Intelligence 100 (2023) 101781

Contents lists available at ScienceDirect

Intelligence

journal homepage: www.elsevier.com/locate/intell

The association between intelligence and financial literacy: A conceptual and meta-analytic review

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ARTICLE INFO

Keywords:
Financial literacy
Cognitive ability
Intelligence
Comprehension knowledge
Numeracy

ABSTRACT

Financial literacy is positively associated with intelligence, with typically moderate to large effect sizes across studies. The magnitude of the effect, however, has not yet been estimated meta-analytically. Such results suggest financial literacy may be conceptualised as a possible cognitive ability within the Cattell-Horn-Carroll (CHC) model of cognitive abilities. Consequently, we present a psychometric meta-analysis that estimated the true score correlation between cognitive ability and financial literacy. We identified a large, positive correlation with general intelligence ($r' = .62$; $k = 64$, $N = 62{,}194$). We also found that financial literacy shared a substantial amount of variance with quantitative knowledge (*Gq*; via numeracy; $r' = .69$; $k = 42$, $N = 35{,}611$), comprehension knowledge (crystallised intelligence; *Gc*; $r' = .48$; $k = 14$, $N = 10{,}835$), and fluid reasoning (fluid intelligence; *Gf*; $r' = .48$; $k = 20$, $N = 15{,}101$). Furthermore, meta-analytic structural equation modelling revealed *Gq* partially mediated the association between cognitive ability (excluding *Gq*) and financial literacy. Additionally, both *Gc* and *Gq* had significant direct effects on financial literacy, whereas the total effect of *Gf* on financial literacy was fully mediated by a combination of *Gc* and *Gq*. While the meta-analyses provide preliminary support for the potential inclusion of financial literacy as primarily a *Gc* or *Gq* ability within the CHC taxonomy (rather than *Gf*), the review revealed that very few studies employed comprehensive cognitive ability measures and/or psychometrically robust financial literacy tests. Consequently, the review highlighted the need for future factor analytic research to evaluate financial literacy as a candidate for inclusion in the CHC taxonomy.

1. Introduction

Financial literacy is often conceived of as a specific form of human capital that encompasses knowledge and skills regarding the understanding and use of personal finance (Huston, 2010). Financial literacy has become increasingly important for several reasons, including increases in requirements for individual retirement planning, the greater availability of financial products to the general public, the development of the gig economy, and advances in financial technology (Campbell, 2006; Lusardi & Mitchell, 2014; Morgan, Huang, & Trinh, 2019; Organisation for Economic Co-operation and Development, 2018). Correspondingly, individual differences in financial literacy have been found to predict a number of important phenomena, including engagement in financial planning, stock market participation, financial resilience to economic crises, and optimal selection of financial products (Klapper, Lusardi, & Panos, 2013; Lusardi & Scheresberg, 2013; Van Rooij, Lusardi, & Alessie, 2011).

Furthermore, research has reported on the association between cognitive ability and financial literacy (e.g., Gerrans, Asher, & Earl, 2022; Li, Baldassi, Johnson, & Weber, 2013). The degree to which cognitive ability is associated with financial literacy, as well as why the correlation exists (e.g., mediators), is important to determine, in order to help our understanding of the acquisition, maintenance, and potential improvement (training) of financial literacy. However, this research has yet to be reviewed systematically or quantitatively, hence the impetus for the present meta-analytic review. We also explore the possibility that quality of cognitive ability measurement (based on the number of tests, number of dimensions, test length, and face validity) may be a potential moderator of the effect. To foreshadow, we hypothesise that financial literacy may be conceptualised as primarily a crystallised ability within the Cattell-Horn-Carroll (CHC) theories, a conceptualisation that has policy implications (e.g., potential utility of financial literacy training interventions).

In the following, we (1) define cognitive ability and describe the CHC

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https://doi.org/10.1016/j.intell.2023.101781
Received 28 March 2023; Received in revised form 22 June 2023; Accepted 3 July 2023
Available online 8 August 2023

Table 1
Stratum II abilities with theoretical linkages to financial literacy.

Narrow Ability	Definition	Example Test
Comprehension–Knowledge (*Gc*)		
Ability to comprehend and communicate culturally valued knowledge. Includes the depth and breadth of both declarative and procedural knowledge, and skills such as language, words, and general knowledge developed through experience, learning and acculturation.		
General knowledge (K0)	The breadth and depth of knowledge considered essential, practical, or worthwhile for everyone in a culture to know.	WJ General Information
Language development (LD)	Ability to comprehend language and use it to communicate; the general understanding of spoken language at the level of words, idioms, and sentences. Intermediate factor between *Gc* and VL, LS, CM, and MY.	D-KEFS Proverb Test
Lexical knowledge (VL)	Knowledge of the definitions of words and the concepts that underlie them (i.e., vocabulary).	WAIS Vocabulary
Listening ability (LS)	The ability to understand speech. Starts with comprehending single words and increases to long complex verbal statements.	WJ Oral Comprehension
Communication ability (CM)	The ability to use speech to communicate effectively.	KBNA Picture Description Oral
Grammatical sensitivity (MY)	Awareness of the formal rules of grammar and morphology of words in speech	DAB-3 Grammatic Completion
Fluid Reasoning (*Gf*)		
The use of deliberate and controlled procedures (often requiring focused attention) to solve novel, “on-the-spot” problems that cannot be solved by using previously learned habits, schemas, and scripts.		
Induction (I)	Ability to observe a phenomenon and discover the underlying principles or rules that determine its behaviour (i.e., rule inference).	Matrix Reasoning
General Sequential Reasoning (RQ)	Ability to reason logically using known premises and principles (i.e., deductive reasoning or rule application).	WJ Analysis-Synthesis
Quantitative Reasoning (RG)	Ability to reason with quantities, mathematical relations, and operators.	Number Series
Quantitative knowledge (*Gq*)		
The depth and breadth of declarative and procedural knowledge related to mathematics.		
Mathematical knowledge (KM)	Range of general knowledge about mathematics, not the performance of mathematical operations or the solving of math problems	WJ Quantitative Concepts (Concepts subtest)
Mathematical achievement (A3)	Measured (tested) mathematics achievement	WJ Calculation

Note. Definitions are from Schneider and McGrew (2018). Key narrow stratum I abilities within in each broad stratum II ability are indicated in italics. Example tests selected from classifications in Flanagan, Ortiz, and Alfonso (2013). D-KEFS = Delis-Kaplan Executive Function System; WAIS = Wechsler Adult Intelligence Scale; WJ = Woodcock-Johnson; KBNA = Kaplan-Baycrest Neuropsychological Assessment; DAB-3 = Diagnostic Achievement Battery 3.

theories; (2) define financial literacy; (3) review some of the published associations between cognitive ability and financial literacy to establish the need for a quantitative review; (4) explore why cognitive ability measurement quality may potentially moderate the association between cognitive ability and financial literacy; and (5) examine the unique contributions of broad cognitive abilities to financial literacy and suggest why positive associations may exist. Finally, we present a meta-analytic review of the empirical literature on the association between cognitive ability and financial literacy.

1.1. Cattell-Horn-Carroll (CHC) theories of cognitive abilities

At a high level of abstraction, cognitive ability (or intelligence) has been defined as the ability to adapt to any environmental context (Pintner, 1921; Sternberg, 1997). Operationally, it refers to “…an entity's maximal capacity to complete a novel, standardised task with veridical scoring using perceptual-cognitive abilities” (Gignac, 2018, p. 440). Arguably, the most widely adopted taxonomy of cognitive abilities is the CHC theories (McGrew, 2023), which integrates multiple overlapping theories including Spearman (1904) general cognitive ability (*g*), the extended Gf-Gc model (Horn & Blankson, 2005; Horn & Cattell, 1966) and Carroll's (1993) three-stratum model (McGrew, 1997).

The CHC taxonomy is a framework that conceptualises cognitive abilities within a three-stratum hierarchical model (McGrew, 2005; McGrew, 2009; Schneider & McGrew, 2012; Schneider & McGrew, 2018). At stratum I, there are over 80 narrow abilities that align to specific tasks or tests, for example, lexical knowledge (VL) could be assessed by a vocabulary test of knowledge of the definition of words (Schneider & McGrew, 2018). Broad abilities at stratum II represent highly-correlated clusters of narrow abilities including: fluid reasoning (*Gf*), working memory capacity (*Gwm*), learning efficiency (*Gl*), retrieval fluency (*Gr*), processing speed (*Gs*), reaction and decision speed (*Gt*), comprehension-knowledge (*Gc*), domain-specific knowledge (*Gkn*), reading and writing (*Grw*), quantitative knowledge (*Gq*), visual processing (*Gv*), and auditory processing (*Ga*); and tentatively: psychomotor speed (*Gps*), olfactory abilities (*Go*), tactile abilities (*Gh*), kinesthetic abilities (*Gk*), psychomotor abilities (*Gp*), and emotional intelligence (*Gei*; McGrew, 2009; Schneider & McGrew, 2018). Examples of narrow stratum I ability clusters associated with broad stratum II abilities can be seen in Table 1[1]. Finally, at stratum III is general intelligence, *g* (Schneider & McGrew, 2018). We discuss the broad stratum II abilities of interest (i.e., *Gf, Gc, Gkn,* and *Gq*), as well as their theoretical linkages to financial literacy, in detail in a later section of this introduction.

Although there is some disagreement in the literature (see Johnson & Bouchard, 2005; Sternberg, 1999), all cognitive abilities could theoretically be conceptualised and categorised within the CHC taxonomy. Further, the CHC theories is an evolving framework, and it is acknowledged that future revisions are required as new evidence accrues (Schneider & McGrew, 2018; Wilhelm & Kyllonen, 2021). Accordingly, we suggest financial literacy could be considered for potential classification as a stratum I ability, contingent upon its associations with other established cognitive abilities, as well as other criteria, as we describe below (see Schneider & McGrew, 2018).

1.2. Financial literacy

Definitions of financial literacy in the literature vary in conceptual breadth. A number of reviews have identified several, arguably distinct, concepts within definitions of financial literacy, including knowledge,

[1] For more information associated with the stratum II abilities not described in this paper (e.g., definitions, included stratum I abilities, and further details), see the summary in Schneider and McGrew (2018).

ability or skills to apply knowledge, numeracy, behaviours, attitudes, motivation, decision-making, and confidence (e.g., Hung, Parker, & Yoong, 2009; Huston, 2010; Remund, 2010; Titko & Lace, 2013). Remund (2010) provided the following comprehensive definition of financial literacy: "Financial literacy is a measure of the degree to which one understands key financial concepts and possesses the ability and confidence to manage personal finances through appropriate, short-term decision-making and sound, long-range financial planning, while mindful of life events and changing economic conditions" (p. 284). However, comprehensive conceptualisations that take a holistic view of what it is to be financially literate are incongruent with the knowledge measures that are typically used to assess financial literacy (Fernandes, Lynch Jr, & Netemeyer, 2014). Further, it is arguably inappropriate to include antecedents and consequences as definitional characteristics of financial literacy, while simultaneously investigating them as correlates (MacKenzie, 2003). Therefore, from a construct validity and psychometric perspective, narrower definitions of financial literacy are more defensible; for example: "…knowledge of…financial concepts..." (Lusardi, 2008, p. 2). While financial decision-making competence and money values may be predictors or outcomes of financial literacy, attitudes and outcomes do not constitute financial literacy itself (Finke & Huston, 2014; Hung et al., 2009). Further, related dimensions such as financial decision-making (e.g., making optimal credit card repayments) and financial behaviours (e.g., staying within a budget) have been found to be impacted by non-cognitive factors, such as emotion and motivation (Eberhardt, Bruine de Bruin, & Strough, 2019). Therefore, for the purposes of this review, we consider the combination of financial literacy, money values, financial decision-making, and financial behaviours as better conceptualised as dimensions of *financial capability* (Xiao, Huang, Goyal, & Kumar, 2022). Accordingly, financial capability may be considered an aptitude complex rather than a cognitive ability (Snow, 1991). As an aptitude complex, the contextual factors comprising financial capability such as motivation, confidence, values, and decision-making competence - in addition to financial literacy - are considered when accounting for financial behaviours and outcomes (Snow, 1991; Wilhelm & Kyllonen, 2021). Stated alternatively, financial capability is a holistic conceptualisation of the factors that impact an individual's ability to put their financial literacy into practice.

In light of the above, we define financial literacy relatively narrowly in a format analogous to stratum I ability *general knowledge* (i.e., K0; Schneider & McGrew, 2018), so as to facilitate a clearer understanding of the nature of the results. Correspondingly, we define financial literacy as the breadth and depth of knowledge of personal finance concepts and principles considered essential, practical, or beneficial for everyone in a culture[2] to know. Specifically, this includes common knowledge to most members of a society or information that most adults would have been exposed to related to budgeting (e.g., tracking expenses), saving (e.g., compound interest, time value of money), borrowing (e.g., credit cards, mortgages), investing (e.g., stocks, bonds, mutual funds), and protecting resources (e.g., diversification, insurance; as identified in Huston, 2010; Remund, 2010; Titko & Lace, 2013). The breadth and depth of financial literacy covers personal finance knowledge that is valuable to all members of a particular society, regardless of occupation, and excludes expertise required for finance- and economics-related professions. For example, understanding how inflation impacts the value of money over time (e.g., knowing that if the inflation rate exceeds the interest rate on a savings account, that the buying power of the money in the account decreases over time) is within the scope of financial literacy, whereas understanding the broader economic impacts on inflation (e.g., labour productivity) is not. Further, dimensions related to financial capacity (i.e., the ability to manage one's personal finances independently from a medical and legal standpoint; Marson, Triebel, & Knight, 2012), such as being able to count cash, calculate the amount of change when purchasing items with different banknotes or coins, or read a cheque or receipt are excluded from the definition of financial literacy.

Accordingly, tests of financial literacy considered potentially useful for our meta-analysis were those that included questions that assessed the comprehension of terms and the application of principles to hypothetical scenarios in the context of budgeting, saving, borrowing, investing, and protecting resources (Huston, 2010; Remund, 2010; Titko & Lace, 2013). Studies were included regardless of their administration methodology (e.g., online, paper, in-person interview, phone interview). Non-performance measures based on self-rated financial literacy, financial behaviours, or financial outcomes, were excluded from this meta-analytic review.

It should be noted that current measures of financial literacy vary in quality, as several include too few items to achieve respectable levels of internal-consistency reliability (see Gignac & Ooi, 2022). The *Big Three* (includes three questions based on the time value of money, compound interest, and diversification; Lusardi & Mitchell, 2011) and *Big Five* (Hastings, Madrian, & Skimmyhorn, 2013) financial literacy measures are arguably the most commonly used measures of financial literacy, due to their brevity, history, and inclusion in large publicly available data sets. However, consistent with Gignac and Ooi (2022), Huston (2010) noted that tests with fewer items (e.g., the Big Three) do not capture the full spectrum of financial literacy. Additionally, Gignac and Ooi (2022) recommended the measurement of financial literacy with at least 13 questions, in order to achieve adequate test score reliability. While brief measures were designed to fit within the constraints of larger national surveys (e.g., Lusardi & Mitchell, 2011), they are, nonetheless, psychometrically limited. Thus, the variation in the magnitude of the reported correlations between financial literacy and cognitive ability across studies likely reflects, in part, the variation in construct validity, as well as internal-consistency reliability of the financial literacy and cognitive ability test scores. Therefore, a comprehensive psychometric meta-analysis (i.e., correlations disattenuated for imperfect reliability) appears warranted to help evaluate the true score association between financial literacy and cognitive ability. We next review some of the empirical literature pertinent to the association between cognitive ability and financial literacy to date and make a case for the consideration of financial literacy as a stratum I ability.

1.3. CHC theories and financial literacy

Financial literacy has been found to be positively associated with cognitive ability to varying degrees. For example, Stanovich, West, and Toplak (2016) reported a positive correlation of .63 ($N = 747$) between scores on a 30-item financial literacy measure and Comprehension-knowledge (*Gc*) composite scores (i.e., analogy, antonym, and vocabulary tasks). In another study, Bucher-Koenen and Ziegelmeyer (2011) found that financial literacy correlated positively with the 3-item Cognitive Reflection Test (CRT) at .29 ($N = 2{,}012$). As a final example, Llados-Masllorens and Ruiz-Dotras (2022) reported a significant correlation of .17 ($N = 205$) between the Big Three and the CRT. This brief review suggests that financial literacy may be associated positively with cognitive ability and the magnitude of the effect appears to be between typical and relatively large, based on Gignac and Szodorai's (2016) correlation guidelines. Consequently, we conducted a meta-analytic investigation of the association between composite cognitive ability (*g*) and financial literacy. Acknowledging that *Gq* may be considered a cognitive ability or achievement (i.e., ACH-*g*) domain distinct from general cognitive ability (i.e., COG-*g*; Kaufman, Reynolds, Liu, Kaufman, & McGrew, 2012), we also estimated a meta-analytically derived correlation between composite cognitive ability excluding *Gq* (*g*-ex*Gq*) and financial literacy.

[2] As in the case of general knowledge, specific financial literacy concepts may differ between cultures, depending on the respective available products, laws, policies, and/or practices (e.g., religion).

1.3.1. Cognitive ability test quality

Previous meta-analytic intelligence research suggests that cognitive ability test quality may be a potential moderator of the association between cognitive ability and a criterion (e.g., Gignac & Bates, 2017; Walker, Palermo, Callis, & Gignac, 2023). Gignac and Bates (2017) identified four categories of cognitive ability measurement quality (*poor* = 1, *fair* = 2, *good*= 3, *excellent* = 4) based on the number of tests administered, number of CHC stratum II ability dimensions represented, test duration, and anticipated correlation with *g*. To account for brief measures and correlation with *g*, Gignac and Bates' (2017) expanded on Jensen's (1998) recommendation that cognitive ability test batteries should include at least nine tests and three dimensions, and specified that *excellent* measures should be at least 40 minutes long and correlate with *g* at ≥ .95. *Good* cognitive ability test batteries measure two to three dimensions of cognitive ability, based on two to eight tests, have a testing duration of 20-39 minutes, and correlate with *g* between .72 and .94 (Gignac & Bates, 2017).

As an example, the cognitive ability measures employed by Noon and Fogarty (2007) may be considered good quality, as they administered three tests that measured three dimensions (*Gf, Gc,* and *Gq*). *Fair* measures of cognitive ability include up to two tests on one or two dimensions, for 10-19 minutes, and correlate with *g* between .50 and .71 (Gignac & Bates, 2017). Accordingly, the cognitive ability test battery included in the forementioned study by Stanovich et al. (2016) may be considered *fair*, as the three tests measured only one dimension of cognitive ability. By contrast, *poor* quality cognitive ability tests are based on a single, brief measure (three to nine minutes long) as a proxy for *g*, correlating with *g* at ≤ .49. For example, the CRT is a brief three-item measure of cognitive ability that is commonly included in financial literacy surveys (e.g., Bucher-Koenen & Ziegelmeyer, 2011; Llados-Masllorens & Ruiz-Dotras, 2022) and has been found to have relatively poor reliability (average reliability estimate: .61; $k = 12$; Otero, Salgado, & Moscoso, 2022). Consequently, many cognitive ability and financial literacy studies may be considered to have employed poor measures, based on Gignac and Bates' (2017) guidelines. Therefore, it was considered useful to conduct a comprehensive review of the cognitive ability measurement quality in the area of financial literacy. Further, Gignac and Bates' (2017) found that cognitive ability measurement quality moderated the association between cognitive ability and brain volume. Specifically, each increase in quality rating was associated with a .08 increase in the corrected correlation. Additionally, Walker et al. (2023) found the same moderated effect (.08) in a meta-analysis of the association between cognitive ability and face memory. Thus, we hypothesised that cognitive ability measurement quality may moderate positively the association between cognitive ability and financial literacy.

1.3.2. Stratum II abilities and financial literacy

In addition to cognitive ability test quality, the variability in effect size between existing studies likely reflects the different cognitive ability dimensions (i.e., stratum II abilities) that have been tested. Furthermore, larger effects observed with measures of *Gc*, as described in greater detail below, suggest that financial literacy may be a *Gc* ability. Correspondingly, some researchers have acknowledged financial literacy as a probable facet of *Gc* (e.g., Gignac, Gerrans, & Andersen, 2023; Gerrans et al., 2022; Dohmen, Falk, Huffman, & Sunde, 2018; Hershey, Austin, & Gutierrez, 2015; Gc_{FL} [Li et al., 2013; Li et al., 2015]). Additionally, Fogarty and MacCarthy (2006; $N = 126$) found that *Gf, Gc,* and *Gq* accounted for 28% of the variance in financial literacy scores (15% when controlling for demographic variables), with *Gc* and *Gq* contributing unique variance (reported in Noon & Fogarty, 2007). Building on this research, we posit that, theoretically, financial literacy may be considered a stratum I cognitive ability, potentially within the *Gc* broad ability domain of the CHC taxonomy, though other broad domains may also be involved (e.g., *Gf* and *Gq*).

1.3.3. Comprehension-knowledge (Gc) and financial literacy

Comprehension-knowledge (*Gc*; also known as crystallised intelligence) represents intellectual tasks that require skill based on the application of prior learning (experiential-educative-acculturation influenced; Cattell, 1963; Horn & Cattell, 1966). *Gc* abilities are developed through typical exposure to culture, language, formal and informal education, and general life experiences (Newton & McGrew, 2010). In the context of financial literacy, individuals are exposed to financial concepts through their everyday interactions with media (e.g., news, podcasts, social media), use of financial products (e.g., banking, financial technology), and/or general discussion (e.g., with parents as children, friends, colleagues), through a process of financial socialisation (Ward, 1974; Hilgert, Hogarth, & Beverly, 2003; Sohn, Joo, Grable, Lee, & Kim, 2012; Tang & Peter, 2015; Rudeloff, 2019; included in Fig. 1). Accordingly, it may not be appropriate to consider financial literacy to be a domain specific knowledge (*Gkn*) ability (i.e., knowledge and expertise in specialised domains acquired through motivated effort; Newton & McGrew, 2010), due to the prevalence and exposure to financial information in everyday life. Additionally, while Schneider and McGrew (2018) do not explicitly refer to financial literacy in their description of the CHC theories, "budgeting" is listed as an example of general knowledge that forms part of *Gc* rather than *Gkn*, as it is "… considered important for any member of the population to know" (p. 119). Consequently, financial literacy may be tentatively classified, at least theoretically and in part, as a *Gc* ability in the CHC taxonomy. Arguably, individuals with higher levels of cognitive ability (e.g., prior knowledge, vocabulary) will be better able to learn, retain (i.e., crystallise), comprehend, and communicate the concepts and principles they are exposed to, and be more knowledgeable (i.e., financially literate) as a result (Plomin & Petrill, 1997; Gignac, 2018; i.e., see the indirect effect of *Gf* and direct effect of *Gc* on financial literacy depicted in Fig. 1). Further, people's level of *Gc* may predispose them to opportunities to learn about financial literacy (e.g., exposure) as a result of a general interest in learning or interest in an adjacent content area (e.g., mathematics; Ackerman & Heggestad, 1997; Hambrick, Pink, Meinz, Pettibone, & Oswald, 2008; Ackerman, 1996; Ackerman, Bowen, Beier, & Kanfer, 2001). In addition to having similar modes of acquisition, developmental evidence for financial literacy across the lifespan follows the same pattern as *Gc*, peaking at age 45-54, whereas *Gf* peaks at age 20-24 and declines steadily into old age (Finke, Howe, & Huston, 2017; Hartshorne & Germine, 2015; Kaufman, 2001). Consequently, we present meta-analytic estimates of the associations between *Gc* and financial literacy and *Gf* and financial literacy.

1.3.4. Fluid reasoning (Gf) and financial literacy

Fluid Reasoning (*Gf*; also known as fluid intelligence) represents intellectual tasks that require concept formation and attainment, reasoning, and abstracting in novel situations where prior learning is no benefit (biologically influenced; Cattell, 1963; Horn & Cattell, 1966). Such cognitive processes may play a role in the acquisition of financial literacy (Willis, Rohwedder, Kézdi, & Hudomiet, 2014). Cattell's (1987) investment theory of cognitive abilities suggests that the extent to which an individual can learn complex content (e.g., financial literacy) is dependent on their level of *Gf*, such that *Gc* is an outcome of *Gf*. The associations between *Gf* and *Gc, Gq,* and financial literacy in Fig. 1 illustrate the investment of *Gf* in the acquisition of knowledge (i.e., *Gc*, *Gq,* and financial literacy). Financial literacy development begins in childhood as children are exposed to, gain experience with, and develop

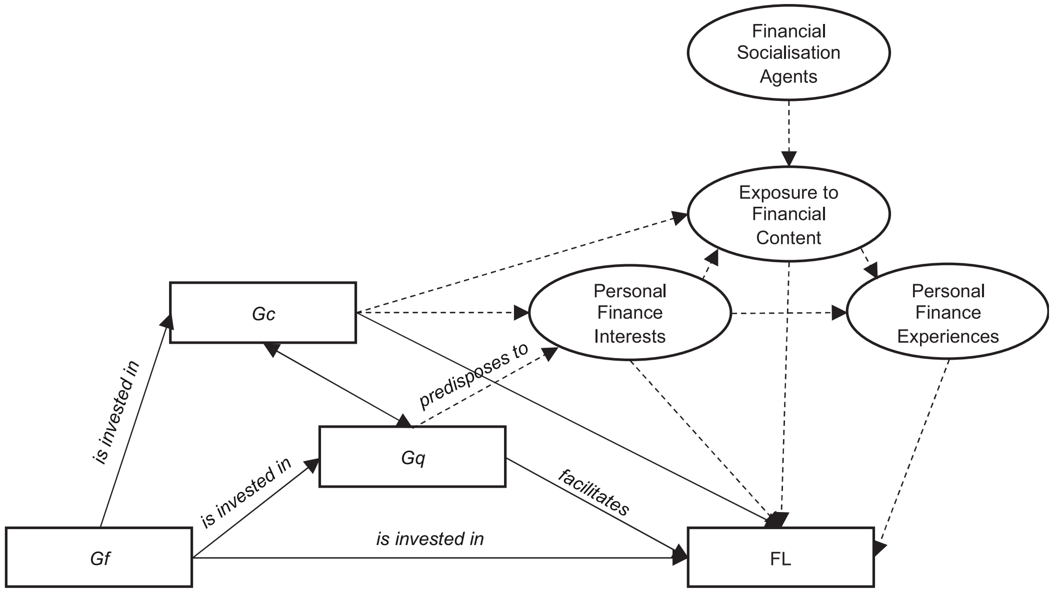


Fig. 1. Hypothesised associations between cognitive abilities and financial socialisation processes in the acquisition of financial literacy.
Note. Gf = fluid reasoning; *Gc* = comprehension-knowledge; *Gq* = quantitative knowledge; FL = financial literacy. Model integrates financial socialisation research with the investment theory of intelligence (Cattell, 1987); process, personality, interests, and knowledge model (Ackerman, 1996); and supportive knowledge hypothesis (Ackerman et al., 2001). Relationships are adapted from the structural equation model in Hambrick et al. (2008) and the path model in Beier and Ackerman (2005). Solid lines indicate the path analytic model of cognitive abilities we tested in the current study. Dotted lines indicate the theoretical relationships with non-ability factors.

an understanding of money, transactions, pocket money/income, and banking (Agnew, 2018; Berti & Bombi, 1981; Furnham & Cleare, 1988; Lewis & Scott, 2000). Through everyday exposure to financial content, engagement in managing personal finances, or receiving financial education, *Gf* is *invested* in these learning situations, which in turn, impacts the level of financial literacy (i.e., *Gc*). These financial socialisation experiences provide opportunities for the identification of financial concepts and formation of schemas (Leiser, 1983). Inductive and deductive reasoning abilities (i.e., *Gf*) facilitate the understanding of relationships between these concepts, prediction of outcomes, identification and correction of inconsistencies, and organisation of an integrated system of crystallised financial literacy knowledge (i.e., *Gc*; Leiser, 1983; Furnham & Cleare, 1988; Cattell, 1987). Consequently, we would expect *Gf* to be positively correlated with financial literacy as a marker of learning capacity (Fogarty & MacCarthy, 2006).

Based on data from the Cognitive Economics (CogEcon) and Cognitive and Ageing (CogUSA) linked studies, number series scores were positively correlated with scores on a 13-item financial literacy test at $r = .40$ ($N = 825$; Willis et al., 2014). Similarly, other studies have yielded large correlations between financial literacy and progressive matrices (e.g., $r = .29$; $N = 418$; Li et al., 2015) and Shipley's abstraction test (e.g., $r = .37$; $N = 94$; Noon & Fogarty, 2007). Notably, in the latter examples, numerically larger correlations were observed between financial literacy and *Gc* measures such as the Wechsler Adult Information Scale information subtest ($r = .40$; Li et al., 2015) and Shipley's vocabulary test ($r = .42$; Noon & Fogarty, 2007). Further, factor analytic research by Li et al. (2013; $N = 336$) found that financial literacy test items yielded higher factor loadings on *Gc* than *Gf*. This structural evidence is consistent with the conceptualisation of financial literacy as a *Gc* ability, as we would expect financial literacy to be more highly correlated with other *Gc* dimensions than *Gf*. Accordingly, it may be hypothesised that the association between *Gf* and financial literacy may be mediated, partially or wholly, by *Gc* (as indicated in Fig. 1), a hypothesis we tested via meta-analytic structural equation modelling.

1.3.5. *Quantitative knowledge (Gq) and financial literacy*

Quantitative knowledge (*Gq*) refers to the acquired knowledge[3] and performance of mathematical operations (Newton & McGrew, 2010). Theoretically, financial literacy should be related to *Gq*, as it inherently includes quantitative units such as those related to money, time, and interest. To our knowledge, only three studies have reported the correlation between financial literacy and a measure of *Gq* as conceptualised in the CHC taxonomy (i.e., the Wide Range Achievement Test 4 Math Computation; $r = .26$; $N = 105$; Demakis, Szczepkowski, & Johnson, 2019; $r = .36$; $N = 88$; Sunderaraman, Barker, Chapman, & Cosentino, 2022; $r = .47$; $N = 50$; Solesbee, 2015). However, many studies have reported positive correlations between numeracy and financial literacy, though they vary in magnitude. For example, Fernandes et al. (2014) reported correlations of $r = .50$ ($N = 543$) to $r = .63$ ($N = 506$) between a 13-item financial literacy measure and an 11- and 8-item numeracy measure, respectively. By contrast, Hardy (2015) reported a correlation of $r = .14$ ($N = 238$) between the Big Three and a 7-item numeracy measure with questions from the Berlin Numeracy Test (BNT) and the Lipkus Numeracy Scale (Cokely, Ghazal, Galesic, Schulz, & Garcia-Retamero, 2012; Lipkus, Samsa, & Rimer, 2001). Due to significant research interest in the association between numeracy and financial literacy, we have included numeracy in our study as a proxy for *Gq*.

Theoretically, numeracy and *Gq* may be considered inter-related but distinct constructs. *Gq* represents the acquired mathematical knowledge itself, whereas reasoning with this knowledge represents *Gf* (i.e.,

[3] While *Gc* and *Gq* are described as separate constructs, it should be noted that *Gc, Gkn, Gq*, and *Grw* are not technically distinct broad abilities in the CHC taxonomy and may be conceptualised as part of a higher order acquired knowledge factor (Schneider & McGrew, 2012; Schneider & McGrew, 2018). Consequently, acquired knowledge tests may draw on multiple narrow abilities across the broad dimensions, for example, reading comprehension tests (*Grw*: RC) may tap general knowledge and verbal comprehension (i.e., K0 and VL; Schneider & McGrew, 2018).

quantitative reasoning [RQ], a stratum I ability in the *Gf* domain; McGrew, 2005). Accordingly, we consider numeracy to be a proxy, but not a pure measure of *Gq*. *Gq* is a knowledge construct that is relatively abstract and context-free, whereas numeracy involves four key facets; cognitive processes, mathematical content, representation, and contexts (Ginsburg, Manly, & Schmitt, 2006; Tout, 2020). Specifically, numeracy is the capacity to access, use, and reason critically with mathematical information represented in multiple formats (e.g., text, symbols, images, structured information, or dynamic applications) for the purposes of engaging with and solving mathematical problems in real-world contexts (Tout, 2020). While numeracy itself has not been conceptualised within the CHC theories, theoretical propositions relevant to numeracy specify a number of cognitive abilities that we consider to be abilities within the CHC taxonomy. For example, numeracy problem solving requires knowledge of the mathematical concepts involved (i.e., mathematical knowledge [*Gq*:KM]), identification and comprehension of relevant concepts (i.e., *Gc*:K0, Lexical knowledge [*Gc*:VL], and paragraph comprehension [*Grw*:PC]), logical reasoning about the relationships between variables within the problem (i.e., sequential reasoning [*Gf*:RG]), formulation of a strategy to solve the problem (i.e., *Gf*:RQ), and performance of the necessary calculations (i.e., arithmetic performance [*Gq*:A3]; Ginsburg et al., 2006; Karaali, Villafane Hernandez, & Taylor, 2016). The cognitive processes involved in numeracy utilise mathematical content (e.g., real number line, time, measurement, fractions, proportions, percentages, and probabilities; Reyna, Nelson, Han, & Dieckmann, 2009) to communicate and solve problems in personal, work-related, and community-related scenarios (Tout, 2020). Thus, numeracy can be seen as the application of *Gq,* though it is likely more reflective of RQ (e.g., Tirre & Pena, 1993).

To illustrate the distinction, consider the Woodcock-Johnson (WJ) calculation test and the WJ applied problems test. The WJ calculation test, classified as a measure of A3 (Flanagan et al., 2013; Mather & Wendling, 2015), presents the test-taker with a set of equations to solve (e.g., $\frac{1}{2}+\frac{1}{4}=?$). By comparison, the WJ applied problems test includes mathematical story problems such as, "The Roberts have four people in their family. For breakfast they each eat three muffins. If the muffins come in packages of six, how many packages do they need each morning?" (Mather & Wendling, 2015). Unlike the WJ calculation test, the test-taker must interpret the story, identify the data to include, and determine the appropriate operations to use, in order to create their own equation to solve. Accordingly, we consider the WJ applied problems test to be a numeracy measure. Additionally, we acknowledge that numeracy may tap cognitive abilities other than *Gq* (e.g., *Gf* and *Gc;* McGrew & Wendling, 2010; Cormier, Bulut, McGrew, & Singh, 2017), as the WJ applied problems is classified primarily as a measure of RQ (i.e., *Gf*) in addition to A3 (Flanagan et al., 2013) and KM (McGrew, 2006).

In the financial literacy literature, some studies include numeracy in their definition of financial literacy (e.g., Balakrishna & Virmani, 2019; Hastings et al., 2013). However, arguably, numeracy (or *Gq*) should be considered theoretically distinct from financial literacy (Hung et al., 2009). While financial literacy may present the real-world context for particular numeracy problems, much of financial literacy is primarily dependent on the crystallised knowledge of financial principles (e.g., purpose of an excess in insurance agreements), rather than the application of *Gq*. Thus, *Gq* may facilitate development of financial literacy, as in the case where knowledge of mathematics may be supportive of knowledge of physics (Ackerman et al., 2001), but it is arguably not a defining feature of the construct. Alternatively, or perhaps additionally, having an interest in mathematics may predispose an individual to be interested in financial knowledge (i.e., the process, personality, interests, and knowledge model; Ackerman, 1996; see Fig. 1).

Consequently, we estimated meta-analytically the association between *Gq* and financial literacy. Further, we assessed meta-analytically whether the association between *g*-ex*Gq* and financial literacy is mediated by *Gq*. Finally, we tested meta-analytically the hypothesis that *Gq* may mediate, partially or wholly, the association between *Gf* and financial literacy.

1.4. Summary and purpose

Previous financial literacy research suggests a positive association between cognitive ability and financial literacy (e.g., Bucher-Koenen & Ziegelmeyer, 2011; Llados-Masllorens & Ruiz-Dotras, 2022; Stanovich et al., 2016). However, an estimate at the population level has not yet been reported, nor has the magnitude of the true score effect been estimated precisely. Importantly, the purpose of this study is to synthesise the current cognitive ability and financial literacy research that suggests that, theoretically, financial literacy could potentially be included within the CHC taxonomy. Further, we aim to highlight the limitations in the existing literature and make recommendations for future research to better test this hypothesis. Consequently, we present psychometric meta-analyses of the associations between *g* and financial literacy and *g*-ex*Gq* and financial literacy (i.e., correlations disattenuated for imperfect reliability).

Moreover, our systematic review of existing studies includes an evaluation of the quality of measures of cognitive ability, based on their psychometric properties (i.e., internal-consistency reliability estimates), number of items/tests, number of dimensions, test duration, and validity. Based on this evaluation, we tested the hypothesis that measurement quality moderates positively the association between cognitive ability and financial literacy. Additionally, we examined key stratum II abilities in isolation and present three additional psychometric meta-analyses of the associations between financial literacy and *Gc, Gf,* and *Gq*. Finally, through meta-analytic structural equation modelling, we tested the mediating role of *Gq* on the association between *g*-ex*Gq* and financial literacy; the unique contributions of *Gc, Gf,* and *Gq* to the prediction of financial literacy; and, finally, the mediating role of *Gc* and *Gq* on the association between *Gf* and financial literacy.

2. Method

Studies that included a measure of financial literacy and any measure of cognitive ability were sought for inclusion in the meta-analysis. Alternative measures of financial literacy, including debt literacy and economic literacy measures, were also assessed for relevance (i.e., face validity). Financial literacy measures that examined financial capacity, used proxies (e.g., owning shares), or included fewer than three test items were excluded. A study was considered to measure cognitive ability if it included at least one test of a stratum I ability (e.g., mathematical achievement [A3]), a battery of measures to ascertain *g*, or an overall cognitive ability test (e.g., Wonderlic Personnel Test, CRT). Ineligible cognitive ability measures were those that were too simple (e.g., included items such as "What is today's date?") or based on academic achievement (e.g., school mathematics exam scores). Studies that investigated an intervention (e.g., repeated-measures design) were included in the meta-analysis, but only baseline data were considered. Details of the review, synthesis, and data analysis methodology are reported below, in line with the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA; Page et al., 2021). The PRISMA flow diagram in Fig. 2 illustrates the study selection process.

2.1. Literature search

Literature for this meta-analysis was retrieved from EBSCOhost, Ovid, Scopus, Web of Science, and ProQuest. Records were identified if their titles, abstracts, or keywords included the following terms: ("Financ* literacy" OR "Financ* literate" OR "Financ* competen*" OR "Financ* skill*" OR "Financ* capabilit*" OR "Financ* abilit*" OR "Financ* knowledge" OR "Financ* comprehension" OR "financ* understanding" OR "financ* aptitude" OR "economic literacy" OR "debt literacy") AND ("Cognitive abilit*" OR "Cognitive skill*" OR Intellect* OR

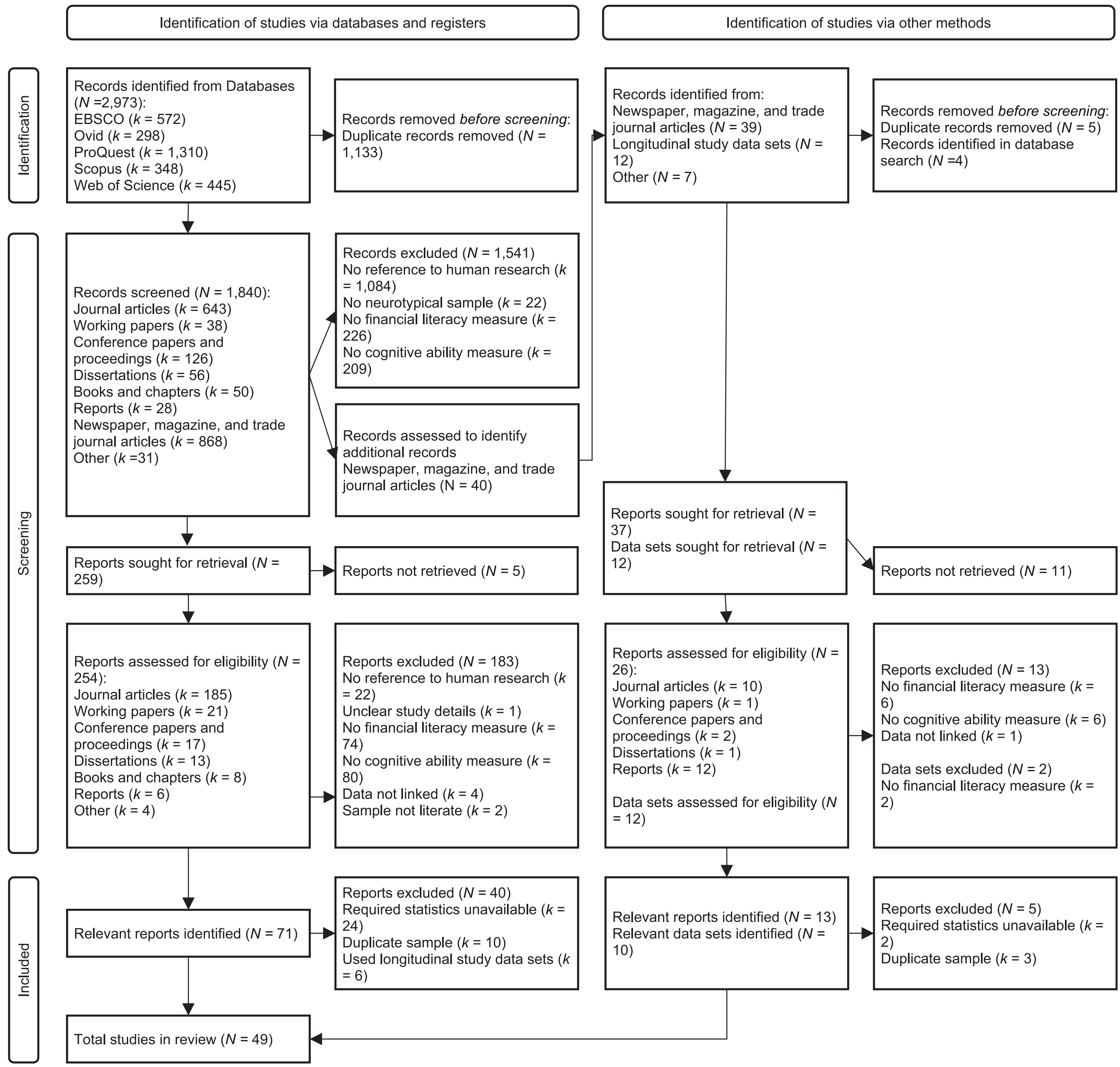


Fig. 2. Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) flow diagram.

"Cognitive aptitude" OR "Cognitive capabilit*" OR "cognitive reflection" OR Intelligence OR IQ OR "Ravens progressive" OR "working memory" OR "digit span" OR Numeracy OR "Numerical abilit*" OR "Numerical skill*" OR "Numerical reasoning" OR Math* OR "quantitative literacy" OR "quantitative reasoning" OR arithmetic). The search was conducted on the 6th of November 2021 and included all databases within each platform. To identify research in the grey literature, results were not limited to journal articles (see Fig. 2 for the record types retrieved in the search). Further, there were no restrictions on publication language and no start date was specified (see section VIII in the supplementary document for the specific search strategies for each platform). This search strategy yielded 2,973 records, 1,133 of which were identified as duplicates. Records were considered to be duplicates if they were identical, belonged to working papers where the subsequently published article was also retrieved in the search, were multiple versions of the same news article published in different outlets, or cases where the search pulled both the English translation and the original language of the abstract. The abstracts and keywords of the remaining 1,840 unique records were subsequently reviewed.

2.2. Study selection

2.2.1. Abstract screening

The initial screening was conducted independently by two of the authors (ZC and DW) using the Rayyan platform (Ouzzani, Hammady, Fedorowicz, & Elmagarmid, 2016). Records were excluded if they did not belong to and/or did not make reference to a human research study or report (k = 1,084); had no sample of neurotypical participants (k = 22); had no measure of financial literacy or included a measure designed to assess financial capacity (k = 226); or had no cognitive ability measure (k = 209). After independently reviewing the records, the two authors met to discuss conflicting inclusion decisions until an agreement was reached. Consequently, a total of 259 records were identified for full-text review.

2.2.2. Full-text screening

The full-text review was undertaken by the first author. Five reports could not be sourced from the University library's interlibrary loan document request service, nor from contacting the corresponding author. Thus, 254 reports were assessed for eligibility. Studies published in languages other than English were translated on Google translate and extracted information from those that were deemed relevant for inclusion was sent to the corresponding author to confirm that the interpretation was accurate. Reports were excluded if they were not human research studies ($k = 22$); did not include an appropriate measure of financial literacy ($k = 74$) or cognitive ability ($k = 80$); did not analyse unit record data (i.e., measured financial literacy and cognitive ability in two distinct samples; $k = 4$); or included a sample where some participants were not literate ($k = 2$). One further report was excluded as there was not enough information to ascertain whether the sample included neurotypical participants and the corresponding author could not be contacted to confirm. Thus, a total of 71 reports were eligible for inclusion in the meta-analysis.

2.2.3. Identification of studies via other methods

The unrestricted search strategy employed in the literature search described above yielded 868 abstracts belonging to newspaper, magazine, and trade journal articles. Further, 40 newspaper, magazine, and trade journal article abstracts met the screening criteria and were subsequently reviewed to identify additional reports. Where the report could not be identified from the news article, the author, research centre, and/or organisation referred to in the article were contacted for further information. Additionally, publicly available data sets were retrieved from the Health and Retirement Study (HRS; identified in Kim, Mitchell, & Maurer, 2019 and Finke et al., 2017), Wisconsin Longitudinal Study (WLS; identified in Herd, Holden, & Su, 2012), 1979 National Longitudinal Study of Youth (NLSY79; identified in Gorbachev & Luengo-Prado, 2019), CogUSA and CogEcon (identified in Hsu, 2011), Household Income and Labour Dynamics in Australia (HILDA), and Understanding America Study (UAS). Finally, seven reports were obtained through other means (e.g., suggested articles on Academia and ResearchGate). These processes identified 13 additional reports and 10 data sets that were eligible for inclusion in the meta-analysis.

2.3. Data collection

Correlations between financial literacy and cognitive ability measures, associated descriptive statistics (i.e., score mean and standard deviations) and estimated reliabilities (i.e., Cronbach's α), and demographic information (i.e., sample size, age mean and standard deviation, and gender breakdown), were extracted from the reported studies by the first author and tabulated in Excel. If a study published the data online (e.g., in the supplemental materials) or used a publicly available data set (e.g., the HRS), these data files were retrieved for analysis. Additionally, information about the measures used in the study such as number of questions, question wording, and relevant citations were collected. In cases where the required information was not reported in the study, study supplementary materials, or other published versions of the study, the corresponding author was contacted. If the author was unable to provide the relevant data or statistics, or did not respond, efforts were undertaken to estimate the statistics required for the meta-analysis (see Open Science Framework (OSF) for further details:https://osf.io/e26fg/). The data extraction and synthesis process was reproduced by GG.

Of the 94 identified studies, 19 were excluded as they included overlapping samples, which was either confirmed by the author (i.e., Lind et al., 2020) or the broader research study was reported in the paper (e.g., the HRS). A further 26 studies were excluded as they did not report enough information for estimation or simulation in *R* (described below); and the author no longer had access to the data, did not respond, or could not be contacted. Consequently, 49 studies were included in the meta-analysis.

2.4. Methods of synthesis

The methods used to identify and/or calculate relevant statistics derived from the investigations and/or data files included in the meta-analyses are extensively reported in a folder ('Data Pack – Correlations and Reliabilities') within the OSF: https://osf.io/e26fg/. The typical methods used to transform data (e.g., statistics) from studies that did not report the relevant statistical information in the format required are described below.

2.4.1. Descriptive statistics

If data were available, descriptive statistics were calculated using IBM SPSS Statistics (Version 29; SPSS). If data could be simulated, that is, sample size, means, standard deviations, and intercorrelations were reported by items or subtests, data were simulated in *R* (Version 4.1.2; R Core Team, 2021) using the rnorm_multi function (see DeBruine, 2021a; faux package [DeBruine, 2021b]) and summed and calculated in SPSS.

Score means and standard deviations reported in the study as percentages were converted to raw scores by multiplying the reported percentage by the number of items in the measure. If means and standard deviations were split by groups, the weighted mean was calculated and the combined sample standard deviation was estimated using the following formula (Higgins, Li, & Deeks, 2022): $SD_{1+2} = \sqrt{\left(\frac{(N_1-1)SD_1^2+(N_2-1)SD_2^2+\frac{N_1N_2}{N_1+N_2}\left(M_1^2+M_2^2-2M_1M_2\right)}{N_1+N_2-1}\right)}$

Some studies did not report the mean and standard deviation associated with the age of the participants, financial literacy test scores, and/or cognitive ability test scores. In some cases, a frequency table was presented, providing the number or proportion of participants against each score or age. This table was reproduced in Excel and the mean and standard deviation were calculated. Where only the proportion of participants was reported, the percentage was multiplied by the total sample size and rounded to the nearest whole number. If the scores or ages were reported in bands, the average for each range was calculated, for example, 18-24, 25-34, 35-44, becomes 21, 29.5, and 39.5.

One study (Fernandes et al., 2014; Study 1) did not report the number of participants. To estimate the sample size, the reported intercorrelations were examined to determine which non-significant r value had the greatest numerical value and which significant r value had the lowest numerical value (.16 and -.17, respectively). The sample size was estimated at 142 by inputting .165 into the r to p calculator on the VassarStats platform (Lowry, 2023) and trialling different sample sizes to find the value that yielded a p-value closest to .05.

2.4.2. Reliability estimates

The internal consistency reliability estimates associated with each of the measures were obtained through a variety of methods. In cases where Cronbach's α was not reported, the corresponding author was contacted and asked to provide the Cronbach's α reliability estimates for their test scores. If the author instead provided the data at the item-level or the data were available online or simulated (as described above), McDonald's coefficient ω was estimated using SPSS. To estimate the internal consistency reliability of a composite cognitive ability measure from a battery of cognitive ability tests, scores were transformed into z-scores and coefficient ω was estimated from the z-scores for each of the measures. In cases where an item/test had a negative factor loading, SPSS could not estimate ω. Consequently, McDonald's ω was estimated by recoding the negative factor loadings as 0 and inputting the positive factor loadings from a forced single factor, maximum likelihood exploratory factor analysis into an Excel spreadsheet developed by

McNeish (2018), based on the formula: $\omega = \frac{\left(\sum_{i=1}^{k}\lambda_i\right)^2}{\left(\sum_{i=1}^{k}\lambda_i\right)^2 + \sum_{i=1}^{k}\theta_{ii}}$.

Where studies measured intelligence with only two tests, Cronbach's α was estimated based on the inter-correlation between the two tests (in SPSS), as recommended by Gignac (2014).

Additionally, for measures where a reliability estimate was not reported, data were not available at the item-level, and/or the corresponding author did not respond, a modified Kuder-Richardson 21 (K-R21') formula was used to estimate internal consistency reliability (developed by Wilson et al., 1977, as cited in Frisbie, 1988). The raw score mean and variance (obtained through the methods described above) and the number of items were input into the following formula: $KR21' = 1 - \left(\frac{(0.8*M)*(Number\ of\ items - M)}{(Number\ of\ items*S)}\right)$.

In cases where the mean and/or standard deviation was also not reported the corresponding reliability estimate from Otero et al. (2022; CRT) or Gignac and Ooi (2022; financial literacy) was used.

Finally, it should be noted that, in some cases, efforts were made to improve internal consistency reliability. Specifically, where available data sets included relevant additional test items or measures that were not reported in the associated study, these items or tests were included to estimate relevant correlations and included in the meta-analysis. This was particularly beneficial in cases where tests with three or four items were used. Conversely, in cases where coefficient ω was estimated at less than .50, and the reliability analyses indicated that it would be advantageous to remove an item, it was removed. Again, see the 'Data Pack – Correlations and Reliabilities' folder within the OSF to learn all of the details for each study: https://osf.io/e26fg/.

2.4.3. Correlations

If study data or simulated data (as described above) were available, Pearson correlations between financial literacy and cognitive ability were estimated in SPSS. Where studies used a battery of cognitive ability measures, scores were transformed into *z*-scores and averaged to estimate a composite score. The correlation was then estimated between financial literacy and the composite cognitive ability scores. Correlations were estimated using all participants that completed the variables relevant to the respective meta-analysis, resulting in slight variation in sample sizes for the same study across analyses. However, the correlations were re-estimated for the structural equation modelling (meta-SEM) to ensure that sample sizes were equal across correlations in the matrix for each sample.

Where correlations were reported in correlation matrices, or in text without a corresponding *p*-value, the associated *p*-value was estimated using the *r* to *p* calculator on the VassarStats platform (Lowry, 2023). If there was no matrix, but correlations were reported for individual tests, the correlation was averaged via Fisher's *z* transformation and back-transformation using an online calculator (Lane, 2023) to estimate a composite correlation.

2.4.4. Disattenuated correlations

The internal consistency reliability coefficients were used to correct the correlations between financial literacy and cognitive ability, for the purposes of conducting the psychometric meta-analyses. The corrected correlation coefficients were disattenuated for imperfect measurement reliability, using the classical test theory disattenuation formula (Nunnally & Bernstein, 1994): $r' = \frac{r_{xy}}{\sqrt{r_{xx}*r_{yy}}}$

2.4.5. Analysis of administered measures

The items and tests used to measure financial literacy and cognitive ability were retrieved from the study, or associated supplementary materials, where available. In cases where only a test name or reference for the measure was provided, item details were retrieved from the referenced source where possible. If test/item information details were unclear, the corresponding author was contacted for further information.

Cognitive ability measures were reviewed and coded to the stratum I abilities in the CHC taxonomy. Table 2 presents an overview of the abilities represented in the samples included in the meta-analyses (for a list of tests coded to each stratum I ability, see Table S1 in the supplementary document). The quality of the cognitive test batteries was assessed with Gignac and Bates' (2017) guidelines (1 = *poor*, 2 = *fair*, 3 = *good*, 4 = *excellent*), based on the number of tests, the number of corresponding stratum II broad abilities, and test-taking time. Where test time was not reported, test time was estimated based on times reported in manuals or other studies, or the number of items in the test. Authors ZC and GG independently evaluated the cognitive ability tests against the criteria in Gignac and Bates (2017) and gave each sample (*k*) a rating between 1 and 4. Conflicting ratings were discussed until an agreement was reached. A full record of the tests mapped to the CHC taxonomy and corresponding cognitive ability measurement quality ratings for each study is available in the 'CHC Coding Summary Tables' document within the OSF (https://osf.io/e26fg/).

2.5. Data analysis

Barebones meta-analyses were conducted on the observed correlations and psychometric meta-analyses were conducted on the true-score correlations (i.e., disattenuated for imperfect reliability). The barebones and psychometric meta-analyses were conducted via a random effects model with the Hunter-Schmidt estimation in *R*, using the metafor package (Viechtbauer, 2010). Corresponding heterogeneity tests (Cochran's *Q* and I^2), sensitivity analyses, and publication bias analyses (funnel plots, trim-and-fill analyses, and Egger's regression test) were also conducted. Where the sensitivity analyses identified any samples as potentially influential, the leave-one-out method was consulted. If the re-estimated meta-analytic correlation excluding any sample did not differ from the original estimate by |.09| or more, the sample was not considered to be overly influential and the original estimate was interpreted.

A series of five meta-analyses were performed to establish the association between: (1) *g*[4] and financial literacy; (2) *g*-ex*Gq* and financial literacy; (3) *Gc* and financial literacy; (4) *Gf* and financial literacy; and (5) *Gq* and financial literacy. Further, to assess whether cognitive ability measurement quality moderated the correlation between cognitive abilities and financial literacy, meta-regression analyses were conducted. Associated statistical significance and confidence intervals were estimated via 2,000 random permutations of the data using the *R* 'permutest' function (Viechtbauer, 2010). Finally, two meta-analytic mediation path-analyses were conducted: (1) to examine *Gq* as a potential mediator of the association between *g*-ex*Gq* and financial literacy; and (2) to evaluate the unique and combined effects of *Gc, Gf,* and *Gq* on financial literacy. The corresponding two-stage random effects estimation models were performed with the metaSEM package in *R* (Version 1.2.5.1; Cheung, 2015), based on syntax from Jak (2015) and Cheung (2022). The commands and associated outputs can be accessed in a folder ('Syntax and Output') within the OSF: https://osf.io/e26fg/.

3. Results

3.1. Study characteristics

Table 3 presents a summary of the study characteristics of the samples included in each of the five meta-analyses (see the 'Study Information and Summary Tables' document within the OSF for further

[4] It is acknowledged that many of the studies included in this meta-analysis did not satisfactorily measure *g* (see Table 5 for cognitive ability test quality overview). However, for the purposes of simplicity, we refer to composite cognitive ability as *g*.

Table 2
Stratum I and Stratum II abilities measured by the samples included in the meta-analyses.

Measure	*g and FL*		*g*-ex*Gq and FL*			
	N	%	*N*	%	*N*	%
Gc					Gc and FL	
(VL) Lexical Knowledge	12	18.2%	12	29.3%	13	92.9%
(K0) General Knowledge	4	6.1%	4	9.8%	4	28.6%
Total *Gc*	13	19.7%	13	31.7%	14	100.0%
					Gf and FL	
Gf						
(I) Induction	10	15.2%	10	24.4%	10	50.0%
(RG) General Sequential Reasoning	4	6.1%	4	9.8%	4	20.0%
(RQ) Quantitative Reasoning	11	16.7%	11	26.8%	13	65.0%
Total *Gf*	18	27.3%	18	43.9%	20	100.0%
					Gq and Fl	
(*Gq*:A3) Mathematical Achievement						
Total *Gq*	38	57.6%			43	100.0%
Grw						
(RC) Reading Comprehension	1	1.5%	1	2.4%		
(RD) Reading Decoding	5	7.6%	5	12.2%		
Total *Grw*	5	7.6%	5	12.2%		
Gs						
(P) Processing Speed	2	3.0%	2	4.9%		
(Ps) Perceptual Speed–search	1	1.5%	1	2.4%		
(N) Number Facility	7	10.6%	7	17.1%		
Total *Gs*	9	13.6%	9	22.0%		
Other abilities						
(*Gwm*:Wa) Auditory Short-term Storage	12	18.2%	12	29.3%		
(*Gl*:M6) Free-recall Memory	9	13.6%	9	22.0%		
(*Gr*:LA) Speed of Lexical Access	6	9.1%	6	14.6%		
(*Gv*:Vz) Visualization	1	1.5%	1	2.4%		
(*Ga*:PC) Phonetic Coding	1	1.5%	1	2.4%		
General Cognitive Ability (*g*)	16	24.2%	16	39.0%		
Total	66	100.00%	41	100.00%		

Note. *g* = composite cognitive ability; *g*-ex*Gq* = composite cognitive ability excluding *Gq*; *Gc* = comprehension-knowledge; *Gf* = fluid reasoning; *Gq* = quantitative knowledge; *Grw* = reading and writing; *Gs* = processing speed; *Gwm* = working memory capacity; *Gl* = learning efficiency; *Gr* = retrieval fluency; *Gv* = visual processing; *Ga* = auditory processing; General Cognitive Ability (*g*) = samples that relied on a global measure of cognitive ability (e.g., Cognitive Reflection Test), not a battery of tests; FL = financial literacy. Tests were coded to stratum I abilities based on classifications and ability/task descriptions in Flanagan et al. (2013), Jewsbury, Bowden, and Duff (2017), and Schneider and McGrew (2018), see the 'CHC Coding Summary Tables' document in the OSF folder for specific tests and associated codes: https://osf.io/e26fg/. Codes are mutually exclusive, even though it is acknowledged that some tests may tap multiple abilities. Stratum II totals may not equal the sum of the corresponding stratum I totals as counts represent the number of samples that included at least one test of the corresponding ability.

details of the included samples: https://osf.io/e26fg/). In total, there were 48 studies included in the meta-analyses. From these studies, 66 samples were included in the *g* and financial literacy meta-analysis, 41 samples were included in the *g*-ex*Gq* and financial literacy meta-analysis, 14 in the *Gc* and financial literacy meta-analysis, 20 in the *Gf* and financial literacy meta-analysis, and 44 in the *Gq* and financial literacy meta-analysis. As can be seen in Table 3, most studies were published after 2016 (note that the year reported for longitudinal study data sets is the year in which the data/wave was collected). There was wide variability in the mean age of the samples, however, the proportion of women was roughly equal across meta-analyses (≈ 53% women). Further, sample sizes varied from 50 to 12,920 participants, although most (75.4%) samples were sufficiently large (i.e., $N > 190$) to achieve 80% power for a typical effect size (i.e., $r = |.20|$), based on Gignac and Szodorai's (2016) guidelines. It will be noted that approximately one quarter of the samples used as few as three financial literacy test items ($k = 18$; 27.3%), and fewer than half of the samples ($k = 32$; 48.5%) used 11 or more financial literacy questions.

3.2. Overview of meta-analytic results

Prior to reporting each of the psychometric meta-analyses in detail, we summarise the key results of the barebones meta-analytic estimates. The observed score correlations and corresponding reliability estimates for each sample included in the respective meta-analyses are presented on the left side of Figs. 3, 4, 5, 6, and 7. As can be seen in Table 4, the barebones meta-analyses yielded statistically significant overall effects across the five analyses. Specifically, the observed score correlation between *g* and financial literacy was estimated at $r = .39$; between *g*-ex*Gq* and financial literacy at $r = .33$; between *Gc* and financial literacy at $r = .37$; between *Gf* and financial literacy at $r = .31$; and between *Gq* and financial literacy at $r = .43$. The corresponding sensitivity analyses suggested that the *g*, *g*-ex*Gq,* and *Gc* barebones meta-analyses may have each included one sample that was potentially an influential case (see sections II to VI in the supplementary document for full details). However, the respective leave-one-out analyses did not suggest that the removal of any one sample would result in an appreciably different estimate from the original meta-analytic correlation. Further, the barebones meta-analyses were each evaluated for publication bias, based on evaluation of funnel plots (including contour-enhanced), trim-and-fill analysis, and Egger's test of funnel plot asymmetry. The full results are presented in the supplementary materials (see sections II to VI for full discussion and associated funnel plots); however, we note that publication bias was not considered to be a serious threat to the validity of any barebones meta-analyses. Therefore, the bare-bones meta-analytic estimates reported in Table 4 were considered interpretable. In the following, we present the results associated with the true score meta-analytic estimates.

3.2.1. Composite cognitive ability (g) and financial literacy: psychometric meta-analysis

As can be seen in Fig. 3 (right side), the 66 disattenuated correlations between *g* and financial literacy ranged from $r' = .28$ to $r' = 2.28$. Accordingly, sample 57 (Solesbee, 2015) and sample 61 (Sunderaraman et al., 2022) were excluded from the psychometric meta-analysis, as their respective disattenuated correlations exceeded 1.0. The

Table 3
Characteristics of the samples included in the meta-analyses.

	g and FL		*g*-ex*Gq* and FL		*Gc* and FL		*Gf* and FL		*Gq* and FL	
	N	%	*N*	%	*N*	%	*N*	%	*N*	%
Year of publication										
≤ 2010	5	10.2%	5	14.3%	5	38.5%	3	23.1%	3	9.4%
2011-2015	12	24.5%	8	22.9%	4	30.8%	4	30.8%	8	25.0%
2016-2020	24	49.0%	16	45.7%	4	30.8%	5	38.5%	18	56.3%
≥ 2021	8	16.3%	6	17.1%	0	0.0%	1	7.7%	3	9.4%
Number of studies	49	100.0%	35	100.0%	13	100.0%	13	100.0%	32	100.0%
Number of samples (k)	66		41		14		20		43	
Number of participants per sample										
50-100	9	13.6%	5	12.2%	1	7.1%	1	5.0%	7	16.3%
101-200	11	16.7%	10	24.4%	3	21.4%	5	25.0%	4	9.3%
201-500	14	21.2%	10	24.4%	3	21.4%	4	20.0%	8	18.6%
501-1,000	18	27.3%	5	12.2%	4	28.6%	6	30.0%	17	39.5%
1,001-5,000	11	16.7%	8	19.5%	3	21.4%	4	20.0%	5	11.6%
≥ 5,001	3	4.5%	3	7.3%	0	0.0%	0	0.0%	2	4.7%
Mean	944		1,150		774		755		830	
Total	62,332		47,134		10,835		15,101		35,699	
Age mean per sample										
≤ 30	12	18.5%	9	22.5%	3	23.1%	2	10.5%	9	21.4%
30-39	18	27.7%	8	20.0%	0	0.0%	4	21.1%	10	23.8%
40-49	15	23.1%	8	20.0%	3	23.1%	3	15.8%	12	28.6%
50-59	11	16.9%	6	15.0%	2	15.4%	1	5.3%	9	21.4%
≥ 60	9	13.8%	9	22.5%	5	38.5%	9	47.4%	2	4.8%
Age Mean (years)	47.8		50.0		46.9		48.8		45.8	
Women	32,422	53.0%	25,043	53.3%	5,714	53.4%	8,306	55.5%	18,405	53.3%
Number of financial literacy items per sample										
3	18	27.3%	13	31.7%	2	14.3%	8	40.0%	7	16.3%
4	5	7.6%	2	4.9%	1	7.1%	0	0.0%	4	9.3%
5	5	7.6%	5	12.2%	0	0.0%	0	0.0%	2	4.7%
6-10	6	9.1%	4	9.8%	1	7.1%	1	5.0%	4	9.3%
11-15	21	31.8%	8	19.5%	4	28.6%	6	30.0%	17	39.5%
16-25	5	7.6%	5	12.2%	2	14.3%	2	10.0%	4	9.3%
26-30	5	7.6%	3	7.3%	3	21.4%	2	10.0%	5	11.6%
≥ 31	1	1.5%	1	2.4%	1	7.1%	1	5.0%	0	0.0%

Note. g = composite cognitive ability; *g*-ex*Gq* = composite cognitive ability excluding *Gq*; *Gc* = comprehension-knowledge; *Gf* = fluid reasoning; *Gq* = quantitative knowledge. FL = financial literacy; Mean age values exclude three studies that did not include age descriptives. The number and proportion of women in the sample excludes four studies that did not include gender descriptives. Some studies were subsequently published in 2022, but the preprints were retrieved in the literature search conducted in 2021. The year reported for longitudinal study data sets reflects the year in which the data/wave was administered and is not necessarily the year that the data was published.

psychometric meta-analytic correlation was estimated at $r' = .62$, $p < .001$ (95% CI: [.56, .68], $k = 64$, $N = 62{,}194$). Sensitivity analyses suggested samples 28 (Health and Retirement Study, 2016), 47 (NLSY79, 2018; AFQT sample) and 62 (UnderStanding America Study, 2018) may have been potentially influential cases (see Fig. S3 in section II of the supplementary document). However, the leave-one-out analyses re-estimated the correlations at .62, .61, and .62, excluding samples 28, 47, and 62, respectively, suggesting that the original meta-analytic correlation (i.e., $r' = .62$) was interpretable. The degree of heterogeneity was statistically significant $Q^2(63) = 2{,}078.91$, $p < .001$, and high from an effect size perspective, $I^2 = 96.7\%$ (95%CI: [96.5, 98.3%]), suggesting one or more moderators of the effect between *g* and financial literacy (see Fig. 3, right side for psychometric forest plot).

3.2.2. *Composite cognitive ability excluding Gq (g-exGq) and financial literacy: psychometric meta-analysis*

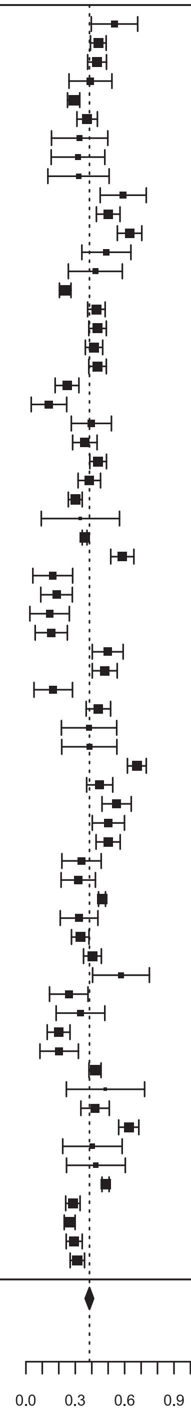
The disattenuated correlations between *g*-ex*Gq* and financial literacy ranged from $r' = .32$ to $r' = .91$, and the corresponding psychometric meta-analytic correlation was estimated at $r' = .60$, $p < .001$ (95% CI: [.53, .67], $k = 41$, $N = 47{,}134$). Similar to the *g* psychometric meta-analysis, studies 16 (Health and Retirement Study, 2016), 27 (NLSY79, 2018; AFQT sample) and 38 (UnderStanding America Study, 2018) were identified by the sensitivity analyses as potentially influential cases (see Fig. S6 in section III of the supplementary document). However, the leave-one-out analyses re-estimated the correlations at .58, .59, and .59, when excluding samples 16, 27, and 38, respectively, thus, the psychometric meta-analysis correlation that included all 41 samples (i.e., $r' = .60$) was considered interpretable. The degree of heterogeneity was statistically significant $Q^2(40) = 1{,}192.43$, $p < .001$, and high from an effect size perspective, $I^2 = 96.2\%$ (95%CI: [96.4, 98.6%]), suggesting one or more moderators of the effect between *g*-ex*Gq* and financial literacy (see Fig. 4, right side for psychometric forest plot).

3.2.3. *Cognitive ability test quality: meta-regression*

Table 5 presents the number of cognitive ability tests and the cognitive ability measurement ratings for the samples included in the *g* ($M = 1.64$, $SD = 0.94$) and *g*-ex*Gq* ($M = 1.80$, $SD = 0.90$) meta-analyses, based on Gignac and Bates' (2017) guidelines (*poor* = 1, *fair* = 2, *good*= 3, *excellent* = 4). As can be seen in Table 5, over half of the samples only included one cognitive ability measure. Accordingly, over half of the samples were classified as having poor quality measures of cognitive ability.

A series of four meta-regression analyses (mixed-effects model) were performed with the cognitive ability measurement quality ratings ordinal variable (i.e., coded: 1 = *poor*, 2 = *fair*, 3 = *good*, 4 = *excellent*) specified as a moderator. The first model was conducted with the observed correlations between *g* and financial literacy. However, quality of cognitive ability measurement ratings was not found to be a statistically significant contributor to the model, $\alpha = .37$, $\beta = .01$, $p = .468$, (95%CI: [-.02, .04]). Similarly, the second meta-regression using the corrected correlations between *g* and financial literacy did not find quality of cognitive ability measurement ratings to be a statistically significant contributor to the model, $\alpha = .62$, $\beta = -.01$, $p = .724$, (95%CI:

Sample	N	r_{xx}	r_{yy}	Barebones	r [95% CI]	p	Psychometric	r' [95% CI]
1 Ackerman & Beier (2006)	141	.88	.75		.54 [.40 , .68]	< .001		.66 [.56 , .77]
2 Bateman et al. (2012)	1,220	.71	.58		.44 [.39 , .49]	< .001		.68 [.65 , .72]
3 Bateman et al. (2018)	854	.61	.59		.43 [.38 , .49]	< .001		.72 [.67 , .76]
4 Bucciol et al. (2021)	164	.69	.75		.39 [.26 , .52]	< .001		.54 [.45 , .64]
5 Bucher-Koenen & Ziegelmeyer (2011)	2,012	.47	.55		.29 [.25 , .33]	< .001		.57 [.54 , .60]
6 CogUSA & CogEcon (2009)	715	.82	.91		.37 [.31 , .43]	< .001		.43 [.39 , .48]
7 Darriet et al. (2020)	96	.39	.61		.33 [.16 , .50]	.001		.67 [.55 , .79]
8 Demakis et al. (2019)	105	.66	.51		.32 [.15 , .48]	.001		.55 [.43 , .66]
9 Earl et al. (2015)	81	.50	.81		.32 [.13 , .51]	.004		.50 [.37 , .64]
10 Fernandes et al. (2014) Study 1	142	.84	.79		.59 [.45 , .73]	< .001		.73 [.62 , .83]
11 Fernandes et al. (2014) Study 2	543	.82	.79		.50 [.43 , .57]	< .001		.62 [.57 , .67]
12 Fernandes et al. (2014) Study 3	506	.85	.75		.63 [.56 , .70]	< .001		.79 [.74 , .84]
13 Fogarty & MacCarthy (2006)	126	.67	.62		.49 [.34 , .64]	< .001		.76 [.65 , .87]
14 Gerrans et al. (2022)	104	.57	.77		.42 [.26 , .59]	< .001		.64 [.52 , .75]
15 Goda et al. (2019)	2,315	.30	.57		.24 [.20 , .27]	< .001		.58 [.55 , .60]
16 Greenberg et al. (2020) Study 1a	985	.49	.61		.43 [.38 , .48]	< .001		.79 [.75 , .83]
17 Greenberg et al. (2020) Study 1b	982	.79	.62		.44 [.38 , .49]	< .001		.62 [.58 , .66]
18 Greenberg et al. (2020) Study 2	1,006	.75	.55		.41 [.36 , .47]	< .001		.64 [.61 , .68]
19 Greenberg et al. (2020) Supp.	978	.79	.59		.44 [.38 , .49]	< .001		.64 [.60 , .68]
20 Grohmann et al. (2015)	530	.40	.59		.25 [.18 , .32]	< .001		.51 [.46 , .57]
21 Hardy (2015)	238	.40	.64		.14 [.03 , .25]	.031		.28 [.20 , .36]
22 HRS (2004)	188	.45	.73		.40 [.28 , .52]	< .001		.70 [.61 , .78]
23 HRS (2008)	507	.68	.70		.36 [.28 , .43]	< .001		.52 [.47 , .57]
24 HRS (2010)	1,090	.53	.78		.44 [.39 , .49]	< .001		.68 [.65 , .72]
25 HRS (2016)	597	.53	.77		.39 [.32 , .45]	< .001		.60 [.55 , .65]
26 HRS (2020)	1,586	.35	.64		.30 [.26 , .34]	< .001		.64 [.61 , .67]
27 Houdek & Rybakova (2017)	50	.39	.52		.33 [.09 , .57]	.020		.74 [.57 , .91]
28 HILDA Wave 16 (2016)	12,920	.52	.61		.36 [.34 , .37]	< .001		.63 [.62 , .64]
29 Indefenso & Yazon (2020)	563	.59	.93 & .92		.59 [.52 , .66]	< .001		.79 [.74 , .84]
30 Kim et al (2017) Sample 1	191	.14	.79		.16 [.04 , .28]	.024		.49 [.40 , .57]
31 Kim et al (2017) Sample 2	302	.05	.84		.19 [.09 , .28]	.001		.91 [.85 , .98]
32 Kim et al (2017) Sample 3	193	.12	.69		.14 [.02 , .26]	.046		.51 [.42 , .60]
33 Kim et al (2017) Sample 4	292	.13	.65		.15 [.06 , .25]	.008		.53 [.46 , .60]
34 Li et al. (2013)	316	.61	.75		.50 [.40 , .59]	< .001		.73 [.66 , .80]
35 Li et al. (2015)	490	.84	.81		.48 [.40 , .55]	< .001		.58 [.53 , .64]
36 Llados-Masllorens & Ruiz-Dotras (2022)	205	.31	.45		.17 [.05 , .28]	.017		.44 [.36 , .53]
37 Meir et al. (2016)	501	.70	.60		.44 [.37 , .51]	< .001		.68 [.62 , .73]
38 Millroth (2020) Study 3	99	.65	.66		.38 [.22 , .55]	< .001		.58 [.46 , .70]
39 Moreira Costa et al. (2021)	100	.80	.73		.39 [.22 , .55]	< .001		.50 [.38 , .63]
40 Mrkva et al. (2021) Study 1	855	.85	.88		.67 [.62 , .73]	< .001		.78 [.74 , .82]
41 Mrkva et al. (2021) Study 2	440	.78	.54		.45 [.37 , .53]	< .001		.69 [.63 , .75]
42 Mrkva et al. (2021) Study 4	355	.83	.70		.55 [.46 , .64]	< .001		.72 [.66 , .79]
43 Mrkva et al. (2021) Study 5	292	.84	.61		.50 [.40 , .60]	< .001		.70 [.63 , .77]
44 Mrkva et al. (2021) Supp.	519	.79	.58		.50 [.43 , .57]	< .001		.74 [.68 , .79]
45 Muñoz-Murillo et al. (2020)	195	.71	.60		.34 [.22 , .46]	< .001		.52 [.43 , .61]
46 Mushafiq et al. (2021)	256	.34	.68		.32 [.21 , .42]	< .001		.66 [.59 , .74]
47 NLSY79 (2018) AFQT	6,014	.42	.92		.46 [.44 , .48]	< .001		.74 [.73 , .76]
48 NLSY79 (2018) IQ	214	.50	.77		.32 [.21 , .44]	< .001		.52 [.44 , .61]
49 Newall (2016) Study 1	981	.78	.41		.33 [.28 , .38]	< .001		.58 [.55 , .62]
50 Newall (2016) Study 5	939	.73	.66		.40 [.35 , .46]	< .001		.58 [.54 , .62]
51 Noon & Fogarty (2007)	94	.68	.71		.58 [.41 , .75]	< .001		.83 [.71 , .96]
52 Oberrauch & Kaiser (2022)	204	.85	.52		.26 [.14 , .38]	< .001		.39 [.31 , .48]
53 Paolacci & Legrenzi (2012)	128	.51	.65		.33 [.18 , .48]	< .001		.57 [.47 , .68]
54 Peprah-Yeboah et al. (2018)	580	.65	.61		.20 [.13 , .27]	< .001		.32 [.27 , .37]
55 Peters et al. (2017)	204	.33	.27		.20 [.09 , .32]	.004		.68 [.60 , .76]
56 Skagerlund et al. (2018)	2,063	.56	.63		.42 [.38 , .46]	< .001		.71 [.68 , .73]
57 Solesbee (2015)	50	.53	.32		.48 [.25 , .72]	< .001		1.17
58 Stanovich et al. (2016) Study RT57	375	.53	.59		.42 [.33 , .51]	< .001		.75 [.69 , .81]
59 Stanovich et al. (2016) Study RT60	747	.72	.94		.63 [.56 , .69]	< .001		.76 [.72 , .81]
60 Stevens (2017)	86	.77	.48		.40 [.22 , .59]	< .001		.66 [.53 , .79]
61 Sunderaraman et al. (2022)	88	.04	.90		.43 [.25 , .60]	< .001		2.28
62 UAS (2018)	5,943	.78	.70		.48 [.46 , .51]	< .001		.65 [.64 , .67]
63 Wiersma et al. (2020)	1,461	.66	.71		.29 [.24 , .33]	< .001		.42 [.39 , .45]
64 WLS (2011) Sample 1	2,583	.76	.62		.27 [.23 , .30]	< .001		.39 [.36 , .41]
65 WLS (2011) Sample 2	1,165	.76	.87		.29 [.24 , .34]	< .001		.36 [.33 , .40]
66 WLS (2011) Sample 3	1,468	.75	.65		.31 [.27 , .36]	< .001		.45 [.42 , .48]
					.39 [.36 , .41]			.62 [.56 , .68]



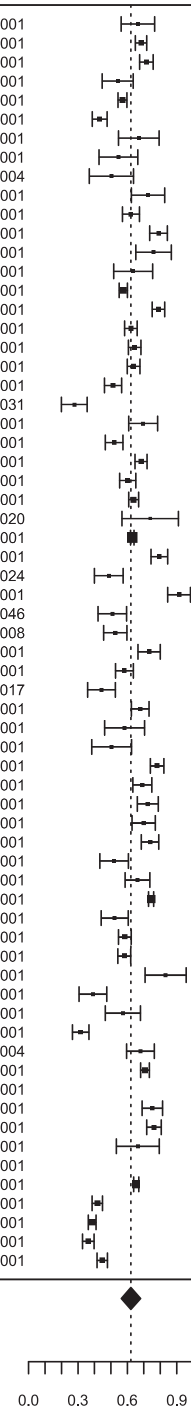


Fig. 3. Sample characteristics and forest plots associated with systematic review: *g*.

Note. Barebones RE Model: $Q^2(65) = 848.31$, $p < .001$, $I^2 = 91.8\%$. Psychometric RE Model: $Q^2(63) = 2{,}078.91$, $p < .001$, $I^2 = 96.7\%$.

g = composite cognitive ability; *N* = sample size; r_{xx} = reliability estimate for financial literacy measure; r_{yy} = reliability estimate for cognitive ability measure; *r* = correlation; CI = confidence intervals; *r'* = disattentuated correlation.

CogUSA = Cognitive and Aging in the USA; CogEcon = Cognitive Economics; HRS = Health and Retirement Study; HILDA = Household, Income and Labour Dynamics in Australia; NLSY79 = National Longitudinal Survey of Youth 1979; AFQT = Armed Forces Qualification Test; UAS = Understanding America Study; WLS = Wisconsin Longitudinal Study (*Bateman et al., 2012; *Bateman et al., 2018; *Bucciol, Guerrero and Papadovasilaki, 2021; *Cognitive Economics Study, 2021; *Darriet, Guille, Vergnaud and Shimizu, 2020; *Department of Social Services, and Melbourne Institute of Applied Economic and Social Research, 2020; *Earl, Gerrans, Asher and Woodside, 2015; *Goda, Levy, Manchester, Sojourner and Tasoff, 2019; *Greenberg, Sussman and Hershfield, 2020; *Grohmann, Kouwenberg and Menkhoff, 2015; *Health and Retirement Study, 2014; *Health and Retirement Study, 2019; *Health and Retirement Study, 2020; *Health and Retirement Study, 2021; *Health and Retirement Study, 2022; *Indefenso and Yazon, 2020; *Kim, Choi and Lee, 2017; *Meir, Mugerman and Sade, 2016; *Millroth, 2020; *Moreira Costa, De Sa Teixeira, Cordeiro Santos and Santos, 2021; *Mrkva, Posner, Reeck and Johnson, 2021; *Muñoz-Murillo, Álvarez-Franco and Restrepo-Tobón, 2020; *Mushafiq, Khalid, Sohail and Sehar, 2021; *Newall, 2016; *Oberrauch and Kaiser, 2022; *Paolacci and Legrenzi, 2012; *Peprah-Yeboah, Frejus and Fianko, 2018; *Stevens, 2017; *Wiersma, Alessie, Kalwij, Lusardi and van Rooij, 2020).

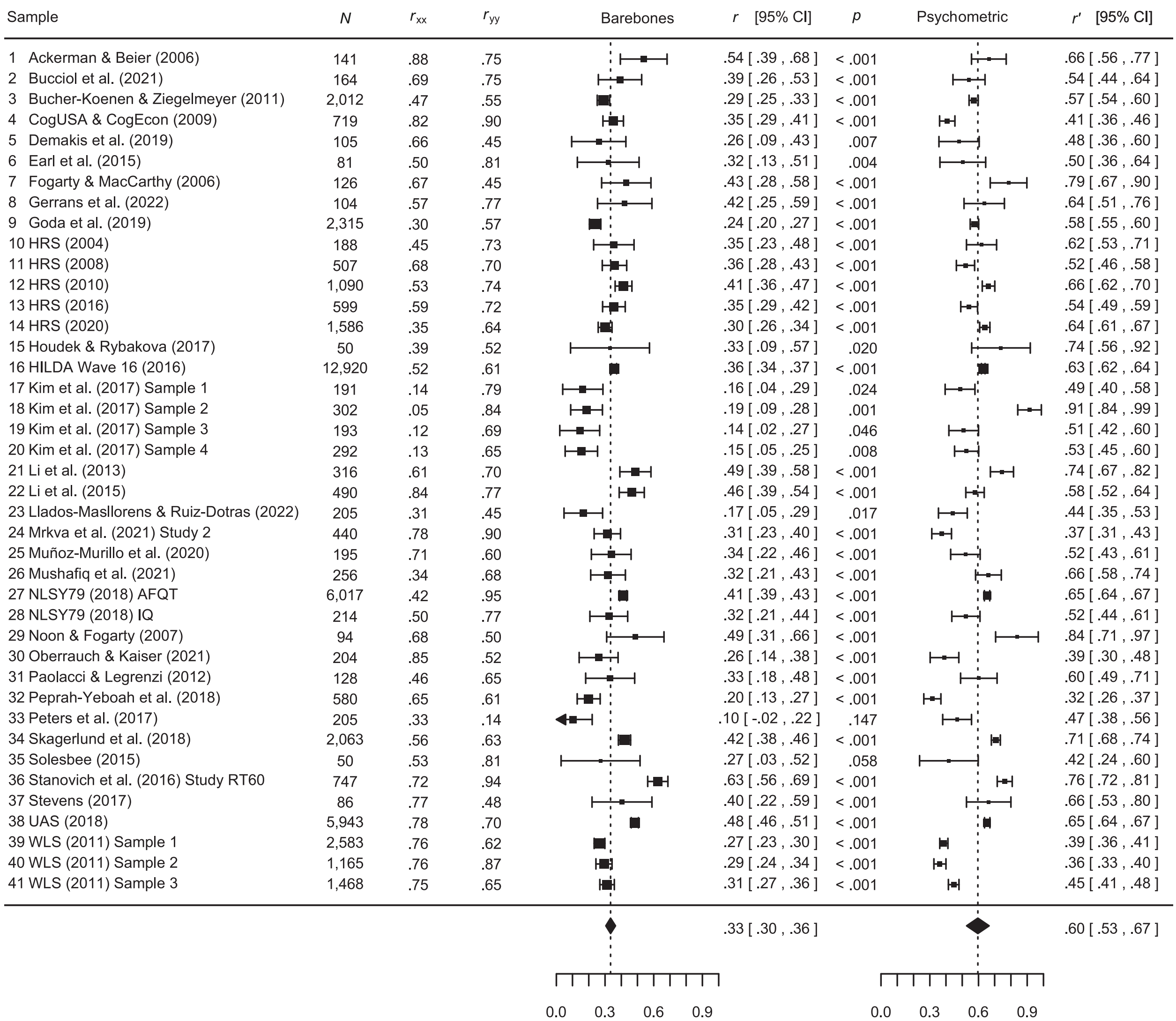


Fig. 4. Sample characteristics and forest plots associated with systematic review: *g*-ex*Gq*.
Note. Barebones RE Model: $Q^2(40) = 461.91$, $p < .001$, $I^2 = 90.2\%$. Psychometric RE Model: $Q^2(40) = 1{,}192.43$, $p < .001$, $I^2 = 96.2\%$. *g*-ex*Gq* = composite cognitive ability excluding *Gq; Gq* = quantitative knowledge; *N* = sample size; r_{xx} = reliability estimate for financial literacy measure; r_{yy} = reliability estimate for cognitive ability measure; *r* = correlation; CI = confidence intervals; *r'* = disattenuated correlation.
CogUSA = Cognitive and Aging in the USA; CogEcon = Cognitive Economics; HRS = Health and Retirement Study; HILDA = Household, Income and Labour Dynamics in Australia; NLSY79 = National Longitudinal Survey of Youth 1979; AFQT = Armed Forces Qualification Test; UAS = Understanding America Study; WLS = Wisconsin Longitudinal Study.

[-.04, .02]). As a non-trivial number of cognitive ability measures were based exclusively upon *Gq* ($k = 25$; 37.9%; all but one were classified as *poor*), a corresponding meta-regression (i.e., the third model) was conducted with the observed correlations between *g*-ex*Gq* and financial literacy. Again, quality of cognitive ability measurement ratings was not found to be a statistically significant contributor to the model, $\alpha = .26$, $\beta = .04$, $p = .059$, (95%CI: [.01, .07]). Finally, the fourth meta-regression with the corresponding corrected correlations also did not find quality of cognitive ability measurement ratings to be a statistically significant contributor to the model, $\alpha = .59$, $\beta = -.01$, $p = .685$, (95%CI: [-.04, .03]).

3.2.4. Comprehension-knowledge (Gc) and financial literacy: psychometric meta-analysis

The 14 disattenuated correlations associated with *Gc* and financial literacy ranged from $r' = .20$ to $r' = .76$ and are presented on the right side of Fig. 5. Identified samples included measures that tapped VL ($k = 13$; 92.9%) and K0 ($k = 4$; 28.6%) stratum I abilities. The psychometric meta-analysis estimated the correlation at $r' = .48$, $p < .001$, (95% CI: [.38, .57], $k = 14$, $N = 10{,}835$). The sensitivity analyses suggested sample 13 (WLS, 2011) may be a potentially influential case (see Fig. S9 in section IV of the supplementary document). However, the leave-one-out analysis did not suggest the removal of sample 13 would yield an appreciably different estimate ($r' = .52$) from the original psychometric correlation (i.e., $r' = .48$). Further, the degree of heterogeneity was statistically significant $Q^2(10) = 255.84$, $p < .001$, and high from an effect size perspective, $I^2 = 93.9\%$ (95%CI: [91.3, 98.4%]; see Fig. 5, right side for psychometric forest plot).

3.2.5. Fluid reasoning (Gf) and financial literacy: psychometric meta-analysis

The disattenuated correlations between *Gf* and financial literacy ranged from $r' = .32$ to $r' = .91$ (see right side of Fig. 6). Identified samples included measures that tapped I ($k = 10$; 50.0%), RG ($k = 4$; 20.0%), and RQ ($k = 13$; 65.0%) stratum I abilities. The corresponding psychometric meta-analytic correlation was estimated at $r' = .48$, $p <$

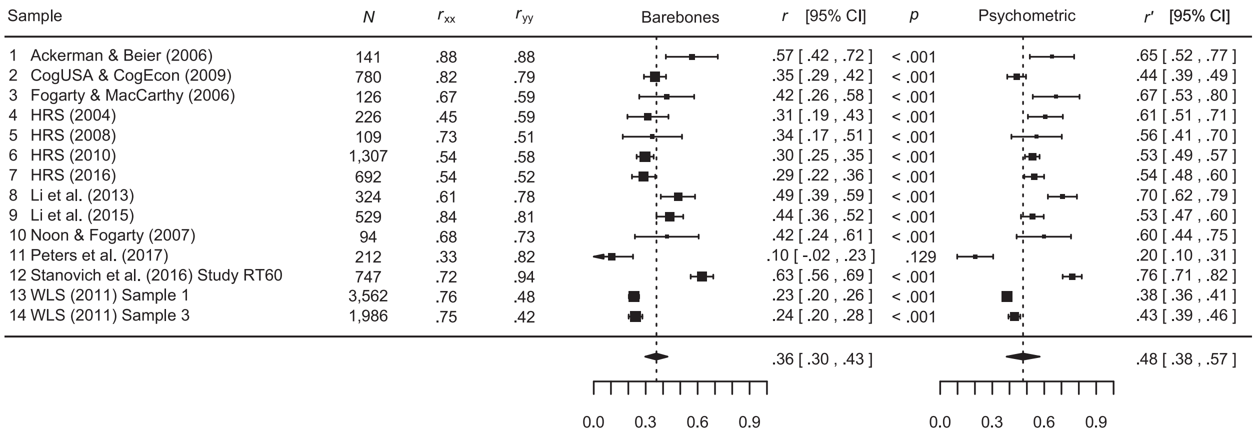


Fig. 5. Sample characteristics and forest plots associated with systematic review: *Gc*.
Note. Barebones RE Model: $Q^2(13) = 178.83$, $p < .001$, $I^2 = 91.3\%$. Psychometric RE Model: $Q^2(13) = 255.84$, $p < .001$, $I^2 = 93.9\%$; *Gc* = comprehension knowledge; *N* = sample size; r_{xx} = reliability estimate for financial literacy measure; r_{yy} = reliability estimate for *Gc* measure; *r* = correlation; CI = confidence intervals; *r'* = disattentuated correlation; CogUSA = Cognitive and Aging in the USA; CogEcon = Cognitive Economics; HRS = Health and Retirement Study; WLS = Wisconsin Longitudinal Study.

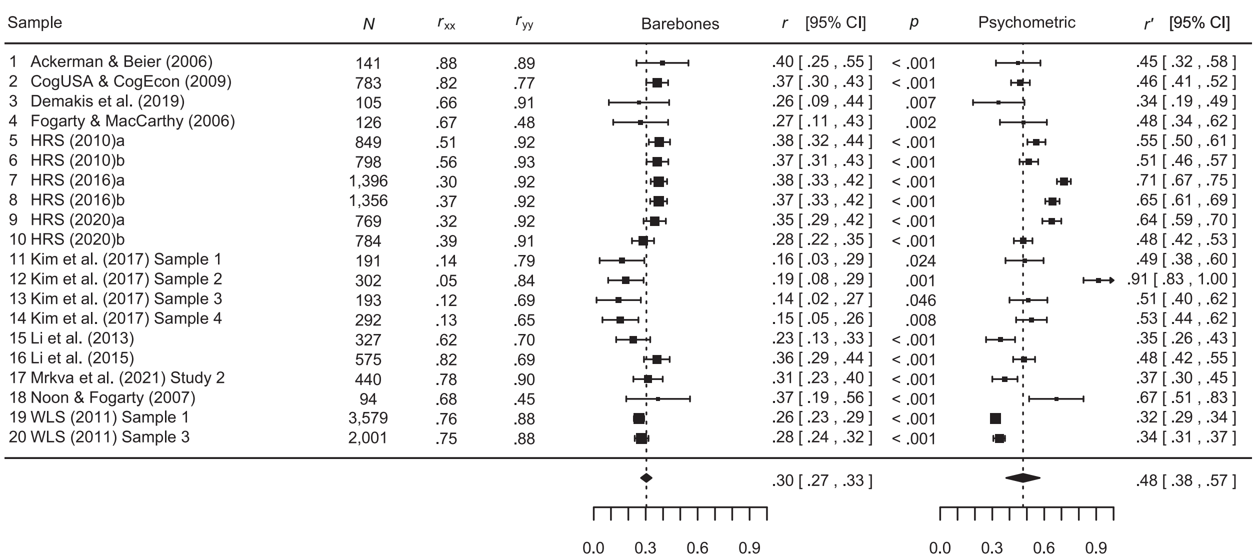


Fig. 6. Sample characteristics and forest plots associated with systematic review: *Gf*.
Note. Barebones RE Model: $Q^2(19) = 73.57$ $p < .001$, $I^2 = 71.5\%$. Psychometric RE Model: $Q^2(19) = 579.72$, $p < .001$, $I^2 = 96.3\%$; *Gf* = fluid reasoning; *N* = sample size; r_{xx} = reliability estimate for financial literacy measure; r_{yy} = reliability estimate for *Gf* measure; *r* = correlation; CI = confidence intervals; *r'* = disattentuated correlation; CogUSA = Cognitive and Aging in the USA; CogEcon = Cognitive Economics; HRS = Health and Retirement Study; WLS = Wisconsin Longitudinal Study; the HRS administered two versions of the number series task, in order to estimate reliability coefficients, they are presented separately and denoted by "a" and "b".

.001 (95% CI: [.38, .57], $k = 20$, $N = 15{,}101$). Similar to the *Gc* analyses, the sensitivity analyses suggested sample 19 (WLS, 2011) may be a potentially influential case (see Fig. S12 in section V of the supplementary document). However, the leave-one-out analysis yielded a re-estimate of *r'* = .53 if sample 19 was excluded, which was not considered to be substantively different from the psychometric meta-analysis correlation that included all 20 samples (i.e., *r'* = .48). Finally, the degree of heterogeneity was statistically significant $Q^2(19) = 579.72$, $p <$ .001, and high from an effect size perspective, $I^2 = 96.3\%$ (95%CI: [92.9, 98.2%]).

3.2.6. Quantitative knowledge (Gq) and financial literacy: psychometric meta-analysis

As can be seen in Fig. 7 (right side), the 43 disattenuated correlations associated with *Gq* and financial literacy ranged from *r'* = .24 to *r'* = 2.28. Consequently, sample 41 (Sunderaraman et al., 2022) was excluded from the psychometric analysis, as the corrected correlation exceeded 1.0. The psychometric meta-analysis estimated the correlation at *r'* = .69, $p < .001$, (95% CI: [.63, .76], $k = 42$, $N = 35{,}611$). Similar to the previous psychometric analyses, samples 31 and 42 from the larger panel studies (i.e., NLSY79, 2018 [AFQT sample] and UnderStanding America Study, 2018) and sample 36 (Skagerlund, Lind, Strömbäck, Tinghög, & Västfjäll, 2018) were identified in the sensitivity analyses as potentially influential cases (see Fig. S15 in section VI of the supplementary document). However, the leave-one-out analyses suggested that the initially estimated psychometric correlation was robust (i.e., *r'* = .69), such that the removal of any one study did not result in an appreciably different estimate (i.e., *r'* = .69, *r'* = .68 and *r'* = .68, excluding samples 31, 36 and 42, respectively). The degree of heterogeneity was statistically significant $Q^2(41) = 1{,}788.76$, $p < .001$, and high from an effect size perspective, $I^2 = 97.5\%$ (95%CI: [97.5, 99.0%]; see Fig. 7, right side for psychometric forest plot).

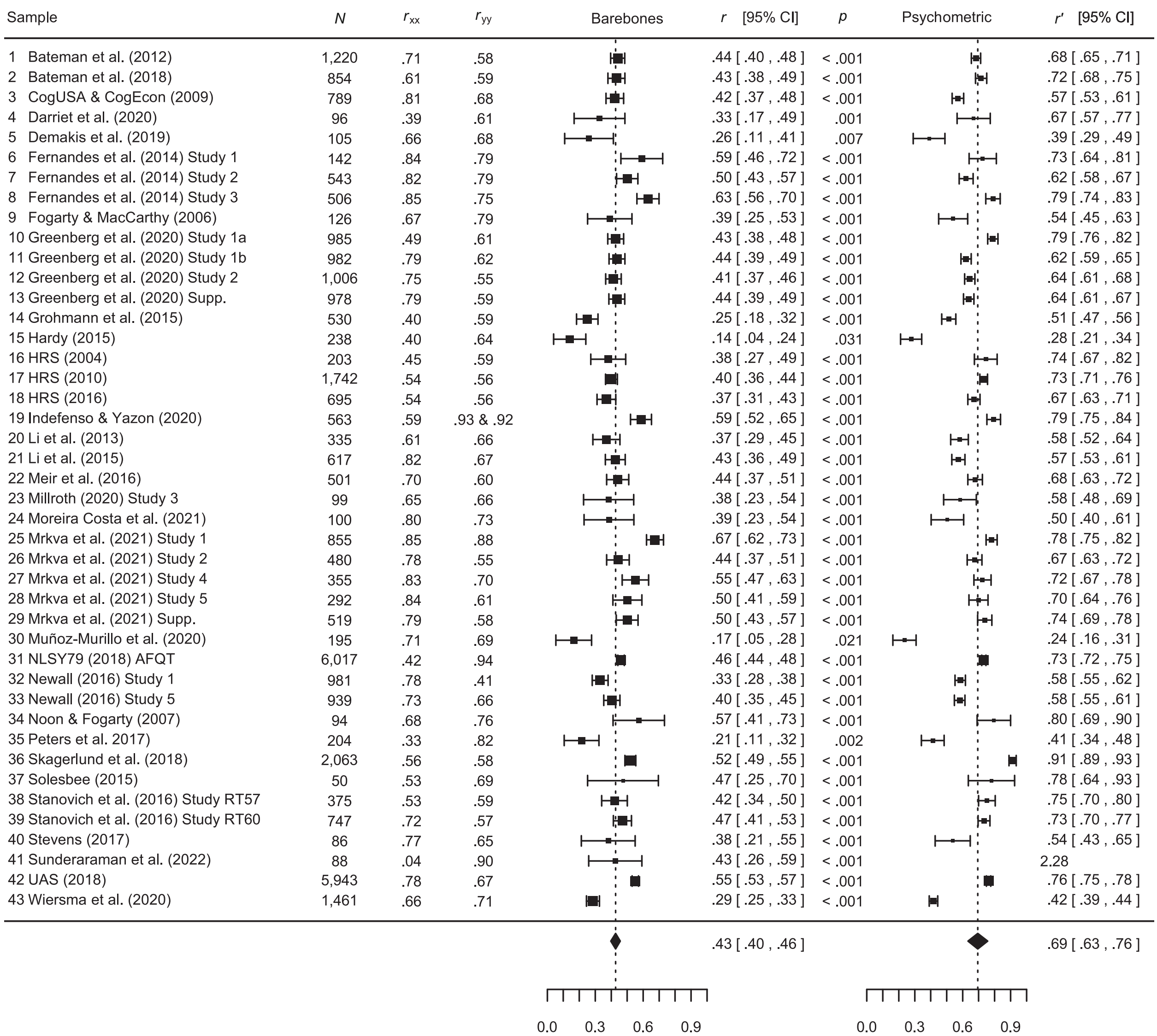


Fig. 7. Sample characteristics and forest plots associated with systematic review: *Gq*.

Note. Barebones RE Model: Q^2 (42) = 478.33, $p < .001$; I^2 = 90.6%. Psychometric RE Model: $Q^2(41)$ = 1,788.76, $p < .001$; I^2 = 97.5% *Gq* = quantitative knowledge; N = sample size; r_{xx} = reliability estimate for financial literacy measure; r_{yy} = reliability estimate for *Gq* measure; #Items = number of items in the measure; r = correlation; CI = confidence intervals; r' = disattentuated correlation.

CogUSA = Cognitive and Aging in the USA; CogEcon = Cognitive Economics; HRS = Health and Retirement Study; NLSY79 = National Longitudinal Survey of Youth 1979; UAS = Understanding America Study; AFQT = Armed Forces Qualification Test Structural Equation Modelling

Table 4

Meta-analytically derived bivariate correlations associated with the barebones and psychometric meta-analyses.

	Barebones							Psychometric						
	N	*k*	*r*	*r*[95% CI]	Q^2	I^2	I^2[95% CI]	*N*	*k*	*r'*	*r'*[95% CI]	Q^2	I^2	I^2[95% CI]
g and FL	62,332	66	.39***	[.36, .41]	848.31***	91.8%	[91.7, 96.2%]	62,194	64	.62***	[.56, .68]	2,078.91***	96.7%	[96.5, 98.3%]
g-ex*Gq* and FL	47,134	41	.33***	[.30, .36]	461.91***	90.2%	[89.2, 96.1%]	47,134	41	.60***	[.53, .67]	1,192.43***	96.2%	[96.4, 98.6%]
Gc and FL	10,835	14	.36***	[.30, .43]	178.83***	91.3%	[86.5, 97.5%]	10,835	14	.48***	[.38, .57]	255.84***	93.9%	[91.3, 98.4%]
Gf and FL	15,101	20	.30***	[.27, .33]	73.57***	71.5%	[58.3, 91.3%]	15,101	20	.48***	[.38, .57]	579.77***	96.3%	[92.9, 98.2%]
Gq and FL	35,699	43	.43***	[.40, .46]	478.33***	90.6%	[89.3 95.9%]	35,611	42	.69***	[.63, .76]	1,788.76***	97.5%	[97.5, 99.0%]

Note. ****p* <.001; *g* = composite cognitive ability; *g*-ex*Gq* = composite cognitive ability excluding *Gq*; *Gf* = fluid reasoning; *Gc* = comprehension-knowledge; *Gq* = quantitative knowledge; FL = financial literacy; *N* = sample size; *k* = number of samples included in the analysis; *r* = barebones correlation estimate; *r'* = psychometric correlation estimate; CI = confidence intervals.

Table 5
Number of cognitive ability tests and measurement quality ratings associated with the samples included in the meta-analyses.

	g and FL ($k = 66$)		*g*-ex*Gq* and FL ($k = 41$)	
	N	%	*N*	%
Number of cognitive ability tests				
1	43	65.2%	22	53.7%
2	3	4.5%	4	9.8%
3	7	10.6%	3	7.3%
4-6	7	10.6%	9	22.0%
7-9	4	6.1%	1	2.4%
≥ 10	2	3.0%	2	4.9%
Quality of cognitive ability measures				
Poor	42	63.6%	20	48.8%
Fair	9	13.6%	10	24.4%
Good	12	18.2%	10	24.4%
Excellent	3	4.5%	1	2.4%

Note. *g* = composite cognitive ability; *g*-ex*Gq* = composite cognitive ability excluding *Gq*; *Gq* = quantitative knowledge. FL = financial literacy; Quality of cognitive ability measure evaluated based on Gignac and Bates' (2017) classification guidelines.

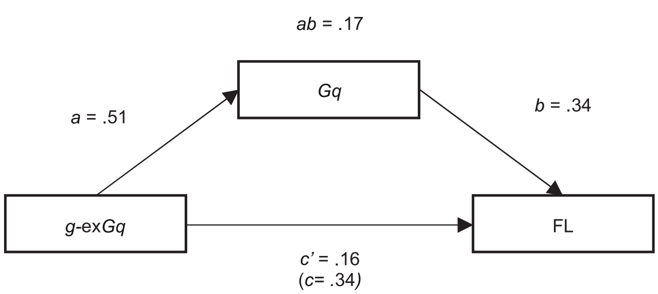


Fig. 8. Path analytic mediation model: *g*-ex*Gq*, *Gq*, and financial literacy.
Note. *g*-ex*Gq* = composite cognitive ability excluding *Gq*; *Gq* = quantitative knowledge; FL = financial literacy. Model estimated via metaSEM package. All coefficients were statistically significant, $p < .05$.

3.3. Structural Equation Modeling

Next, we tested a series of models to test the unique effects of the stratum II abilities on financial literacy. We conducted the metaSEM analyses on the observed score correlations, as the method has not yet been extended to disattenuated correlations. Meta-analytic correlations and associated statistics were re-estimated for the structural equation modelling (metaSEM) and, in some instances, differed slightly, though not appreciably, from the metafor estimates reported in the left side of Table 4 (see Tables S2 and S3 in section VII of the supplementary document for metaSEM estimates). Recall that in some cases, sample sizes for the same study varied across analyses as correlations were estimated using all participants that completed the variables required for each respective meta-analysis. Accordingly, the correlations were re-estimated in metaSEM to ensure that sample sizes were equal across correlations in the matrix for each included study (*k*). For example, in the study by Li et al. (2015), 529 participants completed the *Gc* measures, 575 completed the *Gf* measures, and 617 completed the *Gq* measures. However, only 490 participants completed all measures, therefore, the correlations between financial literacy and *Gc, Gf,* and *Gq* were re-estimated with the subsample of 490 for the metaSEM analyses. Consequently, the sample sizes and number of samples included in the metaSEM analyses differ slightly from previous metafor analyses.

3.3.1. Composite cognitive ability excluding Gq (g-exGq), Gq, and financial literacy

First, we tested the hypothesis that the effect between *g*-ex*Gq* and financial literacy was mediated by *Gq*. For the purposes of conducting

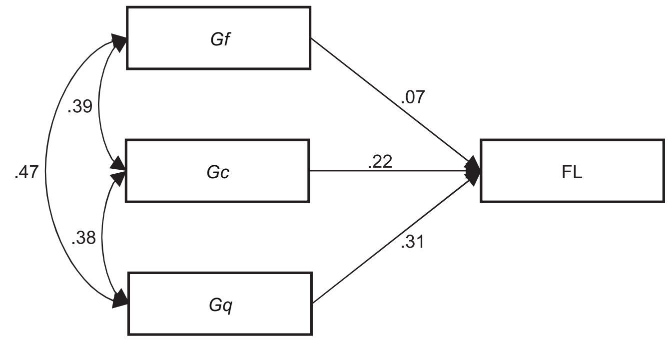


Fig. 9. Path analytic model: *Gf*, *Gc*, *Gq*, and financial literacy.
Note. *Gf* = fluid reasoning; *Gc* = comprehension-knowledge; *Gq* = quantitative knowledge; FL = financial literacy. Model estimated via metaSEM package. All coefficients, except the effect of *Gf* onto financial literacy, were statistically significant, $p < .05$.

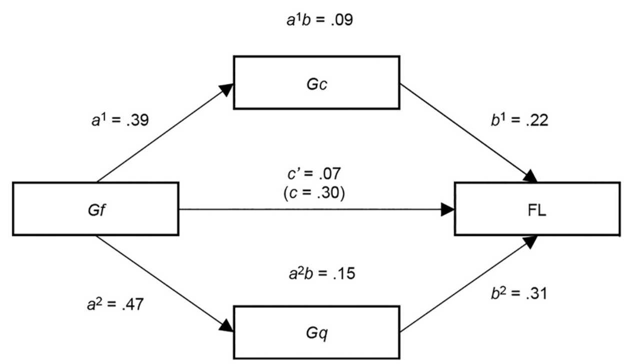


Fig. 10. Multiple mediation model: *Gf*, *Gc*, *Gq*, and financial literacy.
Note. *Gf* = fluid reasoning; *Gc* = comprehension-knowledge; *Gq* = quantitative knowledge; FL = financial literacy. Model estimated via metaSEM package. All coefficients, except for the direct effect of *Gf* onto Financial Literacy, were statistically significant, $p < .05$.

the mediation analysis, the observed score bivariate correlations were re-estimated in metaSEM for the following associations: *g*-ex*Gq* and financial literacy ($r = .34$); *Gq* and financial literacy ($r = .43$); and *g*-ex*Gq* and *Gq* ($r = .51$; see Table S2 in section VII of the supplementary document). The direct effect of *Gq* on financial literacy was significant statistically ($\beta = .34$, 95% CI:[.29, .39]). Further, the direct effect of *g*-ex*Gq* on financial literacy was significant statistically ($\beta = .16$, 95% CI:[.10, .22]). Finally, the indirect effect of *g*-ex*Gq* on financial literacy via *Gq* was significant statistically ($\beta = .17$, 95% CI:[.14, .21]), suggesting the effect was partially mediated by *Gq*.

The model (see Fig. 8) accounted for 20.0% of the variance in financial literacy (model $R^2 = .200$, 95% CI:[.175, .227]). The associated r^2 effect size measures were estimated based on the SPSS macro written by Fairchild, MacKinnon, Taborga, and Taylor (2009). Specifically, 9.3% of the variance in financial literacy was uniquely associated with the mediated effect of *Gq* on *g*-ex*Gq* ($R^2_{med} = .093$, 95% CI:[.070, .120]). An examination of the individual contributions of the variables to the path model indicates that *Gq* accounted for 9.9% of the variance in financial literacy ($r^2_{MY.X} = .099$, 95% CI:[.093, .104]), whereas *g*-ex*Gq* accounted for 2.4% ($r^2_{XY.M} = .024$, 95% CI:[.021, .025]).

3.3.2. Gf, Gc, Gq, and financial literacy

Next, we tested a model to estimate the unique effects of *Gf*, *Gc*, and *Gq* onto financial literacy. The meta-analytic bivariate correlations and corresponding descriptive statistics associated with the *Gf*, *Gc*, and *Gq* stratum II abilities and financial literacy were estimated via a random-effects model in metaSEM (see Table S3 in section VII of the supplementary document). The pooled correlations between financial literacy and *Gf* (r = .30), *Gc* (r = .36), and *Gq* (r = .43) were all relatively large, based on Gignac and Szodorai's (2016) correlation guidelines.

Fig. 9 presents the unique contributions of *Gf, Gc,* and *Gq* to the prediction of financial literacy. The direct effects of *Gc* (β = .22, 95% CI:[.12, .32]) and *Gq* (β = .31, 95% CI:[.25, .37]) on financial literacy were both significant statistically. However, the direct effect of *Gf* on financial literacy was not significant (β = .07, 95% CI:[-.02, .14]). The model accounted for 23.3% of the variance in financial literacy (model R^2 = .233, 95% CI:[.196, .279]).(See Fig. 9)

Finally, to examine the effect of *Gc* and *Gq* as mediators of the association between *Gf* and financial literacy, a mediation analysis was conducted to test the model presented in Fig. 10. Similar to the model in Fig. 9, the direct effect of *Gf* on financial literacy was not significant (β = .07, 95% CI:[-.02, .14]). By contrast, *Gc* (β = .22, 95% CI:[.12, .32]) and *Gq* (β = .31, 95% CI:[.25, .37]) exhibited statistically significant direct effects on financial literacy. An examination of the indirect effects suggested the effect of *Gf* on financial literacy was mediated by both *Gc* (β = .09, 95% CI:[.05, .13]) and *Gq* (β = .15, 95% CI:[.10, .16]). Model R^2 was identical to the previous model.

4. Discussion

To our knowledge, this study is the first meta-analytic review of the association between cognitive ability and financial literacy. We found that financial literacy shared a substantial amount of variance with *g* (r' = .62), as well as *Gc* (r' = .48), *Gf* (r' = .48) and *Gq* (r' = .69). However, we failed to find cognitive ability measurement quality to be significant moderator of the association between cognitive ability and financial literacy. Finally, through meta-analytic structural equation modelling, we found that *Gq* partially mediated the association between *g*-ex*Gq* and financial literacy. Further, both *Gc* and *Gq* had significant direct effects on financial literacy, whereas the total effect of *Gf* on financial literacy was fully mediated by a combination of *Gc* and *Gq*.

4.1. CHC theories and financial literacy

We contended that, theoretically, financial literacy, the knowledge of financial concepts and principles, could be considered as a potential stratum I cognitive ability within the CHC taxonomy. The results of our meta-analysis support this contention empirically. Specifically, the observed score and true score correlations between *g* and financial literacy were estimated at r = .39 and r' = .62, respectively. Additionally, a composite cognitive ability dimension excluding *Gq* (*g*-ex*Gq*) and financial literacy was found to correlate at r = .33 and r' = .60. The meta-analytic estimates are relatively large, based on Gignac and Szodorai's (2016) guidelines. We consider our meta-analysis an important contribution to the literature, as a recent bibliometric review reported there have been very few meta-analytic financial literacy reviews (Goyal & Kumar, 2021).

We also note that the observed score correlations we reported are similar in magnitude to those reported in other meta-analyses between stratum I abilities and *g*. For example, originality (r = .25; Gerwig et al., 2021), mathematical achievement (r = .41) and reading comprehension (r = .38; Peng, Wang, Wang, & Lin, 2019). Thus, from this perspective, financial literacy may be considered a relatively typical stratum I ability.

4.1.1. Stratum II abilities and financial literacy

We posited that, theoretically, financial literacy could be potentially classified as a stratum I ability within the *Gc* domain of the CHC taxonomy, as it represents a type of knowledge that is accumulated through everyday exposure to financial information. Though all relatively large in magnitude (Gignac & Szodorai, 2016), financial literacy actually correlated most substantially with *Gq* (r' = .69), followed by *Gc* (r' = .48) and *Gf* (r' = .48). Furthermore, consistent with Cattell's (1987) investment hypothesis, the combination of *Gq* and *Gc* mediated fully the total effect of *Gf* on financial literacy. Thus, it may be suggested that financial literacy is imbued with both *Gq* and *Gc* variance, both of which are theoretically connected to a higher-order acquired-knowledge factor (Schneider & McGrew, 2012).

Although the meta-analysis between *Gq* and financial literacy yielded the largest correlation among the tested stratum II abilities (i.e., r' = .69), this result should be interpreted with some caution. Recall that *Gq* refers to the acquired knowledge and performance of mathematical operations (Newton & McGrew, 2010). Numeracy is related to *Gq*, such that it applies *Gq* and problem-solving processes to real-world contexts, purposes, or uses (Ginsburg et al., 2006), though it is not currently classified (or explicitly recognised) within the CHC taxonomy. Due to the theoretical importance of *Gq* to financial literacy, we included numeracy measures in the analysis as a proxy for *Gq.* While we acknowledge that numeracy and *Gq* are not synonymous, most of the tests we coded as *Gq* measures were actually probabilistic numeracy tests. Therefore, many of the measures included in the *Gq* and financial literacy meta-analysis likely tapped other stratum II abilities including *Gc* and *Gf,* as as well constructs independent of cognitive ability, such as risk literacy (Cokely et al., 2012; e.g., BNT). In fact, the literature search did not identify any studies that explicitly investigated *Gq* (as it is conceptualised within the CHC taxonomy) and its relationship with financial literacy. In order to address this gap, future research should employ distinct measures of arithmetic (e.g., WJ Calculation test) and numeracy (e.g., Lipkus Numeracy Scale) to investigate their unique contribution to financial literacy and to understand further the association between *Gq* and financial literacy.

4.1.2. Financial literacy as a stratum I ability

Importantly, we note that our findings cannot precisely situate financial literacy within the CHC taxonomy due the limited cognitive ability measures employed by the studies identified in the review. However, we have presented an overview of the existing research with respect to theoretical and preliminary empirical support for future consideration of the inclusion of financial literacy in the CHC taxonomy. Schneider and McGrew (2018) have suggested six criteria that new ability constructs should meet to be included in the CHC theories: (1) the proposed ability must have a clearly defined content domain; (2) the ability must be measurable with performance tests in different formats; (3) tests must demonstrate convergent and discriminant validity; (4) tests should improve the prediction of an important outcome; (5) the ability should be linked to specific neurological functions; and (6) the ability should have plausible links to evolutionary functions (i.e., facilitate survival and reproduction).

With respect to criterion 1, we have defined financial literacy as the breadth and depth of knowledge of personal finance concepts and principles considered essential, practical, or beneficial for everyone in a culture to know. In line with criterion 2, we included performance measures of financial literacy (i.e., those with veridical scoring) that contained questions that assessed the comprehension of terms and the application of principles to hypothetical scenarios in the context of budgeting, saving, borrowing, investing, and protecting resources (Huston, 2010; Remund, 2010; Titko & Lace, 2013). Further, studies were included regardless of their administration methodology (e.g., online, paper, in-person interview, phone interview). While the tests varied in number of items across studies, the operationalisation of financial literacy was fairly consistent, reflecting a general consensus in the literature with regards to financial literacy measurement despite the aforementioned definitional inconsistencies. Accordingly, this suggests that, for the most part, there is agreement about what financial literacy is, even though there is disagreement about how it is described.

Our meta-analyses yielded relatively large, positive correlations between *g, Gc, Gf,* and *Gq* and financial literacy, specifically, which provide preliminary empirical evidence for satisfying criterion 3. Moreover, our findings suggest that the total effect between *Gf* and financial literacy may be spurious, as it was entirely mediated by *Gc* and *Gq*. With respect to criterion 4, there is some supportive evidence for the incremental validity of financial literacy over other established abilities (e.g., Gignac et al., 2023; Hung, Luoto, & Parker, 2018; Li et al., 2013). Further, criteria 5 and 6 may be satisfied by neuroimaging research (e.g., Han et al., 2014) and sociobiological theories associated with outcomes linked to financial literacy (e.g., wealth; Van Rooij, Lusardi, & Alessie, 2012; Stulp, Sear, Schaffnit, Mills, & Barrett, 2016). However, Schneider and McGrew (2018) note that many broad and narrow abilities in the CHC theories have not yet met these two criteria. Our meta-analysis is just one piece of potential evidence for the evaluation of financial literacy as a possible *Gc* ability, particularly with respect to criterion 3. Further work relevant to the criteria delineated in Schneider and McGrew (2018) is needed to confirm (or disconfirm) the place of financial literacy in the CHC theories.

4.2. Implications

Despite the cognitive ability measurement limitations, it is clear from our results that *Gq* does have some role in financial literacy knowledge. Previously, researchers have suggested that financial literacy development may be dependent on numeracy, or that numeracy is the "computational engine" behind financial literacy, and they cite examples such as understanding the mathematics behind calculating interest, percentages, and ratios (Lusardi & Wallace, 2013; Skagerlund et al., 2018). However, financial literacy requires conceptual knowledge beyond mathematics knowledge. While some financial literacy test items require both knowledge of financial concepts and simple calculation (e.g., understanding the difference between simple interest and compound interest and estimating the interest earned on a savings account), most do not (e.g., knowing the definition of a stock mutual fund). Therefore, in the context of the CHC theories, it would not be appropriate to classify financial literacy as a *Gq* ability, or certainly not purely so. Instead, from a theoretical standpoint, *Gq* may be considered a *supportive* knowledge (Ackerman et al., 2001) for financial literacy, such that *Gq* facilitates the understanding and acquisition of financial knowledge, including principles that are not overtly numerical. For example, understanding the concept of negative correlation (i.e., mathematical knowledge [KM]; stratum I ability in the *Gq* domain) may facilitate the understanding of the inverse relationship between interest rates and bond prices. Accordingly, we also found that *Gq* partially mediated the effect of *g*-ex*Gq* on financial literacy.

In contrast to the potential role of *Gq* in financial literacy, our findings suggest that the total effect between *Gf* and financial literacy may be spurious, as it was entirely mediated by *Gc* and *Gq*. Such a result may have implications for financial literacy intervention programs. That is, if financial literacy is primarily a *Gc* or *Gq* ability, rather than a *Gf* ability, then theoretically, financial literacy ability could be improved through financial literacy education. For example, programs have been found to increase people's knowledge and capacity to solve numerical problems (Park & Brannon, 2014; Peters et al., 2017). By contrast, had a substantial effect been found to be unique to *Gf*, it would have undermined the possibility of financial literacy training, as valid attempts to improve *Gf* have failed (Daugherty et al., 2018). Correspondingly, though the effects are often small and inconsistent, previous meta-analyses have found positive impacts of financial education on financial literacy (e.g., Fernandes et al., 2014; Kaiser, Lusardi, Menkhoff, & Urban, 2022; Kaiser & Menkhoff, 2017; Kaiser & Menkhoff, 2020; Miller, Reichelstein, Salas, & Zia, 2015; Steinert et al., 2018). We, of course, acknowledge that there is likely an effect between intelligence and financial literacy independent of education (Lin & Bates, 2022).

Further research is required to classify financial literacy empirically within the CHC taxonomy. Such an investigation should administer a large battery of diverse cognitive ability tests, including financial literacy, and conduct a factor analysis on the data. Accordingly, we next summarise the methodological limitations in the literature and provide specific recommendations for future research.

4.3. Cognitive ability test quality and recommendations for further research

While there was a high level of heterogeneity in effect sizes across samples, the meta-regressions did not find cognitive ability measurement quality to be a significant moderator of the effect, in contrast to two previous meta-analyses that reported significant effects (Gignac & Bates, 2017; Walker et al., 2023). The failure to identify measurement quality as a significant moderator in our study may be due to a low level of variability in quality ratings (i.e., range restriction). Specifically, samples (*k*) categorised as *poor* based on Gignac and Bates' (2017) guidelines included those that only measured a single cognitive ability dimension (e.g., exclusively *Gq*). Further, our structural equation models demonstrated that the magnitude of the correlation between cognitive ability and financial literacy does vary depending on the stratum II ability measured. For example, correlations between financial literacy and *Gq* were classified as *poor* measures of *g*, despite being highly correlated (i.e., $r = .43$; $r' = .69$). However, our meta-regression models that excluded *Gq* (i.e., models 3 and 4) were also not significant. Consequently, the failure to identify measurement quality as a significant moderator may also be due to the overrepresentation of *poor* quality cognitive ability measures among the samples included in our meta-regression models. In fact, most samples in the analyses included cognitive ability measures that were considered to be *poor* (i.e., 63.6%, $k = 42$ and 48.8%, $k = 20$ of *g* and *g*-ex*Gq* measures, respectively) or *fair* (i.e., 13.6%, $k = 12$ and 24.4%, $k = 10$ of *g* and *g*-ex*Gq* measures, respectively). By comparison, the significant effect obtained in Gignac and Bates (2017) was based on a meta-analysis with roughly equal proportions of samples across quality ratings (although no measures were rated as *poor*). In our study, roughly 20% of the samples measured cognitive ability in a respectable manner. Thus, there was a lack of variance in the quality of cognitive ability measurement indicator, a fact that would have impacted negatively the chances of observing a significant effect.

We note that the relative lack of cognitive ability measurement quality in behavioural economics research is not unique to financial literacy. As an example, at least 62.9% of samples in a recent a meta-analytic review of the relationship between cognitive ability and risk aversion (Lilleholt, 2019) used cognitive ability measures that would likely be considered *poor* or *fair* by Gignac and Bates' (2017) guidelines. Further, in both Lilleholt (2019) and our meta-analysis between *g* and financial literacy, a large proportion of samples measured cognitive ability with a single test such as the CRT (30.9%, $k = 30$; and 18.2%, $k = 12$; respectively) or a measure of numeracy (12.4%, $k = 12$; and 37.9%, $k = 25$; respectively). Accordingly, this suggests that cognitive ability tends not to be measured comprehensively in current behavioural economics research.

Overall, the systematic review highlighted the lack of psychometrically respectable investigations in this area. However, there are some exceptions. Specifically, Li et al. (2013), Li et al. (2015), and CogEcon/CogUSA (2009) included cognitive ability measures that were considered to be *excellent* (Gignac & Bates, 2017). However, these studies are limited as they were based on older samples (e.g., CogEcon/CogUSA, 2009) or used brief measures of financial literacy (e.g., Li et al., 2013). Additionally, many of the studies that included comprehensive cognitive ability measures (e.g., Demakis et al., 2019, HRS, and WLS) administered measures that are designed to assess executive function (e.g., Morris et al., 1989). While there has been some work done to conceptualise common neuropsychological tests within the CHC taxonomy (e.g., Gross, Khobragade, Meijer, & Saxton, 2020; Jewsbury et al., 2017; van Rentergem et al., 2020), these test batteries have limited capacity for measuring overall cognitive ability due to their brevity (i.e., tests are usually 1-3 minutes each; Lachman, Agrigoroaei, Tun, & Weaver, 2014) and scope (e.g., few tests were coded as *Gf* or *Gc* measures in Jewsbury et al., 2017).

Moreover, the current study highlighted that fewer studies measured *Gc* specifically compared to other cognitive abilities, despite the potential theoretical links between *Gc* and financial literacy. In order to adequately measure *Gc*, Schneider and McGrew (2018) recommended that test batteries include a general knowledge measure (K0) and either a vocabulary (VL) test or a language development test (LD). While both K0 and VL were represented in our *Gc* meta-analysis, few studies (k = 3; 21.4%) measured both abilities and almost all studies measured VL (k = 13; 92.9%). Thus, it is acknowledged that the meta-analytic estimate of the correlation between *Gc* and financial literacy predominantly reflects the association between VL and financial literacy, which may underestimate the effect with *Gc* to some degree, as larger correlations appear to be reported for K0 measures and financial literacy (e.g., r = .40; r = .42; Li et al., 2015; Fogarty & MacCarthy, 2006). We recommend future research include multiple *Gc* tests to better capture the construct and better evaluate the potential classification of financial literacy as a *Gc* ability within the CHC taxonomy.

By contrast, there was a more balanced representation of the stratum I abilities within the *Gf* meta-analysis. However, we acknowledge that few studies employed comprehensive or even adequate *Gf* measurement at the study level (Schneider & McGrew, 2018). Specifically, only half (k = 10; 50.0%) of our samples measured inductive reasoning (I), the key defining feature of *Gf* (Schneider & McGrew, 2018). Additionally, few studies (k = 4; 20.0%) measured both inductive and deductive reasoning (i.e., I, and RG and/or RQ). Therefore, future research should include multiple *Gf* indicators.

Further, though numeracy has been examined extensively in the literature, no studies measured *Gq* comprehensively. Specifically, although almost all relevant samples included a numeracy test, very few samples included tests that appropriately measured mathematical achievement (A3; stratum I ability in the *Gq* domain), and no samples included a specific measure of mathematical knowledge (KM); however, we acknowledge that numeracy measures would draw on this ability (Schneider & McGrew, 2018). Future research should investigate the association between cognitive ability and financial literacy in unrestricted samples using *good* or *excellent* cognitive ability test batteries (i.e., with at least three dimensions and at least three tests; Gignac & Bates, 2017). Further, test batteries should be comprehensive and include measures of broad cognitive abilities with theoretical links to financial literacy (e.g., *Gc, Gf,* and *Gq*).

4.4. Financial literacy test quality and recommendations for further research

Similarly, financial literacy test quality varied between studies. Test length varied from 3-80 items, and almost half of all samples across the five meta-analyses used a measure with fewer than six items. Such variability in the number of financial literacy test items yielded a range of reliability estimates from as low as .04 to as high as .88. Further, while we disattenuated the correlations to correct for imperfect reliability, it is not possible to correct for validity, and a financial literacy test with only three to five questions unlikely taps the content sampling domain of the construct. Correspondingly, in line with Gignac and Ooi (2022), we recommend that researchers use larger financial literacy measures (e.g., 13 items, Fernandes et al., 2014; 20 items, Knoll & Houts, 2012) to better measure individual differences in financial literacy.

Additionally, in this paper we adopted a narrow definition of financial literacy based on financial knowledge that was consistent with the types of financial literacy tests that are typically employed by financial literacy researchers. Notably, we only identified one study (i.e., Ackerman & Beier, 2006) that utilised a complex financial reasoning/problem-solving type measure that aligned with broader conceptualisations of financial literacy and may have directly tapped *Gf*. Had financial literacy been defined (and measured) more akin to financial capability (e.g., Xiao et al., 2022), it is possible that *Gf* may have been identified as a significant, unique predictor. Consequently, we recommend that researchers ensure that the scope of their proposed definition is consistent with the employed measures. Further, some studies were excluded from the meta-analysis, as they included alternative measures of financial literacy that we considered to be proxies (e.g., using ownership of sophisticated investment products as indicators of knowledge of those investment products, self-rated abilities, or frequency of financial behaviours). Accordingly, we recommend that researchers are careful to avoid conflation with related dimensions when developing financial literacy ability measures that explore the broader conceptualisation of the ability.

4.5. Limitations

While this meta-analytic review was comprehensive, it is not without limitations. Firstly, a number of studies (N = 26) identified in the screening stage could not be included in the analysis due to insufficiently reported results and non-response to author follow-up. Additionally, the publication bias analyses may not be valid, as many of the correlations reported in Fig. 3 (k = 48; 72.7%), Fig. 4 (k = 32; 78.0%), Fig. 5 (k = 10; 71.4%), Fig. 6 (k = 16; 80.0%), and Fig. 7 (k = 28; 65.1%) were not actually published. Although we were able to compute statistics from the raw data of 25 studies, other studies required various transformations or simulations, as the required results were not reported and/or the author could not be contacted for further clarification. For example, data were simulated for four of the studies included in the meta-analysis. Further, for 18 studies, one or more internal consistency reliability coefficients used to correct the correlations for attenuation were estimated with the K-R21' formula. Such methods may have misestimated some of the effects. However, it is unlikely that these limitations biased the results in any particular direction.

Additionally, many of the measures of financial literacy and cognitive ability exhibited poor internal consistency reliability, yielding reliability coefficients less than the minimally acceptable level of .70 (Nunnally & Bernstein, 1994; e.g., g meta-analysis: k = 39; 59.1% and k = 39; 59.1%, respectively). In some cases, such low reliability estimates substantially increased the correlations when they were corrected for attenuation, and in three cases the disattenuated correlations exceeded 1.0 and were, therefore, excluded from the respective psychometric meta-analysis. We suspect these samples likely did not have a sufficiently large sample size to estimate the disattenuated correlations accurately (see Kretzschmar & Gignac, 2019), underscoring our decision to exclude them. On balance, we believe our reported psychometric meta-analyses represent the best estimates of the true score effects between our constructs of interest, though we nonetheless urge readers to interpret our results with some caution.

Finally, as mentioned above, we included probabilistic numeracy tests in the meta-analyses as a proxy for *Gq*, however, we note that there are conceptual differences between *Gq* and numeracy. Further, numeracy and financial literacy scores may have some shared variance due to similarities between the tests in terms of stimuli (e.g., common method variance; Ackerman & Hambrick, 2020) and content. For example, two data sets (the English Longitudinal Study of Ageing identified in Banks, Crawford, & Tetlow, 2015 and the Panel Survey of Income Dynamics identified in Kobayashi & Feldman, 2019) were subsequently excluded from our meta-analyses, as the authors had considered a test similar to the numeracy test used in the HRS waves to be a measure of financial literacy. These tests included money-related numeracy questions based on the calculation of interest, product prices before or after a discount, and the distribution of lottery winnings. We considered these to be tests of numeracy rather than financial literacy, as they did not require conceptual knowledge to obtain the answer. However, we acknowledge that some (albeit relatively few) financial literacy items may be considered numeracy items in that they represent the application of mathematics knowledge to real-word finance scenarios. Consequently, the meta-analytic estimates for the correlations between *g* and *Gq* and financial literacy should be interpreted with these limitations in mind. However, we have also reported the meta-analytic correlation between *g*-ex*Gq* and financial literacy, which excludes all *Gq*-related measures. Further, we also note that the overlap between financial literacy and *Gq* measures may have impacted the reduction of the direct effect of *Gf* on financial literacy to non-significance. Additionally, many samples ($k = 13$; 65.0%) included the number series test as a measure of *Gf* which taps similar abilities (i.e., RQ) to those employed in numeracy tests. Consequently, the results of this meta-analysis suggest that the association between *Gf* and financial literacy was entirely mediated by *Gc* and *Gq*, with the caveat that *Gq* may have accounted for some of the variance due to the similarities between *Gq* and financial literacy measures, and *Gf,* and *Gq* abilities. In light of these limitations, we recommend future research conduct a factor analysis on good quality measures of financial literacy, numeracy, and key broad abilities within the CHC taxonomy (e.g., *Gc, Gf,* and *Gq*). Such an investigation would help determine more clearly the degree to which financial literacy and numeracy are empirically distinct, in addition to the degree to which they are indicators of *Gc*, *Gf*, and *Gq*.

5. Conclusion

The meta-analyses yielded relatively large, positive correlations between cognitive ability and financial literacy, as well as *Gc, Gf,* and *Gq* and financial literacy, specifically. *Gq* was the most substantially correlated stratum II ability with financial literacy, followed by *Gc* and *Gf,* and was found to partially mediate the effect of *g*-ex*Gq* on financial literacy. Further, the effect of *Gf* on financial literacy was fully mediated by *Gq* and *Gc.* Consequently, the results provide preliminary support (criterion 3; Schneider & McGrew, 2018) for the postulation that financial literacy could potentially be classified within the CHC taxonomy as a stratum I cognitive ability. However, more work is required to confirm (or disconfirm) all six criteria specified by Schneider and McGrew (2018), in this context. Additionally, the review revealed three key methodological issues in the existing financial literacy research: (1) the lack of comprehensive cognitive ability measurement, (2) minimal examination of the unique contributions of stratum II cognitive abilities to financial literacy, and (3) the regular use of financial literacy tests with an insufficient number of test items. Future research based on adequate and comprehensive measures of cognitive ability and financial literacy is recommended to further evaluate financial literacy as a narrow ability and inform financial literacy interventions.

Funding

This research was supported by an Australian Government Research Training Program Scholarship through the University of Western Australia.

CRediT authorship contribution statement

Zoe Callis: Conceptualization, Methodology, Formal analysis, Investigation, Data curation, Writing – original draft, Visualization. **Paul Gerrans:** Resources, Writing – review & editing, Supervision. **Dana L. Walker:** Methodology, Validation, Resources, Writing – review & editing. **Gilles E. Gignac:** Conceptualization, Methodology, Validation, Resources, Writing – review & editing, Supervision, Project administration.

Declaration of Competing Interest

The authors declare that they have no conflict of interest. Declarations of interest: none.

Data availability

All data and scripts are available on the OSF (linked in manuscript).

Acknowledgements

We thank the corresponding researchers who provided additional study information, computed statistics, and/or sent through their data sets, for their contribution to the meta-analyses.

Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.intell.2023.101781.

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