Received: 9 April 2022 | Revised: 9 March 2023 | Accepted: 16 March 2023
DOI: 10.1002/acp.4062

RESEARCH ARTICLE

WILEY

Age and skill in chess: Accuracy and speed-accuracy performance in reasoning and knowledge

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Funding information
Diputació de Lleida, Grant/Award Number: 202100063

Abstract

Individual differences in cognitive performance depend on age, skill, and type of task. Nonetheless, whether performance is measured with accuracy (ACC) or with the trade-off between responding speed and accuracy (SAT) could render subtle different relationships. Age and skill might associate more strongly with SAT performance in reasoning tasks, whereas they might relate more similarly with either ACC or SAT in knowledge tasks. These expectations were evaluated here with data from the cognitively taxing domain of chess ($n = 259$). Age was associated more strongly with the SAT than with the ACC measures in reasoning tasks. In contrast, skill related more robustly with the ACC than with the SAT measures in knowledge tasks. The main findings suggest that the associations of age and skill with performance vary depending on the type of task, but also on whether considering accuracy or speed-accuracy measures of cognitive performance.

KEYWORDS
accuracy, age, chess, cognitive performance, skill, speed-accuracy

1 | INTRODUCTION

Age, skill, and type of task, are central interrelated determinants of individual differences in cognitive performance (Ackerman, 2007). For example, there is a substantial degree of interindividual variability in the change over time in cognitive performance. A higher educational level or the involvement in stimulating environments exerts protective effects of cognitive decline (Schaie, 1994), while different abilities decrease at different rhythms with aging. Furthermore, the type of cognitive task may require abilities eventually governed by age differences. Fluid abilities such as information processing, psychomotor speed, memory, or abstract reasoning tend to decline earlier during young adulthood (Verhaeghen & Salthouse, 1997). In contrast, crystallized abilities such as vocabulary, literacy, and specialized domain knowledge peak later than fluid abilities and even increase throughout adulthood (Ackerman, 1996; Baltes, 1987; Cattell, 1987).

Older adults worsen in tasks that involve fluid abilities such as working memory, whereas perform equally well or even above younger adults in tasks that involve crystallized abilities (Bruine de Bruin et al., 2012). Moreover, because knowledge accrues with experience, middle-aged individuals tend to perform better than younger adults in tasks that imply the use of specialized domain knowledge (Ackerman, 2000, 2007). Knowledge and skills acquired over time compensate for aging decrements in ability in what has been coined as the age is kinder to the initially more able hypothesis (Baltes & Baltes, 1990; Gow et al., 2012). Nonetheless, whether successful performance depends on domain knowledge over and above basic reasoning appears as a controversial issue, with basic abilities (i.e., fluid) being apparently as important as domain knowledge for skilled intellectual performance (Hambrick & Meinz, 2011).

High-level conceptual processing and domain knowledge are also important in chess, a suitable domain to study individual differences in cognitive performance related with age, individual skill, and type of task (Bilalic et al., 2008). The Elo chess rating provides a reliable and useful indicator to characterize individual differences and expert performance (Blanch, 2021; Elo, 1978; Glickman, 1995). Moreover, chess implies intensive sequential reasoning, it requires a considerable body of domain knowledge acquired from practice and study over time, and experts show a remarkable better performance than non-experts (Charness et al., 2005). Master chess players hold an overwhelmingly better ability than average players to grasp the correct decisions in complex chess problems through nearly unconscious perceptual processing (Chase & Simon, 1973). Besides, chess masters possess an extensive knowledge base about several facets of the game and an extraordinary memory for chess positions. Moreover, chess experts become more involved in chess playing and intensive practice at younger ages (Bilalic et al., 2007; Gobet & Campitelli, 2007), and perform better than non-experts regardless of time playing constraints (Blanch et al., 2020; Unterrainer et al., 2011; van Harreveld et al., 2007).

Several studies highlight the interplay of age and skill to explain individual differences in chess performance (Blanch, 2018; Blanch et al., 2015; Blanch & Llaveria, 2021; Campitelli & Gobet, 2008, 2011; Grabner et al., 2007; Horgan & Morgan, 1990). Studies with large samples support a lower decrement in performance for older skilled players with a higher tournament activity and involvement in the domain (Roring & Charness, 2007; Vaci et al., 2015). These studies consider the performance in the Elo rating, however, which is a broad measure of chess performance. With substantial variations in performance depending on age, skill, and the type of task, it may be worthwhile to examine accuracy and speed measures of performance in tasks implying basic information processing abilities and domain knowledge (Chassy & Gobet, 2011).

Aging impairs cognitive performance because of decrements in responding accuracy and speed (Salthouse, 1996). Hence, younger individuals tend to be more accurate when facing time constraints by seeking an optimal balance between speed and accuracy, whereas older individuals strive to minimize errors and gather more information before decision making at the stake of sacrificing speed (Starns & Ratcliff, 2010). The reluctance of older adults to commit errors, however, may depend on unconscious factors associated with age differences in brain white matter connectivity (Forstmann et al., 2011). In chess, older or less skilled players are also slower than younger or more skilled players at solving chess problems (van der Maas et al., 2011). On the other hand, experts tend to be more accurate and faster than non-experts in problem solving and decision-making. Expert chess players compared with non-experts are more consistent at integrating slow search and fast pattern recognition processes (Blanch et al., 2020), bear a wider knowledge base accumulated through years of practice (Gobet & Campitelli, 2007; Holding, 1992), and perform better than non-experts (Charness et al., 2005). Therefore, here we contrasted the relationships of age and skill with the performance in reasoning and knowledge chess tasks tapped with two types of measures, accuracy (ACC) and speed/accuracy trade off (SAT). In general, and for reasoning and knowledge related tasks, we expected negative associations of age and positive associations of skill with ACC and SAT performance.

Nonetheless, because reasoning tasks imply a higher degree of abstract and information processing effort, which tend to decline earlier in life, we expected a more robust association of age and skill with the performance in reasoning than in knowledge tasks when measured with SAT compared with ACC performance. Because SAT performance contemplates a constrained response time, it is plausible to assume that in reasoning tasks older or less skilled players should invest longer response latencies while being less accurate, whereas younger or more skilled players should invest shorter response latencies while being more accurate. On the other hand, because knowledge tasks require the acquisition of specialized learning and study over time, which tend to decline later in life, we expected that the response time component in SAT, while important, should be less influential in knowledge tasks compared with reasoning tasks. Hence, age and skill should associate similarly with ACC or SAT measures tapping performance in knowledge related tasks.

2 | METHOD

2.1 | Participants

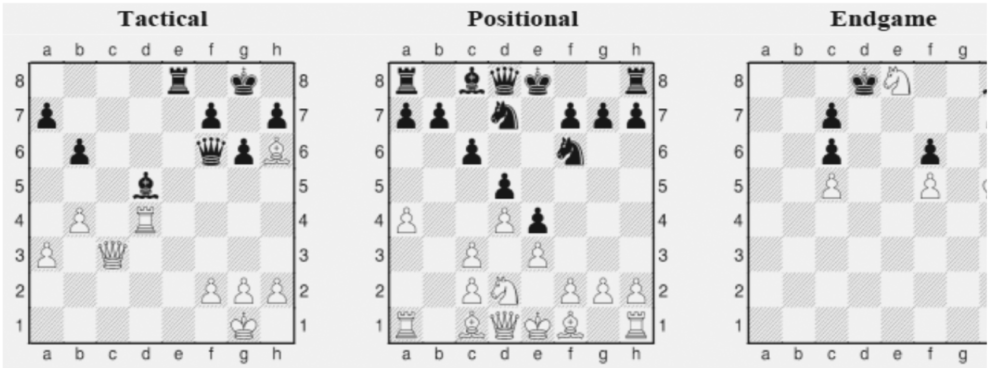
The Amsterdam Chess Test (ACT) comprehends an extensive unique data set ($n = 259$ chess players) from a chess open contest in the Netherlands in 1998, which was downloaded from a webpage[1] that is inactive nowadays, even though it is archived permanently as indicated by a reviewer.[2] This data set appears to be also available in the LNIRT R package (van der Maas & Wagenmakers, 2005). To maximize the number of available observations in all measures, two sub-samples were selected. For three measures (choose-a-move A and B, and verbal knowledge) there were complete data for 223 chess players (15 females), with a mean age of 31 years old (SD = 15) within an age range from 11 to 78 years old, and a mean FIDE Elo rating of 1867 points (SD = 292). For one measure (predict-a-move), there were 234 chess players (16 females), with the same mean age (SD) than the previous sample, an age range from 8 to 78 years old, and a mean FIDE Elo rating of 1868 points (SD = 300).

2.2 | Measures and procedure

The ACT comprises six main subtasks representing specialized skills in chess playing (van der Maas & Wagenmakers, 2005). Two tasks from the ACT were omitted, the motivation questionnaire and the recall test. The four remaining subtasks were used: the choose-a-move test (A and B), the verbal knowledge questionnaire, and the predict-a-move test (Figure 1). The main reason to select these subtasks was because the four of them comprised items tapping key facets or contents of the game, tactical, positional, and endgame (choose-a-move A and B), and opening, middle game, and endgame (verbal knowledge and predict-a-move). The choose-a-move test (A, B) were considered here as more related with information processing tasks, that is, reasoning. On the other hand, the verbal knowledge questionnaire was considered as more related with domain knowledge, whereas the predict-a-move task was considered as a global task implying reasoning and domain knowledge.

FIGURE 1 Three sample items from the Amsterdam Chess Test corresponding to reasoning and knowledge tasks.

Three items from the Choose-a-Move test (Reasoning)



Three items from the verbal Knowledge questionnaire (Knowledge)

Opening	Middle game	Endgame
One usually develops the ... first:	In the middle game a passed centre-pawn should be blocked by a:	In a rook ending with a passed pawn, the defending player should usually place the rook:
Knights Bishops Rooks Queen	Knight Rook King Queen	In the "smaller part" In the "larger part" In front of the pawn Behind the pawn

2.2.1 | Choose-a-move test A and B

These tests include typical chess problems, comprising 20 tactical items, 10 positional items, and 10 endgame items. Tactical problems involve a single move that achieves an immediate winning advantage. Positional problems relate with the strategic principles of the game implying potential winning prospects. Endgame problems represent positions arising in the final stages of a chess game with fewer remaining pieces on the board, and that imply refined techniques. A correct response to each item was scored with 1 and a wrong response with zero. The maximum response time per item was of 30 s.

2.2.2 | Verbal chess knowledge questionnaire

This test comprises 15 four-choice questions about the three main stages of a chess game, the opening, the middle game, and the endgame. Correct responses scored 1 and wrong responses zero. The maximum response time per item was of 15 seconds.

2.2.3 | Predict-a-move

This test is alike to the choose-a-move test. There are 42 chess positions corresponding, however, to a real chess game (12 items for the opening, 17 items for the middle game, and 13 items for the endgame). All these items are somehow related and each of them can bear different solutions, hence, these items were scored from 0 to 5 points according with the quality of the proposed move. The maximum response time per item was of 30 s.

The items from the three tests were presented with a computer interface in either Dutch or English language. In the choose-a-move and predict-a-move tests, participants were required to provide the best move for the white pieces corresponding to each chess problem or position, and the right answer in the verbal questionnaire within the maximum available response time (van der Maas & Wagenmakers, 2005).

2.3 | Test scoring (ACC and SAT)

A global score for each test was obtained with two types of measures, accuracy (ACC) and speed-accuracy trade-off (SAT). The descriptive statistics of the four tests in ACC and SAT are shown within Table 1. Accuracy (ACC) was determined by summing the items with a correct response, which yielded the score in the three dimensions from each specific test.

Speed-accuracy trade-off (SAT) was estimated with the correct item summed residual time scores (CISRT $= \Sigma_i ACC_i \times [MT - t_i]$), which was the SAT measure of choice in the original study of the ACT (van der Maas & Wagenmakers, 2005). The items (i) were scored considering ACC as the accuracy by assigning 0 for incorrect and 1 for correct answers, MT as the maximum completion time (30 seconds for the choose-a-move and predict-a-move items, and 15 s for the verbal chess knowledge items), and t as the actual response latency to each item. Because the CISRT taps the trade-off between speed and accuracy, it makes sense to consider the time left in items with a correct

TABLE 1 Means (M) and standard deviations (SD) for reasoning, and verbal knowledge tasks in accuracy (ACC) and speed-accuracy trade off (SAT).

	ACC			SAT		
Variable	**M**	**SD**	**α**	**M**	**SD**	**α**
Reasoning-A						
Tactical	10.52	3.64	.80	212.85	82.78	.85
Positional	3.32	1.89	.68	60.23	41.76	.73
Endgame	5.45	1.78	.60	115.59	41.78	.71
Reasoning-B						
Tactical	11.95	4.32	.86	259.18	104.76	.90
Positional	4.43	1.84	.55	84.72	41.05	.65
Endgame	4.68	1.91	.67	105.20	43.82	.74
Knowledge						
Opening	2.89	1.12	.41	22.96	10.04	.52
Middle game	3.49	1.09	.41	27.87	11.41	.64
Endgame	2.34	1.17	.33	13.22	8.87	.48
Global						
Opening	15.19	2.25	.56	280.08	46.11	.79
Middle game	18.36	5.75	.48	201.12	66.31	.69
Endgame	15.21	4.20	.57	235.31	59.77	.76

Note: Cronbach's alpha reliabilities are those reported in the original study of the Amsterdam Chess Test.

answer. The CISRT was computed for each ACT measure with the same maximum response times, 30 s for the choose-a-move tests (A, B) and predict-a-move, and 15 s for the verbal knowledge questionnaire. Hence, the results should not be affected because of different maximum response times within each respective ACT test.

2.4 | Data analyses

The association of age and the Elo rating with the reasoning and verbal knowledge tasks was evaluated with structural equation modeling (Bollen, 1989). There were two main stages. In the first stage, a confirmatory factor analysis (CFA) for the reasoning and knowledge tasks evaluated whether the ACC and SAT measures of performance represented different constructs. The ACC and SAT latent variables were specified with three observed variables comprising the tactical, positional, and endgame dimensions from the choose-a-move tests (A, B), or with three observed variables comprising the opening, middle game, and endgame dimensions from the verbal knowledge and predict-a-move tests. The ACC and SAT latent variables were specified as correlated. A model with the factor loadings constrained equal between the ACC and SAT measures was compared with a model with the factor loadings set free to covary. A significant chi-square difference test between both models would support the feasibility of a model with two distinct latent variables, ACC and SAT. A Wald test was used to evaluate the ACC and SAT factor loadings equality in all observed

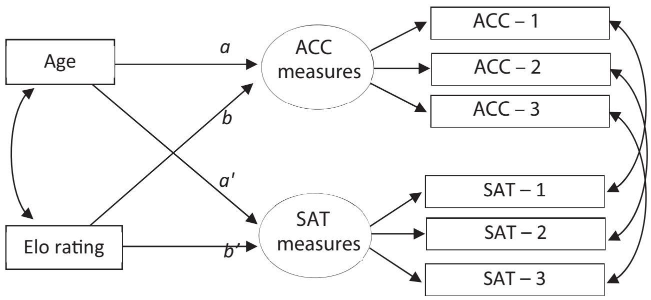


FIGURE 2 Structural equation model with age and Elo rating related with reasoning (tactical, positional, endgame), verbal knowledge, and global tasks (opening, middle game, endgame), tapped with three accuracy (ACC) and three speed-accuracy trade-off (SAT) measures. All ACC and SAT measures were correlated within each specific task, for example, Tactical (ACC) ←→ Tactical (SAT). Age and the Elo rating were negatively correlated, −.22, $p < .001$ in the reasoning and verbal knowledge tasks, and − .17, $p < .01$ in the global task).

variables. The reliability (ω_3) of the latent factors, ACC and SAT, was estimated from the observed covariance matrix (Raykov, 2005).

In the second stage, we evaluated the associations of age and the Elo rating with reasoning, knowledge, and global latent variables determined in the previous CFAs (see Figure 2). A model with equal parameters ($a = a'$, $b = b'$) between the ACC and SAT measures was compared with a model with all parameters set free to covary ($a \neq a'$, $b \neq b'$). A significant chi-square difference between both models would support differential associations of age and the Elo rating with either ACC or SAT latent variables. A Wald test evaluated the equality of the associations of age and the Elo rating with the ACC and SAT measures in reasoning, knowledge, and global tasks.

The model fit in both stages was evaluated with the comparative fit index (CFI), the Tucker-Lewis Index (TLI), and the root mean square error of approximation (RMSEA). Low and non-significant chi-square values, close to one CFI and TLI values, and RMSEA values below .09 would be indicative of a good fit to the observed data (Hu & Bentler, 1999). The models were estimated with the maximum likelihood method from the Lavaan package R software (R Development Core Team, 2014; Rosseel, 2012). The R code is provided in the supplemental material.

3 | RESULTS

Table 1 shows the descriptive statistics for ACC and SAT measures of the reasoning (tactical, positional, endgame), and knowledge and global tasks (opening, middle game, and endgame). The alpha reliabilities were acceptable for the reasoning tasks and somewhat lower for the knowledge task with ACC measures, which could be due to remarkable variations at different latent trait levels in this test (Blanch & Llaveria, 2021).

Table 2 shows the outcomes of the three CFAs with the reasoning and knowledge factors tapped with the ACC and SAT measures.

TABLE 2 Confirmatory factor analyses (CFA, 5 degrees of freedom) with different factor loadings in two types of measures of performance, accuracy (ACC) and speed-accuracy trade-off (SAT).

Performance	ACC	SAT	W	*p*-value
Reasoning-A				
Tactical	.83	.87	2.68	.1020
Positional	.76	.78	.32	.5730
Endgame	.78	.88	10.80	.0010
ω_3	.84	.89		
$\Delta\chi^2[3] = 11.37$ ($p = .0099$), $\chi^2[5] = 11.02$ ($p = .051$), CFI = .997, TLI = .990, RMSEA = .069				
Reasoning-B				
Tactical	.83	.89	7.85	.0051
Positional	.87	.86	.05	.8286
Endgame	.66	.75	16.19	.0000
ω_3	.82	.87		
$\Delta\chi^2[3] = 20.52$ ($p = .0001$), $\chi^2[5] = 17.49$ ($p = .004$), CFI = .994, TLI = .981, RMSEA = .106				
Knowledge				
Opening	.61	.69	2.70	.1005
Middle game	.68	.88	16.14	.0000
Endgame	.48	.60	8.21	.0042
ω_3	.61	.77		
$\Delta\chi^2[3] = 19.95$ ($p = .0002$), $\chi^2[5] = 4.66$ (p = .458), CFI = 1.000, TLI = 1.001, RMSEA = .000				
Global				
Opening	.59	.73	5.76	.0164
Middle game	.60	.77	10.74	.0010
Endgame	.58	.83	28.12	.0000
ω_3	.62	.82		
$\Delta\chi^2[3] = 26.33$ ($p = .0000$), $\chi^2[5] = 2.47$ ($p = .780$), CFI = 1.000, TLI = 1.008, RMSEA = .000				

Note: The reliability (ω_3) corresponds to the respective ACC and SAT latent factors. The Wald-test (W) contrasted whether ACC and SAT loadings were equal. All factor loadings were significant at the $p < .001$ level.

The reliabilities of the latent factors (ω_3) were fairly good, ranging from .61 to .84 for ACC, and from .77 to .89 for SAT, albeit lower for the ACC in the knowledge and global tasks. There was a better model fit with the different factor loadings than with the equal factor loadings constraint for the four evaluated tasks: reasoning ($\Delta\chi^2[\Delta df] = 11.37[3]$, $p = .0099$, and $\Delta\chi^2[\Delta df] = 20.52[3]$, $p = .0001$), knowledge ($\Delta\chi^2[\Delta df] = 19.95[3]$, $p = .0002$), and global ($\Delta\chi^2[\Delta df] = 26.33[3]$, $p = .0000$). Moreover, the Wald tests indicated that the factor loadings in the ACC and SAT measures differed for the tactical and endgame items in reasoning, and for the opening, middle game, and endgame items in knowledge. These outcomes supported a two latent factor model (ACC, SAT).

Table 3 shows the standardized estimates relating age and the Elo rating with the ACC and SAT measures in the reasoning, knowledge, and global tasks (Figure 2). As expected, age was associated negatively, and the Elo rating associated positively with the ACC and SAT measures in all tasks. The association of age and the Elo rating was more robust for the reasoning than for the knowledge and global tasks as highlighted by the larger coefficients of determination (R^2). As depicted in Figure 2, the model specifying different parameters ($a \neq a'$, $b \neq b'$) yielded a better fit than the model specifying equal ($a = a'$, $b = b'$) parameters for reasoning ($\Delta\chi^2[2] = 13.48$, $p = .0012$, $\Delta\chi^2[2] = 15.39$, $p = .0005$), knowledge ($\Delta\chi^2[2] = 6.56$, $p = .0378$), and global tasks ($\Delta\chi^2[2] = 24.99$, $p < .001$).

Table 3 shows in addition the Wald tests (W) comparing the association of age and the Elo rating between the ACC and SAT measures in the four tasks. These outcomes highlight the larger association of age with the reasoning tasks SAT performance, and the larger association of the Elo rating with the knowledge and global tasks ACC performance. For the reasoning tasks, age had a stronger association in the SAT measure (W = 10.74, and W = 8.78, $p = .0030$), whereas the Elo rating had a similar association with the reasoning tasks regardless of the type of measure (W = .36, and W = .34). In contrast and for the knowledge and global tasks, the Elo rating had a stronger association in the ACC measure (W = 5.00, and W = 4.16), whereas age had a similar association with the knowledge and global tasks regardless of the type of measure (W = .97, and W = 1.12).

4 | DISCUSSION

This study evaluated the interrelationship of age and individual skill with cognitive performance tapped with both accuracy (ACC) and speed/accuracy trade off (SAT) measures in the taxing intellectual

TABLE 3 Standardized parameter estimates comparing the association of age and the Elo rating with accuracy (ACC) and speed-accuracy trade-off (SAT) measures in reasoning, verbal knowledge, and global tasks.

	Reasoning-A				Reasoning-B			
	ACC	SAT	W	*p*-value	ACC	SAT	W	*p*-value
Age	−.30***	−.39***	10.74	.0010	−.24***	−.32***	8.78	.0030
Elo rating	.79***	.76***	.36	.5441	.84***	.80***	.34	.5599
R^2	.82	.85	—	—	.85	.85	—	—
$\Delta\chi^2[2]$, p		13.48, $p = .0012$				15.39, $p = .0005$		
$\chi^2[13]$, p		37.17, $p < 0.001$				37.23, $p < 0.001$		
CFI		.989				.990		
TLI		.978				.979		
RMSEA		.086				.090		
	Knowledge				**Global**			
	ACC	SAT	W	*p*-value	ACC	SAT	W	*p*-value
Age	−.20*	−.17**	.97	.3239	−.36***	−.55***	1.12	.2900
Elo rating	.62***	.53***	5.00	.0253	.74***	.51***	4.16	.0415
R^2	.48	.35	—	—	.77	.66	—	—
$\Delta\chi^2[2]$, p		6.56, $p = .0378$				24.99, $p < .001$		
$\chi^2[13]$, p		31.04, $p = .0030$				17.97, $p = .1590$		
CFI		.985				.995		
TLI		.968				.991		
RMSEA		.076				.040		

*$p < 0.05$; **$p < .01$; ***$p < .001$.

domain of chess. We contrasted the ACC and SAT performance in reasoning, knowledge, and global tasks. With reasoning tasks implying a more intensive information processing effort, we expected that both age and the Elo rating would be associated with the SAT reasoning performance. With domain knowledge and global tasks implying learning, experience, and study over time, we expected that age and the Elo rating would associate similarly with both ACC and SAT knowledge performance. The main findings suggested, however, that in the reasoning tasks only age associated more robustly with the SAT measure, whereas the Elo rating associated similarly with both ACC and SAT measures. Furthermore, in the knowledge and global tasks the Elo rating was associated more robustly with the ACC measure, whereas age associated similarly with the ACC and SAT measures.

Age-related more strongly with the SAT performance in reasoning than in knowledge and global tasks. This finding may suggest that the age is kinder to the more able hypothesis could be less consistent for reasoning than for knowledge-related tasks (Gow et al., 2012; Roring & Charness, 2007; Vaci et al., 2015). In this view, aging might take its toll even for more skilled individuals when dealing with reasoning and information processing-related tasks rather than when dealing with knowledge-related tasks. This outcome corroborates the worse performance of older compared with younger adults in tasks implying accurate and fast information processing (Bruine de Bruin et al., 2012; Frey et al., 2015). A similar trend was observed for the global task in SAT performance, which showed the larger negative association with age ($\beta = -.55$, $p < .001$), even though it was analogue to ACC performance.

The higher ability of more expert players in finding the best continuation in chess positions or problems and their overwhelmingly extensive knowledge base is a well-established outcome (de Groot, 1965; Moxley et al., 2012). Therefore, the larger associations of individual skill (i.e., Elo rating) than age with the evaluated tasks make sense within the domain of chess. Hence, although the main outcomes highlight impaired performance with aging, they also suggest eventual protective effects at higher levels of expertise. More skilled players might buffer the aging effects on performance because of having more cognitive resources, better learning abilities, more opportunities for learning, longer careers within the domain (Blanch, 2018; Chase & Simon, 1973; Gobet, 1998; Pfau & Murphy, 1988), or higher domain activity (Roring & Charness, 2007; Vaci et al., 2015). The Elo rating related strongly with performance in the reasoning task. Nevertheless, whereas the association of the Elo rating with reasoning was very similar in both ACC and SAT measures, it was larger in the ACC measure in the knowledge and global tasks. Alternatively, this pattern of relationships could be due to the higher reliabilities of the reasoning tasks, even though the reliabilities for the latent factors representing knowledge tasks (Table 3, ω_3) improved considerably when compared with the reliabilities of the single knowledge measures (Table 1). In any case, this outcome suggests that individual skill may be particularly important for knowledge related tasks where practice, study, and experience play a significant role in performance.

Taken together, the outcomes are somehow congruent with the reported association of age and individual skill with fluid and crystallized abilities (Frey et al., 2015). Fluid abilities decline with age at a faster pace than crystallized abilities, which in contrast show a more stable pattern particularly for more skilled individuals (Baltes, 1987; Cattell, 1987). In addition, the larger association between the Elo rating with the reasoning tasks than with the verbal knowledge and global tasks was somehow consistent with the investment of fluid abilities in subsequent learning and the acquisition of knowledge and skills through experience over time (Blanch, 2015; Cattell, 1987; Kvist & Gustafsson, 2008). Reasoning tasks may underlie in a great extent the essence of the game of chess as a general ability (Blanch et al., 2017) reflecting a complex mixture of quick information processing, memory, sequential reasoning abilities, and knowledge acquired with practice and experience. Controversial debate has arisen, however, on whether individual differences in chess performance depend on practice alone (Ericsson & Moxley, 2012; Howard, 2012b).

Age and skill related with performance in different ways depending on task content but also depending on whether performance was measured with accuracy (ACC) or with speed/accuracy trade off (SAT). Age and skill related more robustly in the expected directions (negatively and positively) with performance in tasks emphasizing quick information processing and calculation of different combinations when solving typical chess problems. It has been suggested, however, that in such chess reasoning tasks accumulated knowledge may be more important with endgame items than with tactical items (van der Maas et al., 2011). Hence, chess reasoning tasks also imply a certain degree of consolidated knowledge and practical experience within the domain. On the other hand, age and skill were also important for tasks emphasizing specialized domain knowledge, which is generally acquired over time with practice and study (Campitelli & Gobet, 2011; Hambrick et al., 2014; Howard, 2012a).

The scores in reasoning and, knowledge, and global performance from the ACT, were obtained with a scoring rule to capture the speed-accuracy trade off, and with the participants being instructed to respond with both accuracy and speed (van der Maas & Wagenmakers, 2005). The correct item summed residual time (CISRT) renders, however, higher scores for faster than for slower correct responses, a scoring scheme that has been criticized because of being prone to guessing. Alternatively, the signed residual time (SRT) subtracts residual time with incorrect responses (Maris & Van der Maas, 2012). There are other methods to evaluate the speed-accuracy trade-off in the evaluation of cognitive performance (Estrada et al., 2017; Liesefeld & Janczyk, 2019), while instructions either emphasizing accuracy or speed could affect construct and criterion validity (Ackerman & Ellingsen, 2016). Henceforth, and bearing in mind the higher predisposition of older individuals to accuracy than to speed, different results could arise with scoring rules weighting speed and accuracy in different ways.

There is a considerable degree of variability in cognitive performance depending on age, individual skill, and the nature and content of the evaluated tasks. The current findings from the intellectually demanding domain of chess suggest that the interrelationships amongst such factors are likely to vary with the type of evaluated skills (i.e., information processing, knowledge), but also with the kind of measurement of performance being assessed, accuracy (ACC) or speed-accuracy trade-off (SAT).

4.1 | Open practices statement

The data and methods are detailed within this manuscript. Software code to reproduce the analyses is available in Data S1. The experiments were not preregistered.

AUTHOR CONTRIBUTIONS

Angel Blanch: Project administration; conceptualization; writing – original draft preparation; writing – reviewing and editing; data curation; methodology. **Albert Martínez:** Writing – reviewing and editing; formal analysis; methodology; software; validation; visualization.

ACKNOWLEDGMENTS

This research was done with the support of the Faculty of Education, Psychology and Social Work at the University of Lleida, and the County Council of Lleida (Diputació de Lleida, Award number: 202100063). This research was performed within the Catalonian Consolidated Research Group SGR 2021 SGR 01423.

CONFLICT OF INTEREST STATEMENT

The authors declare that they have no conflict of interest.

DATA AVAILABILITY STATEMENT

Code is provided in the supplemental material. Data are available upon request.

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ENDNOTES

[1] https://hvandermaas.socsci.uva.nl/Homepage_Han_van_der_Maas/Chess_Psychology.html.

[2] https://web.archive.org/web/20050903232725fw_/http://users.fmg.uva.nl/hvandermaas/chesshtml/act.htm.

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SUPPORTING INFORMATION

Additional supporting information can be found online in the Supporting Information section at the end of this article.

How to cite this article: Blanch, A., & Martínez, A. (2023). Age and skill in chess: Accuracy and speed-accuracy performance in reasoning and knowledge. *Applied Cognitive Psychology*, 1–9. https://doi.org/10.1002/acp.4062