66.62	134.77	105.34	14.38
Cube task[c]	−.06	69.92	134.44	104.86	15.26
Matrices[c]	.20	65.26	138.53	103.04	14.34

Correlations were computed between raw scores and ELO ranking.
For reasons of comparability with other studies (e.g., Doll and Mayr, 1987) the descriptive statistics refer to standardised IQ scores ($M = 100$, SD = 15), corrected for age according to the I-S-T 2000 R manual.
[a] Verbal subtests.
[b] Numerical subtests.
[c] Figural subtests.
** $p < .01$.

numerical IQs above 85–90, whereas figural intelligence does not seem to play any role at all. When it is defined as an ELO ranking above 2200 (advanced players or experts, cf. Charness et al., 2005; i.e., 7% of the sample), for verbal and numerical IQs the threshold seems to lie somewhat higher (at about 110–115). Interestingly, the scatterplots also show that the highest-rated participants in the present sample are not those with the highest verbal or numerical IQs.

3.2. Chess questionnaire

3.2.1. Biographical data and tournament activity

At first, the assessed data of developmental milestones and tournament activity (number of games played and average result) of the chess players were analysed regarding their associations with playing strength (see Table 2). The earlier the participant started playing chess on a regular basis, and the earlier he or she joined a chess club and began playing tournaments, the higher is the achieved playing strength. Comparably high correlations were also found with indicators of tournament activity. The ELO ranking is significantly associated with both, number of tournament games and average result (or tournament success). While the association with the average result is somewhat trivial, as the current ELO ranking changes depending on the tournament success, the relation with the number of played games is noteworthy. Of course, it is plausible to argue that those players who are more successful also participate in more games (or vice versa), which is also the case in the present sample ($r = 0.36$, $p < 0.01$); an additional partial correlation (with tournament success factored out) between ELO and number of tournament games, however, does not eliminate the effect ($r = 0.34$, $p < 0.01$). This corroborates the finding that the mere number

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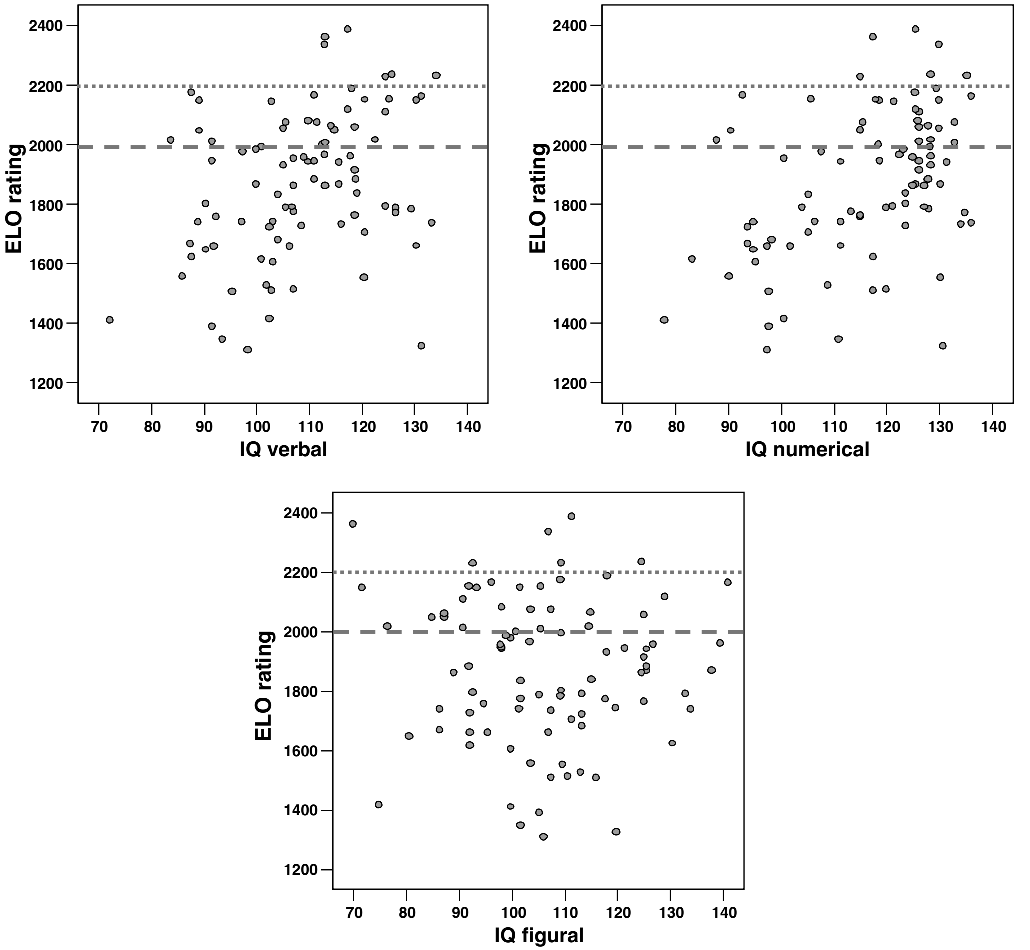

Fig. 1. Scatterplots of the IQ scores and ELO rankings. The dashed line marks the playing strength of strong intermediate players (ELO 2000), the dotted line that of advanced (expert) players (ELO 2200).

of tournament games within 1 year is quite a good predictor for playing strength, independently of how successfully the games were played.

3.2.2. Chess-related attitudes and motivational factors

The seven items on chess-related attitudes were aggregated with respect to their content as described in the method. The respective results (including the two LMT subscales assessing general performance motivation) are also presented in Table 2. Significant positive relations with ELO were solely found for the subjective importance of playing chess and, somewhat stronger, for chess-related performance motivation. No associations emerged with fun in playing chess, chess-related practice motivation and both LMT subscales.

3.2.3. Practice activities

Table 3 gives an overview of the relative number of participants who carry out the respective practice activity and the average number of estimated practice hours per week.

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Table 2
Correlations with ELO and descriptive statistics of the biographical data, tournament activity, chess-related attitudes, and the LMT subscales

	r	Min	Max	M	SD
Biographical data[a]					
Age: start playing chess[e]	−.38**	5.00	40.00	14.18	7.53
Age: enter chess club[f]	−.50**	7.00	49.00	18.03	8.92
Tournament activity[b]					
Number of tournament games	.45**	0.00	36.00	10.54	8.14
Average result of tournament games (%)	.50**	0.00	84.67	49.95	16.18
Chess-related attitudes[c,e]					
Importance of playing chess	.28**	1.00	7.00	4.97	1.22
Fun in playing chess	.06	2.00	7.00	6.06	1.09
Chess-related practice motivation	.07	1.00	6.50	3.42	1.41
Chess-related performance motivation	.39**	1.50	7.00	4.76	1.30
LMT[d,e]					
Performance aspiration	.01	0.00	0.87	0.47	0.20
Assiduity	−.15	0.08	0.92	0.44	0.18

[a] Values given in years. Playing experience in years was corrected for time periods in which participants reported to have not played chess regularly.
[b] The number and results of tournament games were averaged over the testing time period (July 2003 to July 2004). The result of each game is usually indicated as following: 1 (won game), 0.5 (draw), and 0 (defeat). For the present analyses, the percentage result of tournament games (relative to the number of games) was computed.
[c] The values reflect the average rating on seven-graded scales (1–7).
[d] LMT raw scores (0–1).
[e] $N = 89$.
[f] $N = 88$.
** $p < .01$.

Table 3
Descriptive statistics of the practice activities

	$f_{\%}$	Min	Max	M	SD
Practising alone with written material	66	0.10	7.00	1.52	1.38
Practising alone with a computer	53	0.10	19.00	2.55	3.80
Practising together with other players	57	0.50	5.00	1.85	1.18
Playing chess just for fun	70	0.25	20.00	2.84	3.04
Giving private lessons	22	0.50	5.00	1.80	1.25
Getting private lessons	3	0.50	0.50	0.50	0.00
Watching tournaments in the media	56	0.25	4.00	1.19	0.77

$f_{\%}$ stands for the percentage of participants (out of 90) regularly performing these activities.

More than half of the players indicated to engage regularly in chess-related practice; for most types of chess-related practice, the average number of hours per week lies between approximately 1 and 3. Among all practice activities regularly carried out by the tournament players, *practising alone with written material* was rated to contribute most strongly to performance improvement ($M = 7.35$, SD = 1.92), to be most effortful ($M = 6.25$, SD = 2.38), and to be least enjoyable ($M = 4.38$, SD = 2.31). Thus, this type of practice meets all criteria for deliberate practice put forward by Ericsson et al. (1993). Correlational analyses revealed, however, that the current amount of time engaged in *practising alone with written material* is entirely unrelated to playing strength ($r = 0.08$, n.s.). Interestingly, also the number of hours engaged in the other practice activities and the total number of practice hours per week failed to display a significant positive correlation with ELO.

It is striking that *none* of the practice activities displays a positive relation with playing strength. As these activities were assessed by means of a questionnaire, requiring subjective estimations, it might be assumed that the data more strongly reflect the players' attitude to practising (in terms of practice motivation) rather than the actual amount of practice. If this were the case, then the assessed chess-related practice motivation (see above) should be related to the practice activities. Another analysis confirms this assumption: The correlation for the total number of practice hours per week and practice motivation is 0.43 ($p < 0.01$), for practising alone with written material 0.36 ($p < 0.01$).

3.3. Personality and emotional competences

In Table 4, the results for the personality (NEO-FFI) as well as emotional competences (FEK) subscales are presented. The mean scores of virtually all NEO-FFI and FEK subscales were in the normal range between 40 and 60 (±1 SD). Only in the FEK subscale *emotion expression control*, the participants had, on average, a comparably high score ($M = 59.46$), which turned out to be significantly higher than the population mean of 50, $t(88) = 7.98$, $p < .01$. Interestingly, this FEK subscale was also significantly related with playing strength, suggesting that stronger chess players are more capable of controlling their emotional expression than their weaker counterparts. No other correlations between ELO and personality subscales reached statistical significance.

3.4. The prediction of the expertise level

Several variables were investigated regarding potential associations with the expertise level, as reflected by the individual's ELO ranking. The independent contributions of each

Table 4
Correlations with ELO and descriptive statistics of the NEO-FFI and FEK subscales

	r	Min	Max	*M*	SD
NEO-FFI					
Neuroticism	−.08	28.96	77.46	44.95	9.98
Extraversion	.06	21.61	67.74	48.03	10.14
Openness to experience	.04	31.45	69.18	48.37	8.34
Agreeableness	.19	32.05	76.92	54.21	9.38
Conscientiousness	−.12	22.15	69.19	51.37	9.83
FEK					
Perception: own emotions	.11	13.27	74.06	48.79	9.24
Perception: other emotions	−.01	20.29	68.40	43.86	9.79
Emotion expression control	.27**	33.66	83.39	59.46	11.19
Masking emotions	.19	22.97	76.14	49.07	9.58
Regulation: own emotions	.05	21.79	75.84	52.58	10.96
Regulation: other emotions	.00	15.46	71.23	45.14	9.75

Correlations were computed between raw scores and ELO ranking.
For reasons of comparability with other studies the descriptive statistics refer to standardised T-scores ($M = 50$, $SD = 10$). The NEO-FFI T-scores were computed according to the reference sample in the manual, the FEK T-scores are based on a sample of 208 adults.
** $p = .01$; $N = 89$.

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Table 5
Summary of multiple regression analysis (method: stepwise) for variables predicting playing strength as measured by ELO ranking

Variable	*B*	*SE B*	*β*
Constant	1157.95	144.52	
Age: enter chess club	-12.07	2.52	−.44**
Number of tournament games	9.82	2.38	.33**
FEK: emotion expression control[a]	7.78	2.92	.20**
I-S-T 2000 R: numerical intelligence[a]	5.91	1.74	.31**
Age	5.13	1.81	.28**
Chess-related performance motivation	31.54	14.76	.17*

The variable order represents the sequence in which the variables entered the equation.
[a] Raw score.
* $p < .05$.
** $p < .01$.

variable to the variance of playing strength, though, have not been evaluated so far. For gaining an impression of how much variance can be accounted for by these variables, an explorative multiple regression analysis (method: stepwise) was performed, in which ELO ranking was the dependent variable. The following variables were considered as potential predictors:[5] verbal, numerical, and figural intelligence, age at which participants entered a chess club, number of currently played tournament games, chess-related attitudes, LMT, NEO-FFI, and FEK scales, and participants' current age. The respective results are presented in Table 5.

In total, the variables listed in Table 5 account for 58% (55% adjusted) of the variability of the ELO rankings, $R = 0.76$, $F(6, 81) = 18.65$, $p < 0.01$. This result suggests not only that a considerable portion of variance can be accounted for by indicators of playing experience, tournament activity, and chess-specific performance motivation, but also that the general intellectual ability (in this case, numerical intelligence) can significantly contribute to the prediction of the expertise level. In addition, the subscale *emotion expression control* of the FEK entered the regression equation which corroborates the relevance of this personality characteristic for superior chess play. However, the absolute importance of each indicator should be interpreted cautiously considering the restricted sample size and the fact that no data on accumulated deliberate practice is included in the analysis. Therefore, these results are not directly comparable to the findings of Charness et al. (2005).

In addition to this broad regression approach, the question should be addressed of how much variance of expertise can be solely accounted for by participants' general abilities. To this end, another regression analysis was computed, in which verbal, numerical, and figural intelligence were included as independent variables. This analysis revealed that figural intelligence enters the equation with a significant negative beta weight ($\beta = -0.35$), suggesting that once verbal and numerical intelligence are already considered, figural intelligence is negatively associated with playing strength. Since it might be misleading to indicate a percentage variance accounted for by positive and negative relations with intelligence, a regression analysis without figural intelligence was computed. Only numerical intelligence

[5] Similar to the correlation analyses presented in Tables 1 and 4, only the raw scores of the I-S-T 2000 R, NEO-FFI, and FEK were included in the regression analysis. Missing data were deleted listwise (subjectwise).

could significantly contribute to the prediction of playing strength ($\beta = 0.37$), accounting for 22% (20% adjusted) of the skill variance, $R = 0.47$, $F(2, 87) = 12.15$, $p < 0.01$.

4. Discussion

4.1. The (universal) importance of intelligence

José Raul Capablanca, a former chess world champion, once stated: "To play chess requires no intelligence at all." (cited in Cranberg & Albert, 1988, p. 159). Various researchers in chess expertise have adopted Capablanca's view, as virtually no empirical evidence has existed so far that demonstrated a clear-cut relationship between playing strength and intellectual abilities. Even though Doll and Mayr (1987) revealed that expert players possess an above-average IQ, they failed to prove a correlation between ELO ranking and intelligence, most probably because their sample was too restricted with regard to the participants' playing strength. Hence, to the best of our knowledge, this is the first comprehensive study that uncovers a significant and moderate association between different (domain-general) intelligence components and the level of expertise in chess.

The participants' ELO ranking correlated with general intelligence at about 0.35, accounting for about 12% of the variance and reflecting a medium effect size (Cohen, 1992). Thus, stronger tournament chess players are, on average, more intelligent than their weaker counterparts. In line with Doll and Mayr (1987), the highest mean IQ and strongest correlation were found for numerical intelligence, comprising arithmetic problems and inductive reasoning with number material (number series). Doll and Mayr's interpretation of this finding was that stronger chess players are more experienced with number material, since (a) the chess board is notated (partly) numerically, and, (b) moves on the board are represented by two-dimensional addition and subtraction processes. On the one hand, their assumption appears plausible as the familiarity with the notation of the board was reported to be associated with playing strength in previous studies. As an example, Saariluoma (1991) presented slides with notations of chess positions to the players of varying strength, whereupon the participants were required to indicate as fast as possible whether the indicated field is white or black. They observed that stronger players displayed significantly shorter reaction times and also lower error rates. On the other hand, however, we are not aware of any empirical evidence that it is explicitly the numerical domain that taps chess players' search for moves. Contrarily, the majority of the studies on chess players' superior playing skills and on the underlying processes point to a strong involvement of a visuo-spatial component in chess play, as is described below. Therefore, no compelling explanation for this finding can be offered.

With respect to the verbal intelligence component, the association with ELO ranking was found to be somewhat lower than for numerical intelligence. This significant correlation, though, diminished in the regression analyses, indicating that the bivariate correlation may be largely traced back to the influence of general intelligence. This interpretation is supported by additional partial correlations revealing that factoring out general intelligence does not affect the correlation between ELO and numerical intelligence ($r = 0.35$, $p < 0.01$), but that with verbal intelligence ($r = 0.17$, n.s.).

The most striking finding concerning the importance of intelligence for chess expertise, however, was the lack of a correlation for the figural component. Although in line with Doll and Mayr (1987) as well as Waters et al. (2002), this result appears more than surpris-

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ing in face of the paramount importance of visuo-spatial processes in chess performance. Already the early studies by De Groot (1978) and Chase and Simon (1973a, 1973b) emphasised the relevance of pattern recognition for strong chess play, and the more recent investigations on different facets of chess cognition have also substantiated this view. For instance, there is sound evidence from working memory suppression studies that a suppression of the visuo-spatial component of working memory more strongly affects chess performance than the distraction of the phonological loop (e.g., Robbins et al., 1996; Saariluoma, 1991, 1992, 1998). Furthermore, several investigations of blindfold chess play have revealed that playing without sight of the board relies heavily on a strong visual imagery component (Chabris & Hearst, 2003; Saariluoma & Kalakoski, 1998). And, finally, the studies by Horgan and Morgan (1990) as well as Frydman and Lynn (1992) demonstrated that the playing strength in children is related to the performance in a figural matrices test and the performance IQ of the Wechsler intelligence scale (comprising several visuo-spatial subtests). Hence, if chess expertise displays specificity to a certain type of task material (verbal, numerical, or figural/visuo-spatial), the figural/visuo-spatial domain can be expected to loom large (see also Howard, 2005). How, then, can the present finding of a null-correlation between figural intelligence and ELO be explained? In this context, a closer examination of the differential correlations of the figural subscales might be helpful. While the matrices test, requiring inductive reasoning with figural material, displays a positive (though rather weak and insignificant) relation with ELO, the two other subscales (figure selection and cube task) were entirely unrelated to playing strength. Most probably, a general reasoning component seems to be associated with playing strength, as the respective subtests of verbal intelligence (in particular, analogies and finding similarities) and numerical intelligence (number series) display consistent and significant correlations (approximately between 0.30 and 0.40). The two other subscales, however, draw on conventional visuo-spatial processes, requiring either the two- or the three-dimensional manipulation of figures. Mentally joining together dissected pieces or rotating patterned cubes might indeed be of no relevance for playing chess, whereas many forms of logical thinking (inductive or deductive reasoning) are more likely a part of chess skill and potentially involved in the fast recognition of meaningful patterns (e.g., threats) or the forward search for goal-relevant moves (Holding, 1985). Thus, a plausible interpretation of this finding is that skills measured by the two conventional visuo-spatial subscales are simply irrelevant for strong chess play, and, consequently, do not capture any variance in playing strength. Concerning the question whether good visuo-spatial abilities are necessary for strong chess play (Waters et al., 2002), it might therefore at least be concluded that it is obviously not those abilities that are measured by a typical intelligence test.

Regression analyses revealed that about 20% of the variance in playing strength can be accounted for by intelligence and that numerical intelligence significantly contributes to the prediction of the playing strength besides measures of chess experience, tournament activity, and personality variables. Hence, expertise in chess does not stand in isolation, but is also accompanied by general intellectual abilities. Of course, this correlational finding does not allow any conclusions about causal relations between intelligence and chess expertise. Frydman and Lynn (1992), for instance, argued that good general intelligence and strong visuo-spatial abilities are a necessary prerequisite for high-level chess playing since the opposite causal interpretation (chess playing fosters intelligence) would be unlikely in light of studies demonstrating no effect of skill transfer across domains. Moreover, it is possible that both variables are influenced by a third one. As an example, it might

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be speculated that an abstract activity such as chess playing is more attractive to highly intelligent people so that they invest more time and energy in this domain and, eventually, attain a higher skill level than less intelligent individuals. Likewise, intelligence may also come into play in the rate of expertise acquisition. Doll and Mayr (1987) found correlations between intelligence (as measured by the CFT-3) and the changes in playing strength over time periods of 1 and 2 years, suggesting that higher general intelligence was associated with a higher improvement in playing strength. Additional analyses of the trajectories of playing strength over 2 years in the present study, however, failed to show an association between intelligence and the size of skill improvement, which might be traced to the more heterogeneous sample of players under investigation (who differ not only in intelligence but also in many chess-related variables such as attitudes, amount of spare time available for deliberate practice, etc.).

Thus, longitudinal studies with multiple measures of intelligence and chess skill that can trace the process of expertise acquisition are inevitable to elucidate the reason for the observed relation between intelligence and chess expertise. Nonetheless, by looking at the scatterplots of intelligence and ELO we can gain an impression of what level of playing strength can be achieved with different intelligence levels. These revealed that the potential threshold for strong intermediate chess performance (defined as 2000 ELO) is remarkably low (verbal and numerical IQs between 85 and 90), and that expert chess play (defined as above 2200 ELO) can apparently be attained with IQs slightly above average (110–115).

4.2. The long way to chess expertise

The second research question concerns the importance of experience in chess play, tournament participation, and practice activities for the attained level of expertise. Analyses revealed that the current ELO ranking is strongly associated with chess experience. The earlier the participant started playing chess regularly, the higher was his or her achieved level of expertise. However, the results differed with regard to the type of domain-specific experience: While the individual's age at which they started playing chess was correlated with ELO at −0.38, the age at which they entered a chess club (and began playing tournaments) displayed a higher correlation of −0.50. Similar findings were reported by Charness et al. (2005): For their (not age-stratified) sample they observed that ELO ranking was associated with starting age (at which they learned the rules) at about −0.30 and with serious age (at which they started playing chess seriously) at about −0.40. In both cases, that kind of experience (or starting age, respectively) displays a higher correlation with the attained expertise level that more closely refers to what Ericsson et al. (1993) termed deliberate practice. Considering that the chess club experience actually accounts for 25% of the entire skill variance and that this variable is the strongest predictor of playing strength in the regression analysis, it can be assumed that part of the long-term deliberate practice is reflected in this measure. This interpretation gains additional plausibility through the fact that the membership of a chess club is usually linked with more or less regular practice meetings and the participation in tournaments. Besides mere chess club experience, also the current amount of tournament participation turned out to be significantly related to the playing strength. Hence, stronger chess players play more tournament games than their weaker counterparts, irrespective of the tournament results.

It might also be interesting to look at the characteristics of the expert chess players to get an impression about how much experience might be required for expert performance and at what age an individual should begin playing chess on a regular basis. For this purpose, an expert chess player is again defined as a player with an ELO ranking above 2200. On average, the experts started playing chess regularly at 10 years (SD = 3.00; range: 5–13 years) and joined a chess club when they were about 12 ($M = 12.20$; SD = 3.27; range: 8–16). Their chess playing experience lies between 11 and 32 years ($M = 20.20$, SD = 9.03), their club chess playing experience between 10 and 28 years ($M = 18.00$, SD = 8.12), hence, conforming nicely to Simon and Chase's (1973) 10-year rule.

With respect to the role of current deliberate practice for chess expertise, several chess-related practice activities were evaluated with regard to their contribution to the performance improvement, the involved effort, and the amount of enjoyment (cf. Ericsson et al., 1993). Analyses of the ratings revealed that *practising alone with written material* met all three criteria perfectly. This finding conforms to the very recent comprehensive investigation by Charness et al. (2005) who also found *serious analysis of chess positions alone* to be the most relevant deliberate practice activity in the domain of chess. In their study, the current amount of engagement in it was significantly related to the ELO ranking (*r*s between 0.27 and 0.37), suggesting that the maintenance of higher skill levels might also require a higher amount of deliberate practice. Consequently, in the present study, it was hypothesised that the current playing strength of the tournament players is also a function of the time invested in deliberate practice. The respective results, however, were surprisingly disappointing. Although more than half of the players indicated to practise alone regularly, the estimated number of practice hours per week was low and unrelated to the achieved expertise level. In addition, none of the investigated practice activities displayed the expected positive relationship with the participants' ELO ranking. Hence, the present results evidently contradict those of Charness et al. and Ericsson et al. with regard to the role of current practice and skill level. Two explanations might account for the differing results:

First, as already mentioned in the results section, the indicated amount of time invested in the different types of practice might reflect an invalid measure of the participants' actual engagement. This interpretation is substantiated by the strong correlations with practice motivation, suggesting that those individuals who attributed a higher practice motivation to themselves also stated to invest more time in practice. Both variables, however, turned out to be irrelevant for the prediction of playing strength. Hence, for future studies, the (additional) use of alternative assessment methods (such as diaries) might prove more fruitful. Further support of the argument that the chess-related practice activities were not adequately measured by the questionnaire comes from the results concerning the tournament participation of the players. In contrast to the self-estimated extent of practice, the number of tournament games (and the respective results) could be assessed *objectively* by means of the publicly available ELO database and displayed a significant and comparably strong association with the ELO rating.

Second, the procedure used in the present study slightly differs from that in Charness et al. (2005) with regard to the exact formulation of the respective questions. While Charness et al. explicitly asked the players to give estimates of their time investment into "*serious analysis of positions … alone* (using chess books, magazines, data bases, playing postal chess, or the like)" (pp. 164–165), in the present study, we asked for "practice alone with chess books or other written material". It is evident that the former description more specifically refers to the practice process (*what* is practised) whereas the latter only accounts for the medium (*written* material) and leaves the specific type of practice open. Thus, in the present study, that type of deliberate practice which is most relevant might not have been captured appropriately by the questionnaire.

4.3. Expert chess players' personality

The third goal of the present study was to achieve a picture of the psychometrically assessed personality characteristics of expert chess players. For this purpose, they were screened for the big five personality dimensions, emotional competences, general as well as domain-specific performance motivation, and chess-related attitudes. In contrast to previous investigations by Kelly (1985) and Avni et al. (1987), virtually none of the broad (domain-general) personality characteristics displayed a relationship with the attained expertise level. An exception was the FEK subscale *emotion expression control*, which could even significantly contribute to the prediction of playing strength in the regression analysis beyond the other relevant variables. This finding suggests that stronger chess players are more capable of controlling their emotional expression and could be interpreted in terms of self-regulation. Charness et al. (2004), for instance, points to the need of chess players to control emotional influences on cognitive processes while choosing the best move; old homilies such as "sit on your hands" would be addressed to players to avoid impulsive moves. Avni et al.'s finding of higher orderliness in chess players might also be interpreted in this vein: (stronger) chess players possess the ability "to sustain undistracted concentration in the fact of prolonged, tense [tournament] situations" (p. 718). However, although a link between this facet of emotional competence and self-regulation in chess players appears to be highly plausible, the presented post-hoc interpretation has to be regarded as tentative and certainly requires further investigation.

Apart from the association with the FEK subscale, another interesting finding concerns the measures of performance motivation. Here, the domain-general and domain-specific measures clearly differed regarding their associations with playing strength. Both the LMT subscales (performance aspiration and assiduity) were not related to the ELO ranking, but the chess-related performance motivation was. The latter variable even turned out as a significant predictor of playing strength in the regression analysis. While stronger chess players obviously are not driven by the goal to perform better than the others in general, they explicitly pursue this objective in the domain of chess. This finding nicely conforms to the recent investigation by Van der Maas and Wagenmakers (2005) who also observed a link between the score in their chess-specific motivation questionnaire and playing strength. With respect to the size of the correlation, it appears noteworthy that in the present study about 15% of the variance in playing strength could be accounted for by this measure consisting of only two items.

4.4. Conclusion

Taken together, the present results suggest that superior or excellent performance in cognitively demanding domains like chess is not entirely independent of the general mental abilities. The observed association appears to be driven by the (general) reasoning factor, which might be engaged in several chess-related processes such as pattern recognition or forward search for moves (e.g., Howard, 1999). A more thorough examination of the intelligence components revealed a high specificity of this reasoning component for numerical material, whereas the figural component turned out to be largely unrelated to playing

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strength. Although both findings conform to the comprehensive investigation by Doll and Mayr (1987), the question where this specificity for numerical material originates appears largely unresolved. Even though intelligence and expertise turned out to be related, a high level of intelligence seems to be far from sufficient for strong chess play. This study was also designed to evaluate the importance of the players' chess experience, current tournament and practice activities, and facets of their personality for the attained expertise level. The strongest single predictor of playing strength, accounting for approximately 25% of the entire skill variance, was the participants' tournament playing experience. This finding again highlights the relevance of long-term engagement for the development of expertise. In total, chess experience, current tournament activity, numerical intelligence and personality factors could account for the impressive amount of 55% of the variability of playing strength.

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