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Health Literacy, Social Cognition Constructs, and Health Behaviors and Outcomes: A Meta-Analysis

Author
McAnally, Kaylyn

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Health Literacy, Social Cognition Constructs, and Health Behaviors and Outcomes: A Meta-Analysis

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for the degree of Master of Arts

in

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by

Kaylyn McAnally

2021

Professor Martin Hagger (Chair)
Professor Jennifer Howell
Professor Anna Song

The Thesis of Kaylyn McAnally is approved, and it is acceptable
in quality and form for publication on microfilm and electronically:

Chair

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K A Y L Y N M C A N A L L Y
kmcanally@ucmerced.edu

EDUCATION

PhD University of California, Merced Aug 2019-2024 (Expected)
Doctor of Philosophy in Health Psychology
Advisor: Dr. Martin Hagger

B.S. Arizona State University 2015-2019
Kinesiology, Psychology Minor
Barrett, the Honors College
GPA: 3.91
College of Health Solutions Dean's List Fall 2015-Spring 2019

PUBLICATIONS

Hagger, M.S, Moyers, S., **McAnally, K**., & McKinley, L.E. (2020). Known Knowns and Known Unknowns on Behavior Change Interventions and Mechanisms of Action. *Health Psychology Review*, DOI: 10.1080/17437199.2020.1719184

McKinley, L.E., **McAnally, K.**, Moyers, S., Hagger, M.S. (2020). Behavioral Health Theories, Equity, and Disparities in Global Health: A Basic Process Model. In *Handbook of Global Health.* Springer Nature.

Alegria, K. E., Fleszar-Pavlović, S. E., Ngo, D. D., Beam, A., Halliday, D. M., Hinojosa, B. M., **McAnally, K.**... & Song, A. V. (2021). The Role of Risk Perceptions and Affective Consequences in COVID-19 Protective Behaviors. *International Journal of Behavioral Medicine*, 1-7.

WORK EXPERIENCE

Editorial Associate Social Science and Medicine, Health Psychology April 2021-Present

Grad. Stud. Researcher Nicotine & Cannabis Policy Center Summer 2021
University of California, Merced

Teaching Assistant Psychology 145: Human Sexuality Fall 2021
University of California, Merced

Teaching Assistant Psychology 183: Behavioral Genetics Spring 2021
University of California, Merced

McAnally, K. (February, 2021). *Meiosis and Reproduction.* Guest lecture given at the University of California, Merced to Psychology 183 undergraduate class, Merced, California.

Teaching Assistant Psychology 190: Theories of Behavior Change Fall 2020
University of California, Merced

McAnally, K. (October, 2020). *Changing Behavior Using Self-Determination Theory & Autonomy-Supportive Interventions.* Guest lecture given at the University of California, Merced to Psychology 190 undergraduate class, Merced, California.

Teaching Assistant Psychology 125: Cognition, Affect, and Health Spring 2020
University of California, Merced

McAnally, K. (March, 2020). *Lay Illness Perceptions and Health.* Two invited guest lectures given via remote learning at the University of California, Merced to Psychology 125 undergraduate class, Merced, California.

Teaching Assistant Psychology 190: Theories of Behavior Change Fall 2019
University of California, Merced.

McAnally, K. (October, 2019). *Changing Behavior Using Self-Determination Theory & Autonomy-Supportive Interventions.* Guest lecture given at the University of California, Merced to Psychology 190 undergraduate class, Merced, California.

Instructional Aide Biology 181 &182: General Biology Laboratory Fall 2016-Spring 2019
Arizona State University
Teaching Assistant Exercise & Wellness 342: Health Behavior Change Spring 2019
Arizona State University
Behavior Coach New Hope of Arizona Dec 2018-Aug 2019
Worked directly with youth in behavior coaching and mentoring cases to develop positive coping skills and other healthy behaviors.

TRAININGS & CERTIFICATIONS

Preparing to Teach in the Online Environment
University of California, Merced, Center for Engaged Teaching and Learning
Certificate Received
Aug 2020
Methods for Meta-Analysis
Georgia State University, Center for International Business Education and Research
Certificate received
Nov 2020
Institute on Evidence-Based Teaching Practices
University of California, Merced, Center for Engaged Teaching and Learning
Certificate Received
June 2021

POSTER PRESENTATIONS

McAnally, Kaylyn. *An Evidence-Based Resource for Faculty Addressing Non-Course-Specific Student Needs.*
-Celebrating Honors Symposium. Barrett, the Honors College, Arizona State University. Tempe, Arizona. April 2019.
-Downtown Discovers Thesis Presentation. Barrett, the Honors College, Arizona State University. Phoenix, Arizona. April 2019.
-Student Research Symposium. College of Health Solutions, Arizona State University. Phoenix Convention Center. May 2019.

SERVICE

Lab Manager SHARPP Lab, University of California Merced July 2021-Present
Peer Reviewer *Annals of Behavioral Medicine, International Journal of Behavioral Medicine, Psychology of Sport and Medicine, Routledge Publishing, Frontline Learning Research, PLOS One*

Graduate Student "Buddy" "Buddy" to a prospective graduate student during visitation weekend 2020 at the University of California, Merced. Ensured the student was able to participate in all visitation weekend activities, provided transportation, and any other support that the prospective student needed.

Research Affiliate Mayo Clinic, Scottsdale, Arizona Feb 2018-May 2019
Assisted in designing a study to examine the relationship between diabetic patients and their providers through objective measures of emotion.

Abstract

Understanding determinants of health behavior engagement is key to promoting health outcomes. One such determinant is health literacy, the capacity to obtain, process, and understand basic health information and services needed to make appropriate health decisions (Baker et al., 2006). In this study we aimed to meta-analyze the effect of health literacy on health behavior engagement and outcomes across studies. We conducted a systematic search of published and unpublished literature (k = 203) to examine the overall relationship between health literacy, health behaviors, and health outcomes as mediated by social cognition constructs (attitudes, self-efficacy, knowledge, and risk perceptions). Meta-analysis indicated significant correlations between model constructs, particularly health literacy with knowledge and well-being, between self-efficacy and knowledge, attitudes, risk perceptions, and health behavior, and between risk perceptions and attitudes. A structural equation model based on the synthesized correlations indicated that self-efficacy and attitudes mediated the relationship between health literacy and health behavior. There were also total indirect effects of social cognition constructs on the health literacy-health behavior relationship. Analysis of health literacy measure type, sample origin, and behavior type revealed few differences in model results. Findings support that health literacy is associated with health behavior engagement, and this relationship may be explained by various health beliefs. Understanding the effects of health literacy or health beliefs on health behaviors may potentially be informative for future research aiming to promote health outcomes broadly.

Keywords: health literacy; health behavior; self-efficacy; meta-analytic structural equation modeling

Health Literacy, Social Cognition Constructs, and Health Behaviors and Outcomes: A Meta-Analysis

Non-communicable diseases such as heart disease, cancer, and type II diabetes are responsible for considerable morbidity and mortality worldwide (Hyde et al. 2012; Lippke et al. 2012; World Health Organization, 2014). Epidemiological research indicates that incidence of these diseases is associated with participation in health behaviors such as engaging in regular physical activity, eating a healthy diet, adhering to medication, not smoking, and drinking only in moderation (Hales et al., 2018; Hyde et al., 2012; Li et al., 2019; Mesas et al., 2012; Onat, 2001; Ouyang et al., 2012). However, population level participation in health behaviors and abstinence from health risk behaviors remains low and insufficient to reduce disease risk (Murimi & Harpel, 2010). Importantly, research has also indicated that underserved populations in particular have disproportionately higher rates of incidence of these diseases (Braveman, 2006) and lower incidence of health behavior participation (Hyde et al., 2012; Lee & Loke, 2005; Lippke et al., 2012; Mojtabai & Olfson, 2003). For example, studies have shown that socio-structural variables that represent disadvantage such as racial/ethnic group, socioeconomic status, or education level are related to higher disease risk and poorer health outcomes (Braveman, 2006). In addition, these variables have also been associated with lower participation in health behaviors (Schüz et al., 2017; Schüz et al., 2020; Wardle et al., 2016). Governments and health practitioners have, therefore, recognized the need to develop efficacious behavioral interventions aimed at promoting health behavior participation (Haider et al., 2016). This has been identified as a particular priority in underserved populations such as those of lower socioeconomic status or in racial/ethnic minority groups, with the goal of addressing observed disparities in health behavior participation and disease risk.

Development of efficacious behavioral interventions necessitates a fundamental understanding of the behavior and, in particular, potentially modifiable determinants, that may be targeted for change through intervention content (Hagger et al., 2020; Nielsen et al., 2018). A prominent approach to identifying these determinants is through the application of social cognition theories from psychology, which outline how individuals' beliefs regarding a given target health behavior relate to their intention toward, and actual participation in, the behavior in future. The value of identifying these determinants is that they may signal potential targets for change in behavioral interventions. Social cognition theories have been applied extensively in health behavior research, and meta-analyses have demonstrated consistent associations between social cognition constructs such as attitudes, self-efficacy, social norms, and risk perceptions and health behavior participation (Brewer et al., 2007; Sheeran et al., 2016; Zhang et al., 2019).

Recent research has also investigated relations between social cognition beliefs with respect to health behaviors and socio-structural variables that represent disadvantage. The research may assist in providing an explanation of observed disparities in disease incidence and poorer health outcomes in disadvantaged and underserved populations. For example, chronic disadvantage reflected in lower socioeconomic status or education level has been shown to be related to individuals' beliefs regarding their illness risk or the efficacy of behavior in promoting health (Adams et al., 2013; Orbell et al., 2017; Sawyer et al., 2012). These relationships may be because individuals from these disadvantaged groups attach less value to health, do not have adequate knowledge or understanding of the link between behavior and health, or perceive they have limited access to means to engage in health behaviors (e.g., cost of food, access to facilities). Taken together, these findings imply that social cognition variables may form part of the mechanism by which socio-structural variables representing disparity relate to health behavior participation. To this end, researchers have proposed and tested mediation models in which relations between socio-structural variables and health behavior participation are mediated by social cognition constructs (Adams et al., 2013; Hagger & Hamilton, 2021). For example, Adams and colleagues (2013) demonstrated that relations between health literacy and participation in health behaviors (cigarette smoking, fruit and vegetable consumption, physical activity) were mediated by risk perceptions. Similarly, Hagger and Hamilton (2021) further supported this idea by conducting a meta-analysis on the effects of socioeconomic status and constructs from the theory of planned behavior on intention and engagement in health behavior. Although model tests indicated residual effects of the socio-structural variables on intention and behavior, these data demonstrated that relations between socio-structural variables and health behavior participation were at least partially accounted for by social cognition beliefs such as attitudes, perceived behavioral control, and attitudes, and offer a mechanistic explanation for observed disparities in health behavior (for review see McKinley et al., 2020).

A socio-structural variable that has been shown to indicate substantive disadvantage in health contexts is health literacy. Health literacy is defined as the degree to which individuals have the capacity to obtain, process, and understand basic health information and services needed to make appropriate health decisions (Baker et al., 2006). Individuals with ‘adequate’ health literacy are better able to comprehend health information and are able to make informed personal health decisions and understand health consequences (Beauchamp et al., 2015; Sentell et al., 2014). Importantly, health literacy reflects disadvantage as lower or ‘inadequate’ levels are associated with lower education and socioeconomic status (Beauchamp, 2015; Sentell, 2013). Inadequate levels of health literacy are highly prevalent; a study of American adults found only 12% of adults to have proficient levels of health literacy, while 36% have only very basic levels of health literacy (Cutilli & Bennett, 2009). Inadequate health literacy has consistently been linked with poorer health outcomes and higher rates of all-cause mortality (Hawkins et al., 2011; Liu et al., 2015; Peterson et al., 2011). Meta-analyses have shown an association between health literacy and overall health status, as well as an association between health literacy and all-cause mortality (Mayberry et al., 2018; Wolf et al., 2005). In addition, inadequate health literacy is associated with lower levels of participation in health behaviors. For example, lower levels of health literacy are associated with decreased engagement in physical activity and medication adherence (Lim et al., 2021; Zhang et al., 2014).

Considering research proposing that belief-based constructs from social cognition theories may provide a mechanistic explanation for observed disparities in health behavior engagement, as indicated by socio-structural variables, it follows that these constructs may offer a potential explanation for the association between adequate health literacy and health behavior participation and, by extension, health outcomes. Specifically, individuals with adequate levels of health literacy may be more likely to hold adaptive beliefs with respect to health behavior engagement, beliefs which theory and research have been shown to be related to health behavior engagement (Peterson et al., 2007; Soones et al., 2017). As a consequence, the belief-based constructs from social cognition theories may serve to mediate the observed association between health literacy and health behavior participation and outcomes. For example, individuals with inadequate levels of health literacy may lack the knowledge, interpretive capacity, or ability to translate risk-related information, particularly, for example, information linking health with behavior (e.g., linking foods labeled as high in dietary fat or sugar with heart disease risk). This will then be reflected in their evaluations of utility (e.g., attitudes) and risk (e.g., risk perceptions) with respect to their dietary choices. Consistent with theory, these beliefs will be implicated in their decisions to participate in dietary behaviors. In the long run, this may impact health outcomes (e.g., risk of heart disease). Taken together, this implies a mediational model in which effects of health literacy on health behavior and health outcomes is mediated by belief-based social cognition theories.

To date there is no research has studied the proposed mediation of effects of health literacy consistent with the proposed mediation model and with previous research testing social cognition constructs as mediators of effects of other socio-structural variables on health behavior participation and outcomes. However, an emerging body of research has tested associations among health literacy, social cognition constructs, and health behavior participation and outcomes. This affords the opportunity to test effects of the proposed model by pooling correlations among model constructs from this research using meta-analysis with the synthesized data. In the current study we aimed to do precisely that; leveraging the body of existing research reporting correlations among health literacy, social cognition constructs, health behavior, and health outcomes to evaluate the tenability of our unique mediation model. The value of the research lies in its potential to provide a mechanistic explanation for the effect of health literacy on health behavior and health outcomes mediated by social cognition constructs.

Examining relations among health literacy, social cognition constructs, and health behavior, including the mediating effect of social cognition constructs on the health literacy-health behavior and health outcomes relationships across studies using meta-analysis will provide estimates of the size and associated heterogeneity of the effects. Estimation of these overall effects it useful in a general sense as it will provide information the precision of the estimates across studies and whether or not they differ from the null. However, given studies are likely to have been conducted in multiple populations, contexts, and behaviors, variability in effects across studies according to these variables is expected. For example, effect of social cognition constructs relating to normative beliefs may vary by behavior type; behaviors that are likely to affect others (e.g., smoking) or are likely to be co-acting or frequently performed in social contexts (e.g., eating) may be more subject to normative influences than behaviors less likely to affect others (e.g., screening attendance) or usually performed solo (e.g., physical activity). Similarly, effects of health literacy may also be larger for certain behaviors, particularly those where understanding of health information is likely to be central to decisions perform them (e.g., screening, vaccination). We therefore aim to test the moderating effects of key moderator variables on relations among constructs in the proposed model and, by extension, the extent to which social cognition constructs mediate health literacy effects. These proposed moderation effects notwithstanding, we expect observed variability in the correlations among these variables, and in the effects of the proposed model, across levels of the moderator variables to vary in size rather than presence or absence. This is because social cognition models are proposed to represent general decision-making processes, so the expected pattern of effects is expected to be consistent regardless of population, context, and behavior even though the size of the observed effects may differ.

The Present Study

The purpose of the present study was to synthesize relations among health literacy, social cognition constructs, and health behaviors and outcomes using meta-analysis, and use the meta-analytically synthesized relations among these constructs to test our unique model in which effects of health literacy on health behavior and outcomes is mediated by social cognition constructs, consistent with previous primary research testing similar models (e.g., Adams et al., 2013). Our analysis was conducted in two stages. In the first stage, we aimed to synthesize correlations among health literacy, social cognition constructs, and health behaviors and outcomes across studies using meta-analysis. To do so, we identified relevant studies that included measures of the key variables, and coded the health literacy, social cognition constructs, and health behaviors and outcomes measures into relevant categories. Next, we estimated averaged bias-corrected correlations among these variables using meta-analysis. We hypothesized non-zero correlations among health literacy, social cognition, health behavior and health outcomes.

Next, we evaluated the predictions of our proposed mediation model using the synthesized correlation matrices among health literacy, social cognition, health behavior and health outcomes using meta-analytic structural equation modeling. The generalized proposed model is presented in Figure 1. We hypothesized non-zero indirect effects of health literacy on health behavior and health outcomes mediated by the social cognition constructs. In addition, we tested the effects of candidate moderator variables on correlations among the health literacy, social cognition, health behavior and health outcome variables using meta-regression. Candidate moderators included behavior type, type of health literacy scale used, and sample education level. We expected model effects may vary according to behavior type given previous research that has indicated variation in effect of health literacy on behavior (Levin-Zamir et al., 2016), and between social cognition constructs and health behavior and outcomes (Sheeran et al., 2016), even though the pattern of model effects is expected to generalize across behaviors, consistent with the premises of social cognition theorists (e.g., Ajzen, 1991). We also expect the effect of health literacy on behavior to vary according to health literacy measure type, as measurement type varies in predictive capacity (Rudd, 2015) and according to education level, as health literacy is highly correlated with education level (Beauchamp et al., 2015). Data permitting, we aimed to estimate our proposed model through meta-analyses of groups of studies defined by levels of each moderator. The moderator analyses are exploratory in design, and we did not make hypotheses regarding directionality of potential effects. In addition, we also controlled for effects of key demographic and study design covariates in our model tests: sample gender and age, sample type (clinical or non-clinical), study design, and study quality.

Method

Search Strategy and Study Selection

We searched four prominent online databases (PubMed, Web of Science, Scopus, PsycInfo) for articles reporting associations among health literacy, social cognition variables (i.e., health beliefs), health behavior, and health outcomes. Search strings for each database are available in Appendix C (supplemental materials). In addition to the database searches, reference sections of other health literacy meta-analyses were searched to ensure all relevant articles had been identified. Prominent authors in the field were also contacted to identify unpublished data.

The initial pool of articles was screened for duplicates by four researchers. After duplicates (k = 9,222) were removed, the remaining pool of articles (k = 14,077) were screened according to title and abstract screening protocols. Articles remaining after title and abstract screening were subjected to a full-test screening by two researchers each to examine their eligibility against a full-text inclusion criterion. Screening protocols were validated by having each researcher screen of a sub-set of the articles according to protocol and estimating agreement. At each stage, agreement between researchers was good (average Cohen's κ = .85). Disagreements were discussed and resolved among the group of researchers and the screening protocol updated accordingly. When the researchers identified articles that satisfied inclusion criteria but did not report sufficient data to compute effect sizes for analysis, article authors were contacted by email to request the relevant data. Authors were contacted a minimum of two times requesting data access. Flow of articles through the search and screening procedures is reported in the PRISMA diagram in Appendix B (supplemental materials).

Inclusion Criteria

Studies were included in the current analysis if authors reported associations between a measure of health literacy and measure of a social cognition construct, health behavior, or health outcome (e.g., health status, health related well-being). Health literacy measures were included if assessed valid scale. Studies utilizing proxy measures of health literacy (e.g., education level, socioeconomic status) were excluded. Qualitative studies, reviews including narrative and conceptual reviews, systematic reviews, and meta-analyses, study protocols, and editorials were excluded.

Included Studies and Study Characteristics

Article search and screening processes identified 365 articles meeting the inclusion criteria. Articles (k = 162) that did not report sufficient data to compute effect sizes for analysis and for which data from study authors were unavailable were excluded, leaving 203 articles eligible for analysis. A list of included articles is provided in Appendix C (supplemental materials). A number of studies reported data from multiple studies or samples, yielding additional independent samples for analysis (k = 6). The final pool of studies consisted of 209 samples and an overall sample size of 210,622. Behaviors were grouped into health promoting behaviors (k = 180; e.g., physical activity, screening behaviors) or health risk behaviors (k = 45; e.g., smoking, alcohol consumption). Sixty-five percent of studies reported samples with approximately equal proportions of men and women, with 30% comprised predominantly women (> 75% women) and 5% comprised predominantly men (≤ 25% women). In addition, 63% of studies were on samples originating from countries classified as those with a high level of education according to education rankings from online sources (Organisation for Economic Co-operation and Development, 2021).

Effect Size Data Extraction and Classification of Constructs

Data Extraction

Effect size data were extracted from the included studies for relations between health literacy, social cognition constructs, health behaviors, and outcome variables. The zero-order correlation coefficient was identified as the effect size metric as all data relevant to the current analysis was correlational. Where zero-order correlations among study variables were not reported, we computed zero-order correlations from other available effect size data (e.g., odds ratios, mean differences, chi-square tests) using relevant conversion formulae.

Construct Classification

A perennial problem in meta-analysis is ensuring that measures used in studies were sufficiently representative of the key variables included in the analysis. To address this, we applied a classification procedure to ensure measures of health literacy, social cognition constructs, and behaviors were equivalent across studies. Our classification procedure was informed by a priori definitions of study constructs based on theory and conceptual reviews of the relevant variables. The construct definitions and coding protocol are available in Appendix X (supplemental materials).

Health literacy. A number of health literacy measures have been adopted in previous research (for review see Mancuso, 2009). Due to the large number and variation in health literacy measures used in included articles, each measure of health literacy was read and examined by the researchers in order to ensure consistency in measurement. Throughout this process, two broad categories of health literacy measures emerged: confidence measures and comprehension measures. Validated measures of health literacy typically assess the construct by either asking participants to rate their confidence understanding health-related information in medical contexts or to complete health-related tasks and include the Health Literacy Questionnaire (Osborne et al., 2013) and Single Item Literacy Screener (Morris et al., 2006). Alternative approaches prompt completion of health comprehension tasks such as identifying familiar health terms, responding to comprehension questions based on a short health passage, or by interpreting food nutrition labels. The Test of Functional Health Literacy in Adults (Parker et al., 1995), Rapid Estimate of Adult Literacy in Medicine (Murphy et al., 1993), and Newest Vital Sign (Weiss et al., 2005) utilize these health comprehension methods to assess health literacy. Full categorization of health literacy measures is available in supplemental materials (Appendix X). All health literacy measures were sorted into confidence or comprehension categories based on the content of the items. Health-comprehension measures comprised 44% of the included studies and health information-related confidence measures were used in 56% of the studies.

Social cognition constructs. We screened studies to identify available measures specifically developed to tap constructs from leading social cognition theories including social cognitive theory (Bandura, 1977), the health belief model (Rosenstock, 1974), protection motivation theory (Rogers, 1975), and the theories of reasoned action and planned behavior (Ajzen, 1991). We also identified constructs that were measured using bespoke measures of constructs that made reference to social cognition constructs but were not developed according to theory guidelines or adopted more integrated theoretical approaches. Alongside the extraction, we developed a set of definitions of key social cognition constructs informed top-down by prior classification systems used to develop 'core' sets of social cognition constructs from leading theories (e.g., Hagger et al., 2017; McMillan & Conner, 2007; Protogerou et al., 2018) and bottom-up by the reported measures of social cognition constructs from the included studies and the theories on which they were based. The classification system was then used to develop a coding system, which was used to assign measures of social cognition constructs from each study to a defined social cognition construct in the classification. In all cases, we ensured that the assignment was based on the content of the measures rather than the terms used to describe the constructs, as researchers' construct definitions often do not necessarily match the content of the items used (Block, 1995; Hagger, 2014). Coding of study measures in accordance with the classification protocol was conducted by one researcher with a sub-sample of studies independently coded by a second researcher to confirm validity. Inter-coder agreement was high (Cohen's $\kappa = .89$). A majority of studies included measures of specific constructs from typical social cognition constructs with measures of self-efficacy ($k = 32$), knowledge ($k = 42$), attitudes ($k = 3$), and risk perceptions ($k = 8$) occurring most frequently. The classification protocol and definitions of the social cognition constructs are available in Appendix X (supplemental materials).

Behavior measures. We identified the target behavior or behaviors of each study and classified them into broader categories based on prior research (McEachan et al., 2011). The categories included health-promoting and health risk behaviors. The most frequently reported health-promoting behaviors were physical activity, nutrition, medication adherence, illness management behaviors, oral health behaviors, and other general preventive health behaviors (i.e., preventive screening). The most frequently reported health risk behaviors were smoking and alcohol consumption. A number of studies reported multiple target behaviors ($k = 38$). The vast majority of studies measured behavior using self-report methods ($k = 245$) and few adopted non-self-report measures (k = 43). Behavior measures were assessed by standardized validated scales in some cases, but many studies adopted bespoke, single-item frequency measures.

Health outcome measures. Health outcome measures included self-report and non-self-report assessments of health status. Examples of non-self-report measures included glycosylated hemoglobin (HbA1C) in diabetics, blood pressure, asthma quality, or the presence of an illness. Self-report measures included previously validated measures of physical and psychological well-being such as RAND-36 (Hays et al., 1993) and the Quality of Life in Epilepsy Inventory (Cramer et al., 1998). Validated measures of self-rated health included the Short Form 12 Health Survey (Ware et al., 1996), the Addiction Severity Index (McLellan et al., 1992), and the CAGE Questionnaire (Ewing, 1984). We classified outcome measures into two broad categories: health status measures (k = 95) and well-being measures (k = 18). The basis for classification into health status was measures that assessed some sort of physical health outcome, while measures of well-being encompassed those measures assessing psychological outcomes (e.g., health-related quality of life). Identified measures and their classification into status and well-being categories are summarized in Appendix X (supplemental materials).

Moderator and Covariate Coding

Three candidate moderators were selected and coded as potential influences on the relation between health literacy and health behaviors and outcomes: health literacy measure type (comprehension or confidence), health behavior type (protective or risk behavior), and country of origin (based on country's education level; dichotomized as high or low). In addition, a series of study characteristics were coded for covariate assessment, including demographic characteristics of study samples, sample type, and study quality. Moderator and covariate coding is summarized in Appendix X (supplemental materials).

Moderator Variables

We aimed to evaluate whether relations between health literacy, social cognition constructs, and health behavior and outcomes varied according to three candidate moderators: health literacy measure type, sample education level, and health behavior type. We therefore coded studies into meaningful categories according to these moderator variables and aimed to estimate the proposed model in groups of studies in each moderator category.

Health literacy measure type. A number of measures of health literacy were identified in the present sample of studies, with the Short Test of Functional Health Literacy in Adults (Baker et al., 1999) and the Rapid Estimate of Adult Literacy in Medicine (Murphy et al., 1993) measures the most frequently adopted. Content analysis of the items used in these measures in our construct classification identified two broad categories: health-comprehension measures (k =121) and health information-related confidence measures (k = 88).

Education level. We reasoned that relations between health literacy, health beliefs, health behaviors and outcomes would differ across samples according to education level. In the absence of sample-level data on education level, we used national-level data as a broad indicator of sample education level. We therefore coded studies according to the national education level ranking of the country of origin based on the global education indicator published by the Organization for Economic Co-operation and Development (OECD, 2021). Samples were assigned to a *high* or *low* education category if the country of origin appeared top or bottom 50% of OECD global education rankings, respectively.

Health behavior type. Included studies targeted multiple health behaviors, and these were classified into health promoting (k = 180) and health risk (k = 45) behaviors for our moderator analysis, consistent with previous research (McEachan et al., 2011). Health promoting behaviors were defined as those expected to lead to improvement in health outcomes (e.g., physical activity engagement, healthy eating behaviors, medication adherence, screening attendance), and health risk behaviors were defined as those likely to have deleterious health consequences (e.g., tobacco smoking, excessive alcohol consumption, sedentary behavior).

Covariates

Demographic characteristics. Each sample included in the analysis was assessed for demographic characteristics that were included as covariates in the final analysis. Samples were classified as *older* (k = 45) if the reported average age of the sample was 40 years or above with a standard deviation below 15, *younger* (k = 54) if the average sample age was under 40 years with a standard deviation less than 15. Studies with samples with a high range or variability in the age of the included participants were coded as *balanced age* samples. Consistent with previous meta-analyses (Hamilton et al., 2020), samples were coded as majority female (>=75% female; k = 52), majority male (<=25% female; k = 14), or balanced gender profile (>25% female and < 75% female; k = 138). Age and gender coding were included as covariates in subsequent analyses.

Sample characteristics. Samples of the included studies were identified as clinical (k = 109) if studies took place in a hospital or healthcare setting or if diagnosis of a specific health condition (i.e., diabetes, heart disease) was a pre-requisite for inclusion in the study. Non-clinical samples (k = 94) comprised all other samples.

Study quality. The methodological quality of each included study was assessed using the Quality Assessment Checklist for Survey Studies in Psychology (Q-SSP) checklist (Protogerou & Hagger, 2020). The Q-SSP is a twenty-item checklist assessing the quality of reporting of four different categories of the assessed study: introduction, participants, data, and ethics. Assessment of studies using the checklist yields an overall quality score out of 20, which was used as continuous covariate in subsequent analyses. The Q-SSP checklist is available in supplemental materials (Appendix X).

Study design. All data used in this meta-analysis were correlational in design. The majority of studies utilized a cross-sectional design in which all variables were measured on a single occasion (k = 187). A minority of studies longitudinal designs which included a time lag between collection of data on measures of health literacy or social cognition constructs and health behavior or outcome (k = 16). Classification of studies into cross-sectional or longitudinal design was included as a dichotomous covariate in subsequent analyses.

Data Analysis

Multi-level meta-analysis of correlations

In the first stage of the analysis, we estimated the averaged bias-corrected correlations among the health literacy, the social cognition constructs, and health behavior and health outcome measures across studies using random-effects multi-level meta-analysis. Multi-level meta-analysis was used to account for dependency for studies that included multiple effect sizes within each study, such as multiple measures of health literacy, behavior, or outcomes, or measured multiple correlations between variables over time. The multi-level approach is a elegant means to account for dependency as other means such as aggregation results in data loss. The analysis yielded point estimates for each correlation after correcting for sampling error with accompanying confidence intervals and percentage of the total variability attributable to each level of the analysis (Cheung, 2014). Cochran's Q provided a formal estimate of heterogeneity in the effect size for each averaged correlation with an estimate of true variability given by the τ^2 coefficient.

Meta-analytic structural equation models

We tested the predictions of our proposed model in which the effect of health literacy on health behavior and health outcomes was mediated by the social cognition constructs using meta-analytic structural equation modeling (MASEM; Cheung, 2015a, 2015b). In the analysis, the matrix of correlations of model constructs extracted from the included studies in the analysis was pooled using meta-analysis and the fit of a model specifying the proposed relations among the constructs of the proposed model evaluated. The analysis yields overall model fit statistics as well as standardized point and variability estimates of the proposed relations among the constructs as stipulated in the model. The analysis was implemented using two-stage multi-level MASEM using the metafor (Viechtbauer, 2010) and metaSEM (Cheung, 2015b) packages in R. As our data included multiple effect size estimates within studies, we used Wilson et al.'s 2016) procedure to correct each correlation in the matrices used in the MASEM analysis using multi-level meta-analysis. This procedure also allowed for the adjustment of each correlation in the matrix for key covariates: sample age and sex, sample type, study type, and study quality.

Analysis of Moderators

Effects of moderator variables on the effects in our proposed model were tested by separate MASEM estimation of the model in groups of studies at each level of the moderator variables. As with the overall model tests, we used multiple criteria for goodness of fit to evaluate the adequacy of the model in each moderator group. Also consistent with the overall analysis, we estimated models in moderator groups that were adjusted and unadjusted for covariates. We evaluated differences in the standardized parameter estimates for model effects including the indirect effects of health literacy on health behavior and outcomes mediated by the social cognition variables by comparing effect sizes of parameter estimates across moderator groups. We therefore computed the 95% confidence intervals of the difference in the parameter estimates across the models (Schenker & Gentleman, 2001). A statistically significant difference in the parameter estimates across moderator groups was confirmed when the confidence interval did not include zero. A formal difference test is provided using Welch's *t*-test. Finally, in the event of small numbers of studies in the cells of the synthesized correlation matrices precluded model estimation in some moderator groups, we conducted sensitivity analyses instead which enabled us to determine whether our conclusions with respect to model effects changed when the studies at a specific level of the moderator were omitted from the analysis.

Assessment of Bias

Evaluation of potential selective reporting bias on each averaged correlation among study variables was assessed using a panel of bias-correction methods (Carter et al., 2019). The first set of analyses were based on 'funnel' plots of study effect sizes against an estimate of their precision (e.g., the inverse standard error. These included Begg and Mazumdar's (1994) rank correlation test, Duval and Tweedie's (2000) 'trim and fill' analysis, regression tests including Sterne et al.'s (2001) 'classic' regression test and two alternatives, the precision effect test (PET) and the precision effect estimate with standard error (PEESE) (Stanley & Doucouliagos, 2014). A significant rank correlation test, a large number of imputed studies in the trim and fill analysis, and significant effects of the precision estimate in the regression models signal significant bias. The trim and fill and regression tests also provide ostensibly 'bias' free estimates of the correlation. These analyses were implemented using the metafor package in R.

A second set of analyses were based on selection methods derived from Hedges' (1984) original model and modifications thereof (Iyengar & Greenhouse, 1988; Vevea & Hedges, 1995). These methods estimate the extent of bias in an effect size by comparing a selection model in which certain parameters of bias are present with a data model. The models used included Vevea and Hedges' three-parameter selection model, and two recent implementations, known as the *p*-curve and *p*-uniform* procedures. The three-parameter selection model, *p*-curve, *p*-uniform* analyses were implemented using the weightr (Coburn & Vevea, 2019), dmetar (Harrer et al., 2019), and puniform (Van Aert, 2020) functions, respectively, in R.

The bias correction methods were implemented in the zero-order correlations using conventional random effects meta-analysis because bias detection techniques have not been implemented with multi-level models. We therefore aggregated effect sizes within studies using Hunter and Schmidt's (2015) formula and set the within-study correlation between effect sizes at 0.50 (Wampold et al., 1997) using the MAc package (Del Re & Hoyt, 2018) in R.

Results

Meta-Analysis of Correlations

Averaged bias-corrected zero-order correlations and corresponding variability statistics from the multi-level multivariate meta-analysis among health literacy, social cognition constructs, and health behavior and outcomes are presented in Table 1. In all cases, correlations were non-zero and most were small-to-medium in size (range $r = .060$ to .309) with moderate-to high heterogeneity in most cases and statistically significant Q-values. The largest correlations were between health literacy and knowledge and well-being, between self-efficacy and knowledge, attitudes, risk perceptions, and health behavior, and between risk perceptions and attitudes (rs > .200, $p < .001$). There were insufficient studies in the current sample to estimate averaged correlations between the social cognition constructs and well-being, and between risk perceptions and health status.

Tests of the Proposed Model

Standardized parameter estimates and 95% confidence intervals for the direct and indirect effects the proposed model from the multi-level meta-analytic structural equation model for the full sample of studies are presented in Table 5. Focusing on the direct effects, we found statistically significant effects of health literacy on each social cognition construct with small-to-medium effect sizes. There were also statistically significant effects of attitudes, risk perception, and self-efficacy on behavior with small-to-medium effect sizes, while effects of the remaining social cognition constructs on behavior were no different from zero. In addition, direct effects of social cognition effects on health status were no different from zero. Finally, there were direct effects of health literacy on both behavior and health status.

Importantly, there were statistically significant indirect effects of health literacy on behavior mediated by self-efficacy and attitudes. That there was a residual effect of health literacy on health behavior indicated that the indirect effects of health literacy on behavior through self-efficacy and attitudes represented partial mediation. However, the sum of indirect effects of health literacy on health behavior accounted for a substantive proportion of the total effect of health literacy on health behavior. The mediation proportion statistic (P_M; Ditlevsen et al., 2005), which provides ratio of the total effect to a mediated effect, indicated that the sum of indirect effects of health literacy on behavior through these social cognition constructs accounted for over one half of the total effect of health literacy on health behavior ($P_M = .569$).

By contrast, there were no significant indirect effects of health literacy on health status through any of the social cognition constructs. However, we found a statistically significant sum of indirect effects of health literacy on health status through all of the social cognition constructs. Although each of the constituent indirect effects were small and not statistically significant, when added together they yield a significant total indirect effect. In fact, the sum of indirect effects of health literacy on health status through the social cognition constructs accounted for over one-third of the total effect of health literacy on health status (P_M = .391). These findings indicate that while health literacy contributes uniquely to health behavior participation and health outcomes, social cognition constructs explain substantive proportions of these effects.

Analysis of Moderators

We planned to examine effects of our candidate moderator variables (behavior type, health literacy moderator type, country of origin) on relations among constructs in our proposed model by estimating the model separately in groups of samples at each level of the moderator. However, there were insufficient studies at some levels of the moderator analyses leading to empty cells in the pooled matrix of correlations used as input for the meta-analytic structural equation model. As a consequence, we were unable to estimate the model in groups of studies at the health risk behavior level of the behavior type moderator, at the comprehension measures of health literacy level of the health literacy measure moderator, and at the high education country level of the country-of-origin moderator. Our alternative approach was to conduct sensitivity analyses to evaluate the extent to which excluding studies from the sample at these levels of the moderator affected our conclusions on model effects based on the analysis in the overall sample. Overall model results of the models estimated in the sensitivity analysis are presented in Table 3 and parameter estimates, 95% confidence intervals, and formal comparison of effects across the sensitivity analysis models with the model estimated in the overall sample are presented in Table 6.

For the health literacy measure type analysis, results indicated larger effects of health literacy on self-efficacy and knowledge in the model excluding studies using comprehension measures of health literacy relative to the overall model. In addition, sums of indirect effects and total effects of health literacy on behavior were also larger in this group compared to the model in the overall sample. For the education level sensitivity analysis, result revealed a smaller effect of health literacy on knowledge for the model excluding studies from countries with higher education level compared to the model in the overall sample. In addition, the indirect effect of health literacy on behavior through self-efficacy, and the sums of indirect effects and total effects of health literacy on behavior, were smaller compared to the model in the overall sample. Finally, for the behavior type sensitivity analysis, we found no differences in model parameter estimates in the model excluding health risk behavior relative to the model estimated in the overall sample. Overall, high heterogeneity was observed in all models in the sensitivity analyses based on statistically significant *Q*-values and I^2 values greater than 50%.

Assessment of Publication Bias

Results of the publication bias analyses applied to the averaged correlations among study variables are presented in Table 4. Taken together, the profile of estimates across the panel of bias analyses suggests limited evidence of systematic bias in the correlations in the present study, a small number of idiosyncratic findings of significant bias excepted. For the analyses based on the funnel plot, we found non-significant rank correlation tests, non-significant *z*-tests from the Sterne's regression analyses, and low numbers of imputed studies in the trim and fill analyses. Similarly, for the analyses based on selection models, we found significant skewness and non-significant flatness estimated for the *p*-analyses, non-significant bias estimates from the *p*-uniform* analysis, and non-significant bias estimates from the 3PSM analysis. Correlations corrected for bias from these analyses were also not appreciable different from the original correlation in most cases. It is important to note that we cannot rule out the possibility of significant publication bias for correlations effects where we were unable to compute publication bias statistics due to small sample sizes. Furthermore, it is also important to note that substantive heterogeneity was observed in most of the averaged correlations, and some bias analyses do not provide precise estimates under conditions of high heterogeneity. These limitations notwithstanding, the current analyses provided limited evidence of extensive bias among the correlations in the current analysis.

Discussion

The purpose of the present study was to synthesize relationships between health literacy, belief-based constructs from social cognition theories (attitude, self-efficacy, norms, self-efficacy, treatment beliefs), health behaviors, and health outcomes (health status, psychological well-being) across samples using meta-analysis. In addition to estimating the averaged zero-order correlations among these variables and their heterogeneity across studies, a key aim of the study was to estimate a proposed model in which relations between health literacy and health behavior and outcomes were mediated by social cognition constructs using meta-analytic structural equation modeling. Results indicated statistically significant averaged correlations among the study variables across studies, with particularly strong correlations between health literacy and knowledge, attitudes, and well-being, between self-efficacy and attitudes and health behavior, and between risk perceptions and attitudes. Tests of the proposed model indicated that relations between health literacy and health behavior were mediated by attitude and self-efficacy, leading to significant sums of indirect effects of health literacy on health behavior. There were also significant sums of indirect effects of health literacy on health outcomes mediated by social cognition constructs, even though none of the specific indirect effects exceeded conventional levels of statistical significance. Sensitivity analyses used to examine moderator effects in the proposed model revealed larger effects of health literacy on self-efficacy and knowledge, and larger sums of indirect effects and total effects of health literacy on behavior, when studies using comprehension measures of health literacy were excluded. In addition, effects of health literacy on knowledge, the indirect effect of health literacy on behavior through self-efficacy, and the sums of indirect effects and total effects of health literacy on behavior, were smaller when studies conducted in countries with higher education level were excluded. Taken together, current results yield important information on potential mechanisms by which health literacy may relate to health behavior and health outcomes, and the contextual variables that likely affect these relations.

Health Literacy, Social Cognitions, and Health Behavior and Outcomes Relations

Current findings corroborate results of previous studies examining relations between health literacy and participation in health behavior and health outcomes. For example, research has demonstrated that adequate health literacy is associated with better diet quality and food label use (Cha et al., 2014), decreased smoking incidence (Husson et al., 2015), and higher rates of physical activity participation (Husson et al., 2015). Our research extends these findings by demonstrating that adequate levels of health literacy are associated with increased participation in behaviors that promote health (e.g., physical activity, healthy eating, screening attendance) and inadequate levels of health literacy are associated with increased participation in health risk behaviors (e.g., screening avoidance, smoking, excessive alcohol consumption). In addition, previous research has shown that adequate health literacy is associated with better health outcomes including subjective reports of health, and lower incidence of, or effective management of, chronic conditions (Kim, 2009). Consistent with this research we found positive associations between health literacy and health status across studies. Taken together our findings further corroborate the notion that individuals who lack capacity to comprehend or interpret health-related information are less likely to participate in behaviors that are likely to support good health, and more likely to report poor health outcomes and lower levels of psychological well-being. Our further contributes to the evidence base indicating considerable disparities in health behavior participation and health outcomes, particularly among underserved populations with lower levels of income and education (Crook & Peters, 2008; Freedman et al., 2011; Mackenbach et al., 2008).

A further important finding of the current study is the significant correlations between health literacy and social cognition constructs across studies. These findings are also consistent with observed relations between socio-structural variables that may indicate inequality (e.g., socio-economic status, race, education level) and social cognition constructs that are likely implicated in previous behavioral engagement (Adams et al., 2013; Hagger & Hamilton, 2021; Orbell et al., 2017). Specifically, our results indicated that adequate levels of health literacy were associated with increased self-efficacy, knowledge, and attitudes, and lower risk perceptions, with respect to health behavior participation across studies. This further extends research that has identified disparities in health behavior among those with inadequate health literacy by indicating that similar disparities exist in individuals' beliefs known to be implicated in health behavior participation (Adams et al., 2013). Individuals with inadequate health literacy, therefore, may be less likely to express beliefs with respect to the utility, risk, capacity, and know-how when it comes to health behaviors. Prior research on health disparities has speculated that this lower endorsement of beliefs may be attributable, for example, to disenfranchisement or prejudice in the healthcare system or, as in the case of the health literacy effects observed in the current study, inadequate provision of, and clarity in, health-related information by the health education systems that serve these communities.

In addition, our analysis also indicated that self-efficacy, risk perceptions, knowledge, and attitudes were associated with participation in health behavior across studies, supporting research indicating that these constructs are consistent predictors of health behavior consistent with social cognition theories (Brewer et al., 2007; McEachan et al., 2011; Zhang et al., 2019). Further, our findings are also consistent with research identifying attitudes and self-efficacy as, generally, having the largest effects across studies – indicating that beliefs in behavioral utility in producing outcomes and capacity in performing behavior are central to the decision-making process that leads to future participation. We also observed that self-efficacy and knowledge were correlated with health status, which corroborates prior research on links between social cognition constructs and health outcomes (Kumsar et al., 2021; Sarkar et al., 2007). Although not immediately apparent in correlational findings, the belief-outcome associations are presumably because these beliefs line up participation in behaviors likely to be consequential, in the long run, to adaptive health outcomes.

Tests of the Proposed Model

A unique aspect of the current research is that it enabled us to leverage the synthesized correlations to demonstrate that social cognition constructs mediated relations between health literacy and health behavior across studies. This is consistent with previous primary studies indicating that beliefs mediated the relationship between health literacy and participation in certain health behaviors (e.g., Adams et al., 2013), and, more broadly research demonstrating that social cognition constructs mediate effects of other socio-structural variables that indicate inequity on health behavior (e.g., Orbell et al., 2017). Specifically, we found that attitudes and self-efficacy mediated the health literacy-health behavior relationship and accounted for a substantive proportion of the effect. These findings implicate beliefs relating to the utility of the behavior in producing outcomes (i.e., attitudes), and beliefs in capacity to perform it (i.e., self-efficacy), are key to explaining this relationship. Individuals with adequate health literacy are more likely to be better equipped to access, interpret, and apply health information, such as messages linking health outcomes with behavior, and modify their beliefs and actions accordingly. By contrast, those with inadequate health literacy may not have the capacity to process health-related information, which is likely to be reflected in their beliefs with respect to health behaviors, such as valuing the behavior less or not having sufficient confidence to perform it, and their subsequent participation in health behaviors.

Our model findings also suggest that this pattern of effects extends to health outcomes. The social cognition constructs also mediated the relationship between health literacy and health status, although indirect effects through specific beliefs were not statistically significant. This finding demonstrates that individuals' beliefs about future participation in health behavior effectively account for the variance shared between health literacy and health outcomes (e.g., self-reported health status, HbA1c). Adequate levels of health literacy, or, adequate understanding of health information, is not only reflected in adaptive beliefs regarding health behaviors and actual participation in health behavior, but also in actual health outcomes, likely the consequence of health behavior participation. These are important findings given that explaining variance in health behavior participation does not necessarily imply concomitant explanation in health outcomes.

Effects of Moderators

The current analysis also provided important information on the potential conditions that may determine the magnitude of effects in the proposed model. Sensitivity analyses revealed larger effects of health literacy on self-efficacy and knowledge, and larger indirect effects of health literacy on behavior through these variables, when estimating the model in the sample of studies excluding comprehension measures of health literacy compared to when it was estimated in the full sample. Confidence health literacy measures reflect estimates of capacity when it comes to interpreting and applying health-related information and is likely to be closely aligned with general motivation toward health and its determinants, particularly estimate of capacity to perform health behaviors. Confidence measures may also represent levels of generalized self-efficacy. Similarly, such beliefs reflect greater confidence in applying health information.

Our sensitivity analyses also revealed a smaller effect of health literacy on knowledge, a smaller indirect effect of health literacy on behavior through self-efficacy, and a smaller sum of indirect effects and total effect of health literacy on behavior, when the model was estimated in the sample of studies excluding those from countries with higher education level compared to the model estimated in the full sample. The pattern of effects may indicate that individuals from lower education backgrounds may, therefore, may be more likely to discount, or be less reliant on, their capacity to understand health information when estimating their beliefs about health behaviors. This may indicate the importance of accounting for general education levels when considering the potential impact of health literacy as a source of information when individuals estimate their beliefs about health behaviors, and their future engagement in health behaviors.

Finally, we found no differences in model effects when the model was estimated in a sample of studies that excluded health risk behaviors. This provides some evidence that the pattern of effects in the model is consistent across behaviors, and provide some initial, albeit limited, support for the premise that effects of belief-based constructs in social cognition theories present a generalized decision-making process that precedes behavior.

Contribution, Limitations, and Avenues for Future Research

The current study is the first to synthesize relations among health literacy, social cognition constructs, health behaviors and outcomes in the extant literature, and leverage these synthesized data to test effects of a proposed model in which health literacy relates to health behavior mediated by social cognition variables. These findings have value because they contribute to the emerging evidence indicating that health literacy is not only related to health outcomes and health behavior participation, reflecting disparities in observed health, but also to the sets of beliefs that likely inform decisions to participate in health behavior based on social cognition theories. The research makes an important initial contribution to an evidence base of a potential mechanism by which health literacy is associated with health behavior and health outcomes.

Current findings should be interpreted in light of several limitations. One notable limitation was the relatively small number of included studies that reported relations between health literacy and treatment beliefs and well-being. Not only did this mean small samples sizes when estimating the averaged correlations for these variables, but also empty cells in the matrix of correlations among study variables when they were included. These variables were therefore dropped from the proposed model. In addition, only small numbers of studies were available at each level of our proposed moderators which precluded full moderation analyses, so we had to resort to sensitivity analyses. Although the sensitivity analysis allowed us to make inferences regarding the potential moderator effects, they precluded drawing definitive conclusions. As the research literature on relations among health literacy, social cognition constructs, and health behaviors and outcomes, future syntheses that extends to other potential mediators, such as treatment beliefs, and other outcomes such as well-being, and that conducts more complete moderator analyses should be possible.

An additional limitation of the current research is the sole reliance on correlational data, which precluded inference of causality in the predictions of our proposed model. This means that other, equally plausible models may fit the data even though they may be contraindicated theoretically. It should therefore be stressed that the proposed directional relations among model constructs, and the associated mediated effects, are inferred from theory alone, not the data. Future researchers should prioritize longitudinal or experimental tests of the proposed model that will better enable directional and causal inferences in effects of health literacy on social cognition variables, health behaviors, and outcomes.

Conclusion

Overall, this meta-analysis is the first to provide information on the overall association between health literacy and health behavior and outcomes mediated by social cognition variables. Specifically, health literacy, attitudes, and self-efficacy have been found to have unique effects on health behavior and may therefore be viable determinants of health behavior engagement. Based on findings from this study, researchers should investigate additional proposed mechanisms by which health literacy influences health behavior, as social cognition variables did not explain the total variance seen in the effect of health literacy on health behavior. To improve health behavior engagement, this study researchers could design interventions in order to target self-efficacy, attitudes, risk perceptions, and knowledge of health behaviors, as the sum of these social cognition constructs help explain how health literacy influences health behavior. Researchers could also design large scale education interventions, especially in disenfranchised communities as a way to bolster health literacy levels, which will have a positive effect on health beliefs, health behavior engagement, and health status.

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Table 1

Results of Multi-Level Meta-Analysis of Zero-Order Correlations Among Study Variables Including and Excluding Moderators

Model	*k*	*r*	95% CI		σ^2 within	σ^2 between	*Q* (residual heterogeneity)	AIC	I^2	var σ^2		Moderator tests		ANOVA[a]
			LL	UL						within	between	*Q*	df	LRT
HL-SE	120	.198***	.165	.231	.008	.002	392.591***	-139.955	69.59	53.01	16.58	-	-	-
		.333***	.140	.524	.006	.001	263.518***	-138.634	63.73	54.97	8.75	17.561*	8	14.679
		.336***	.145	.527	.006	.001	263.517***	-136.767	64.00	55.66	8.34	17.809*	9	14.811
HL-KN	78	.296***	.247	.344	.003	.019	810.954***	-80.460	92.63	12.12	80.51			
		.184	-0.152	.520	.003	.014	566.263***	-73.524	91.27	15.84	75.44	10.493	8	9.064
		.155	-0.217	.527	.003	.013	535.906***	-71.644	91.31	16.01	75.30	10.713	9	9.184
HL-RP	8	.177**	.068	.286	.023	.000	116.135***	-0.927	93.43	93.43	0.00	-	-	-
	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	-	-	-	-	-	-	-	-	-	-	-	-	-	-
HL-AT	50	.144***	.073	.216	.007	.008	179.509***	-52.064	73.65	32.52	41.12	-	-	-
		1.101***	.587	1.614	.003	.000	77.846**	-64.582	35.29	35.29	0.00	57.281***	6	24.518**
		1.190**	.348	2.032	.003	.000	77.465**	-60.751	35.77	35.77	0.00	58.064***	8	24.687**
HL-TB	9	.144	-.002	.290	.005	.018	98.079***	-5.833	96.88	19.89	76.99	-	-	-
	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	-	-	-	-	-	-	-	-	-	-	-	-	-	-
HL-BEH	570	.150***	.129	.170	.006	.012	5475.542***	-747.697	93.66	31.84	61.82	-	-	-
		.153*	.021	.285	.006	.010	4818.260***	-741.688	93.32	34.15	59.17	10.484	8	9.991
		.156*	.024	.288	.006	.010	4535.567***	-748.754	93.13	33.98	59.16	22.030*	10	21.057*
HL-ST	447	.117***	.092	.141	.006	.011	5767.179***	-642.838	94.64	32.19	62.44	-	-	-
		.250**	.089	.411	.006	.010	5027.656***	-640.010	94.20	35.05	59.15	13.875	8	13.171
		.245**	.086	.403	.006	.009	4185.609***	-639.885	94.05	35.79	58.25	18.276	10	17.047
HL-WB	26	.228***	.174	.282	.000	.010	83.427***	-53.585	87.39	0.00	87.39	-	-	-
		-0.056	-0.475	.363	.000	.007	71.975***	-42.739	87.36	0.00	87.36	5.840	8	5.154
		-0.006	-0.416	.404	.000	.006	66.782***	-40.782	87.50	0.00	87.50	8.332	10	7.197
SE-KN	10	.220***	.136	.303	.012	.000	32.785***	-5.124	73.37	73.37	0.00	-	-	-
		1.455	-3.836	6.747	.005	.000	21.555**	1.184	73.21	73.21	0.00	4.849	5	3.692
	-	-	-	-	-	-	-	-	-	-	-	-	-	-
SE-RP	6	.233***	.181	.286	.003	.000	14.822*	-11.683	59.52	59.52	0.00	-	-	-
	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	-	-	-	-	-	-	-	-	-	-	-	-	-	-
SE-AT	59	.309**	.120	.498	.008	.042	217.577***	-51.719	88.40	13.85	74.55	-	-	-
		2.878**	.987	4.769	.007	.014	158.976***	-48.539	77.54	27.25	50.29	9.518	5	6.820
	-	-	-	-	-	-	-	-	-	-	-	-	-	-
SE-BEH	83	.240***	.190	.290	.046	.000	886.930***	0.283	92.68	92.68	0.00	-	-	-
		.141	-0.210	.493	.041	.000	506.697***	6.243	92.45	92.45	0.00	8.482	7	8.040
		.133	-0.305	.572	.041	.000	506.153***	9.798	92.60	92.60	0.00	8.975	9	8.485

SE-ST	69	.156**	.054	.257	.010	.025	484.982***	-58.502	92.08	26.43	65.65	-	-	-
		.921***	.504	1.338	.010	.004	331.661***	-58.388	83.84	59.89	23.95	21.565**	6	11.887
		.945***	.510	1.380	.010	.004	331.657***	-56.570	84.12	59.43	24.69	21.484**	7	12.068
KN-RP	6	.128	-0.025	.282	.035	.000	126.883***	1.200	95.27	95.27	0.00	-	-	-
	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	-	-	-	-	-	-	-	-	-	-	-	-	-	-
KN-AT	13	.186***	.101	.272	.000	.006	24.844*	-24.658	65.75	0.00	65.75	-	-	-
	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	-	-	-	-	-	-	-	-	-	-	-	-	-	-
KN-BEH	32	.142***	.093	.192	.011	.003	458.607***	-30.944	92.85	76.29	16.56	-	-	-
		.376**	.099	.653	.007	.000	195.754***	-31.028	89.21	89.21	0.00	22.267**	8	16.083*
		.208	-0.105	.520	.005	.000	157.163***	-31.842	87.60	87.60	0.00	32.097**	10	20.898*
KN-ST	15	.070**	.023	.118	.004	.000	39.889**	-18.833	68.39	68.39	0.00	-	-	-
	-	.128	-3.088	3.344	.000	.000	22.584**	-14.832	0.00	0.00	0.00	17.304**	6	8.000
	-	-	-	-	-	-	-	-	-	-	-	-	-	-
RP-AT	13	.239***	.123	.355	.044	.000	336.079***	2.739	96.17	96.17	0.00	-	-	-
	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	-	-	-	-	-	-	-	-	-	-	-	-	-	-
RP-BEH	8	.127***	.054	.199	.008	.000	41.727***	-7.334	80.38	80.38	0.00	-	-	-
	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	-	-	-	-	-	-	-	-	-	-	-	-	-	-
AT-BEH	41	.189***	.130	.249	.030	.000	232.408***	-10.857	86.08	86.08	0.00	-	-	-
		.183	-0.558	.924	.028	.000	221.402***	-0.714	87.29	87.29	0.00	1.897	6	1.857
		.130	-0.946	1.206	.028	.000	221.292***	1.268	87.61	87.61	0.00	1.916	7	1.875
AT-ST	22	.179	-0.089	.447	.002	.036	87.060***	-25.599	81.88	3.33	78.54	-	-	-
	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	-	-	-	-	-	-	-	-	-	-	-	-	-	-
TB-BEH	15	.060*	.005	.116	.010	.000	337.534***	-15.935	96.83	96.83	0.00	-	-	-
	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	-	-	-	-	-	-	-	-	-	-	-	-	-	-
BEH-ST	124	.084***	.048	.121	.004	.006	768.052***	-213.783	91.42	36.05	55.38	-	-	-
		.285*	.042	.528	.004	.004	546.802***	-203.304	90.60	43.07	47.52	3.939	7	3.521
		.245*	.020	.470	.004	.003	533.111***	-204.441	89.22	50.28	38.94	10.550	9	8.658
BEH-WB	8	.189***	.080	.298	.005	.008	33.428***	-3.650	78.19	31.08	47.11	-	-	-
		.040	-0.012	0.093	.000	.000	6.132	-8.118	0.00	0.00	0.00	27.295***	4	12.468*
	-	-	-	-	-	-	-	-	-	-	-	-	-	-

Note. *k* = Number of studies; *r* = Average sample-weighted correlation; σ^2 between = Between-study variance; σ^2 within = Within-study variance; *Q* = Cochrane's *Q* statistic; df = Degrees of freedom; AIC = Akaike's Information Criterion; var σ^2 = Percentage of overall variance attributable to within and between study variance components. [a]Degrees of freedom = 3 in each analysis. HL = Health literacy; SE = Self-efficacy; KN = Knowledge; RP = Risk perceptions; AT = Attitudes; BEH = Behavior; ST = Health status. Cells with dashes (-) indicate analyses that were unable to

run due to small samples. Associations for the following relations were omitted due to small samples: SE-WB, KN-WB, AT-WB, RP-WB, RP-ST, AT-TB, TB-WB, TB-ST.
$^{*}p < .05$ $^{**}p < .01$ $^{***}p < .001$

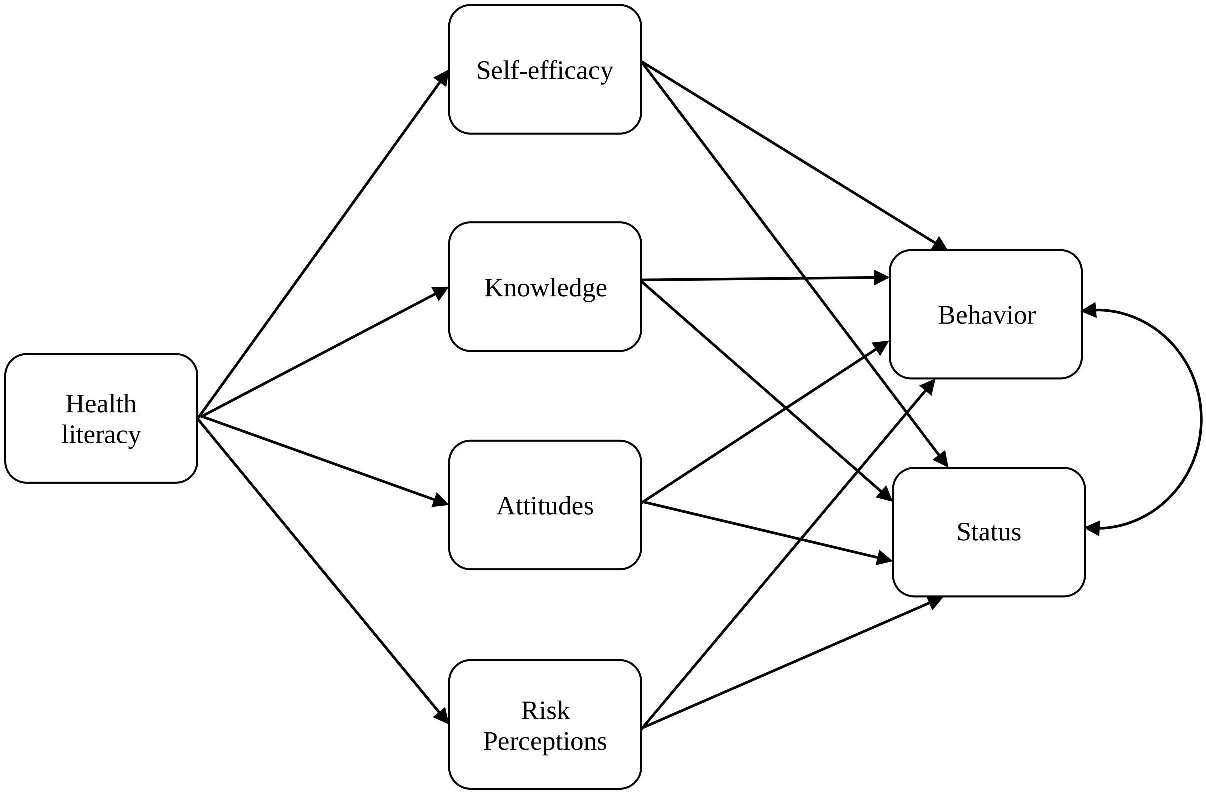
Table 2
Standardized Parameter Estimates of Direct and Indirect Effects in Multi-Level Meta-Analytic Structural Equation Model for the Full Sample Analyses Unadjusted and Adjusted for Covariates

Effect	Model unadjusted for covariates			Model adjusted for covariates		
	β	95% CI		β	95% CI	
		LL	UL		LL	UL
Direct effects						
HL→SE	.228***	.196	.260	.219***	.187	.251
HL→KN	.299***	.265	.333	.290***	.256	.325
HL→RP	.175***	.091	.259	.166***	.082	.250
HL→AT	.167***	.122	.211	.158***	.113	.202
HL→BEH	.064***	.038	.090	.062***	.037	.087
HL→ST	.074***	.030	.118	.071**	.028	.113
SE→BEH	.218***	.168	.261	.214***	.169	.258
SE→ST	.030	-.035	.095	.028	-.035	.091
KN→BEH	.048	-.008	.104	.045	-.010	.101
KN→ST	.014	-.069	.096	.010	-.071	.092
RP→BEH	.023	-.070	.116	.020	-.072	.112
RP→ST	.200	-.049	.450	.193	-.055	.441
AT→BEH	.124***	.069	.180	.121***	.067	.176
AT→ST	.025	-.061	.110	.022	-.062	.106
Indirect effects						
HL→SE→BEH	.050***	.036	.063	.047***	.034	.059
HL→SE→ST	.007	-.008	.022	.006	-.008	.020
HL→KN→BEH	.014	-.003	.031	.013	-.003	.029
HL→KN→ST	.004	-.021	.029	.003	-.021	.027
HL→RP→BEH	.004	-.012	.020	.003	-.012	.019
HL→RP→ST	.035	-.012	.083	.032	-.013	.077
HL→AT→BEH	.021***	.010	.032	.019***	.009	.030
HL→AT→ST	.004	-.010	.018	.003	-.010	.017
Sums of indirect effects						
HL→BEH[a]	.089***	.064	.113	.082***	.059	.106
HL→ST[b]	.050*	.010	.091	.045*	.006	.084
Total effects						
HL→BEH[c]	.153***	.134	.172	.144***	.125	.163
HL→ST[d]	.124***	.103	.146	.115***	.094	.137
Correlations						
SE↔KN	.154***	.070	.237	.150**	.066	.233
SE↔RP	.190***	.095	.285	.185***	.090	.280
SE↔AT	.348***	.307	.389	.342***	.302	.383
KN↔RP	.073	-.023	.168	.068	-.028	.164

KN↔AT	.155***	.082	.227	.150***	.077	.222
RP↔AT	.202***	.134	.271	.196***	.127	.265
BEH↔ST	.059***	.026	.092	.056***	.024	.089

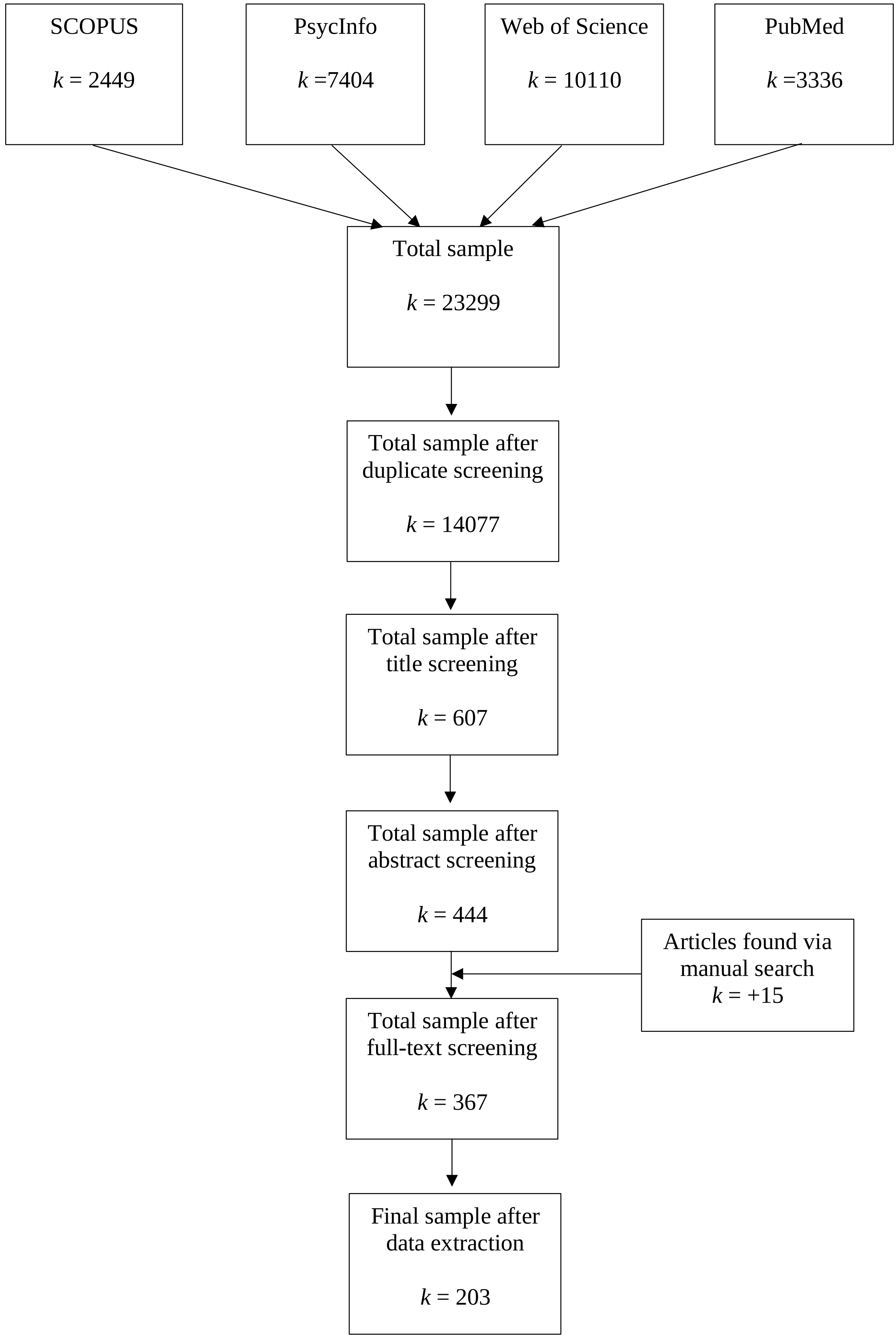
Note. Model parameters are adjusted for the following covariates: publication year, age, gender, sample type (clinical vs. non-clinical), study quality, and study design. [a]Sum of indirect effects of health literacy on behavior through all variables; [b]Sum of indirect effects of health literacy on status through all variables; [c]Total effect of health literacy on behavior; [d]Total effect of health literacy on status. β = Standardized path coefficient; 95% CI = 95% confidence interval of parameter estimate; LL = Lower limit of 95% CI. ; HL = health literacy; SE = self-efficacy; KN = knowledge; RP = risk perceptions; AT = attitudes; BEH = behavior; ST = status.
$^{***}p < .001$ $^{**}p < .01$ $^{*}p < .05$

Figure 1. Proposed model indicating hypothesized relations between health literacy, social cognition constructs, behavior, and status.



Supplemental Materials

Preferred Reporting Items for Systematic Reviews and Meta-Analyses Diagram for Study Inclusion Strategy



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Search Strings used to conduct initial searches in each Database

Psyc info:(health literacy OR nutrition literacy OR food literacy OR mental health literacy OR activity literacy) AND (self-effi* OR attitud* OR norm* OR intent* OR competen* OR belief* OR percept* OR behav* OR health behav* OR physical activi* OR diet* OR condom* OR sunscreen* OR therap* OR counsel* OR exercis* OR water)

Scopus: TITLE-ABS-KEY (health AND literacy OR nutrition AND literacy OR food AND literacy OR mental AND health AND literacy OR activity AND literacy) AND TITLE-ABS-KEY (self-effi* OR attitud* OR norm* OR intent* OR competen* OR belief* OR percept* OR behav* OR health AND behav* OR physical AND activi* OR diet* OR condom* OR sunscreen* OR therap* OR counsel* OR exercis* OR water)

pubmed:"health literacy" OR "nutrition literacy" OR "food literacy" OR "mental health literacy" OR "activity literacy" AND ("self-effi*" OR "attitud*" OR "norm*" OR "intent*" OR "competen*" OR "belief*" OR "percept*" OR "behav*" OR "health behav*" OR "physical activi*" OR "diet*" OR "condom*" OR "sunscreen*" OR "therap*" OR "counsel*" OR "exercis*" OR "water")

Web of science:TOPIC: ("health literacy" OR "nutrition literacy" OR "food literacy" OR "mental health literacy" OR "activity literacy" AND ("self-effi*" OR "attitud*" OR "norm*" OR "intent*" OR "competen*" OR "belief*" OR "percept*" OR "behav*" OR "health behav*" OR "physical activi*" OR "diet*" OR "condom*" OR "sunscreen*" OR "therap*" OR "counsel*" OR "exercis*" OR "water")

Table D1

Results of Multi-Level Multivariate Meta-Analysis of Relations Among Health Literacy, Social Cognition, and Outcome Variables for Model With and Without Adjustment for Covariates

Effect	Unadjusted for covariates				Adjusted for covariates[a]			
	r	SE	95% CI		*r*	SE	95% CI	
			LL	UL			LL	UL
HL-SEF	.228***	.016	.196	.260	.219***	.016	.187	.251
HL-KN	.299***	.018	.265	.334	.290***	.018	.256	.325
HL-RP	.175***	.043	.091	.260	.166***	.043	.082	.250
HL-AT	.167***	.023	.122	.211	.158***	.023	.113	.203
HL-BEH	.153***	.010	.134	.172	.144***	.010	.125	.163
HL-ST	.124***	.011	.103	.146	.115***	.011	.094	.137
SEF-KN	.222***	.043	.138	.307	.213***	.043	.129	.298
SEF-RP	.230***	.049	.134	.327	.221***	.049	.125	.318
SEF-AT	.386***	.022	.342	.430	.377***	.022	.331	.420
SEF-BEH	.296***	.019	.260	.333	.287***	.019	.251	.323
SEF-ST	.106***	.020	.066	.146	.097***	.020	.057	.137
KN-RP	.125*	.050	.029	.222	.116*	.049	.020	.213
KN-AT	.205***	.038	.131	.279	.196***	.038	.122	.270
KN-BEH	.144***	.024	.096	.191	.135***	.024	.087	.182
KN-ST	.073*	.036	.003	.143	.064	.036	-.007	.134
RP-AT	.231***	.036	.160	.303	.222***	.036	.151	.294
RP-BEH	.119**	.045	.032	.207	.110*	.045	.022	.197
RP-ST	.228*	.116	.000	.456	.217	.117	-.010	.445
AT-BEH	.234***	.024	.186	.282	.225***	.024	.177	.273
AT-ST	.098**	.033	.034	.162	.089**	.033	.025	.153
BEH-ST	.111***	.015	.0981	.141	.102***	.015	.072	.132

Note. [a]Effect sizes adjusted for the following covariates: publication year, age, gender, sample type (clinical vs. non-clinical), study quality, and study design. r^+ = Zero-order correlation corrected for sampling error; 95% CI = 95% confidence interval of r^+; LL = Lower limit of 95% confidence interval; UL = Upper limit of 95% confidence interval; SE = Standard error; HL = health literacy; SEF = self-efficacy; KN = knowledge; RP = risk perceptions; AT = attitudes; BEH = behavior; ST = status.

$^{***}p < .001$ $^{**}p < .01$ $^{*}p < .05$

Table D2

Heterogeneity Statistics for Multi-Level Multivariate Meta-Analytic Models for the Full Sample and Sensitivity Analyses

Model	L2 σ^2	L3 σ^2	Q^a	df	I^2	L2 var	L3 var
Full sample							
Unadjusted	.010	.010	16645.842***	1754	93.65	48.00	45.65
Adjusted[a]	.010	.010	16517.755***	1754	93.61	48.36	45.25
Sensitivity analyses							
Excluding studies using comprehension (unadjusted)	.014	.011	11861.503***	1053	95.68	41.93	53.75
Excluded comprehension HL measures (adjusted)[a]	.014	.011	11670.725***	1053	95.63	42.46	53.18
Excluding studies on health risk behaviors (unadjusted)	.010	.011	15140.936***	1663	92.82	48.82	44.00
Excluded studies on health risk behaviors (adjusted)[a]	.010	.011	14984.844***	1663	92.75	49.31	43.44
Excluding studies on samples with higher education (unadjusted)	.004	.009	8966.703***	1115	91.68	64.34	27.34
Excluding studies on samples with higher education (adjusted for covariates)[a]	.004	.009	9104.008***	1115	91.62	64.81	26.81

Note. [a]Model adjusted for the following covariates: age, gender, sample type (student vs. non-student), sample type (clinical vs. non-clinical), study quality, and study design. L2 = Level 2 variance component of multi-level model (variance between effect sizes within studies); L3 = Level 3 variance component of the multi-level meta-analytic model (variance between studies); σ^2 = Estimate of 'true' variability in the effect; Q = Cochran's Q test; df = Degrees of freedom for Q; I^2 = Higgins and Thompson's (2002) I^2 statistic; L2 var. = Percentage of total variability attributable to variability between effect sizes within studies (level 2); L3 var. = Percentage of total variability attributable to variability between studies (level 3); HL = health literacy.

$^{***}p < .001$ $^{**}p < .01$ $^{*}p < .05$

Table D3

Publication Bias Statistics for Meta-Analysis of Relations Among Health literacy, Social Cognition, and Outcome Variables

Effect	τ^a	Trim and fill				Regression tests			*p*-curve[b]		*p*-uniform*					3PSM			
		r^+	95% CI		*k*0	*z*	r^+_{PET}	r^+_{PEESE}	*z* (right skewness)	z^a (Flatness)	r^+	95% CI		τ^2	$\chi^2_{p\text{-uni.*}}$	r^+	95% CI		$\chi^2_{3PSM}{}^a$
			LB	UB								LB	UB				LB	UB	
HL-SEF	.019	.278***	.236	.319	9	-0.459	.250***	.233***	-15.499***	12.267	.289***	-	.331	.005	4.512	.231***	.192	.269	8.524**
HL-KN	.013	.330***	.281	.380	2	-0.102	.323***	.307***	-27.597***	23.852	.265***	.164	.358	.045	2.369	.271***	.179	.363	3.423
HL-RP	.333	.245***	.198	.293	0	-0.220	.301	.272	-10.495***	8.869	.251***	-	.294	0	.390	-	-	-	-
HL-AT	-.167	.191***	.102	.280	0	-0.622	.262*	.212**	-8.056***	6.460	.186	.045	.315	.013	.038	.176*	.034	.317	0.092
HL-BEH	.071	.173***	.149	.198	0	1.324	.146***	.168***	-39.440***	32.751	.171***	.128	.214	.026	.319	.167***	.129	.205	0.190
HL-ST	.066	.175***	.144	.206	17	-0.289	.146***	.145***	-29.396***	24.294	.132***	.082	.180	.022	.259	.139***	.094	.183	0.002
HL-WB	.250	.239***	.182	.296	0	1.264	.162*	.205***	-16.856***	13.669	-	-	-	-	-	.215***	.128	.302	0.887
SEF-KN	-.200	.251***	.170	.330	2	-1.694	.398***	.311***	-6.148***	5.459	-	-	-	-	-	.276***	.183	.369	1.844
SEF-RP	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
SEF-AT	-.200	.380**	.120	.639	0	-0.159	.442	.381	-12.186***	11.475	.462	.124	.757	.066	.203	.374*	.017	.732	0.002
SEF-TB	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
SEF-BEH	-.200	.290***	.201	.378	0	0.709	.218*	.278***	-16.022***	13.783	.346**	.229	.455	.024	.536	.301***	.187	.416	0.082
SEF-ST	-.076	.210**	.087	.334	1	-0.050	.193	.194	-12.842***	11.496	.191	-.025	.396	.049	.040	.170	-.018	.358	0.034
SEF-WB	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
KN-RP	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
KN-AT	-.333	.202***	.091	.313	1	0.258	.176	.191	-7.162***	5.425	.257***	-	-	.003	.777	.218**	.077	.359	0.001
KN-TB	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
KN-BEH	.070	.167***	.106	.228	0	0.263	.155**	.148***	-14.378***	12.501	.177***	.079	.269	.017	.199	.170***	.085	.254	0.008
KN-ST	.109	.015	-.038	.068	4	2.498*	-.012	.013	-	-	.123**	-	-	.002	2.739	.071*	.005	.137	2.082
KN-WB	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
RP-AT	1.000	-	-	-	-	-	-	-	-	-	.471**	.133	.768	.041	.192	.432***	.246	.617	0.047
RP-TB	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
RP-BEH	-1.000	.179***	.105	.253	2	-1.033	.210**	.160***	-	-	.109	-	.208	.002	.132	-	-	-	-
RP-ST	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
RP-WB	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
AT-TB	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
AT-BEH	-.048	.183***	.120	.245	2	0.216	.195*	.210***	-7.035***	4.927	.206***	-	.285	.004	.285	.210***	.139	.280	0.006
AT-ST	-1.000	-	-	-	-	-	-	-	-	-	.293	-.137	.684	.037		-	-	-	-
AT-WB	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
TB-BEH	.000	.054	-.055	.164	1	0.746	.010	.031	-	-	.129	-.046	.308	.011	.259	.111	-.060	.282	.536
TB-ST	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
TB-WB	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
BEH-ST	-.177	.111*	.007	.107	7	0.157	.095*	.098**	-13.852***	10.823	.098*	.023	.172	.013	.030	.098**	.000	.027	0.168
BEH-WB	.600	.196**	.062	.331	0	4.510***	-.075	.015	-3.966	2.359	.190	.055	-	.003	1.713	.116	-.088	.319	1.190
ST-WB	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-

Note. Test statistic non-significant ($p > .05$) in all cases. [b]Power estimate (1-β) is >99% in all cases. τ = Kendall's τ from Begg and Mazumdar's (1994) rank correlation test; Trim and fill = Duval and Tweedie's (2000) trim and fill analysis; r^+ = Corrected meta-analytic effect size estimate from publication bias test; 95% CI = 95% confidence interval of corrected effect size estimate; *k*0 = Estimated number of 'missing' studies on the right-hand/left-hand side of the funnel plot from trim and fill analysis; Regression tests = Publication bias tests based on regression of study effect size on precision estimate; *z* = Funnel plot

asymmetry test statistic from Sterne, Egger, and Davey Smith's (2001) regression test; PET = Stanley and Doucouliagos' (2014) precision effect test; PEESE = Stanley and Doucouliagos' (2014) precision effect estimate with standard error; *p*-curve = Simonsohn, Nelson, and Simmons' (2014) *p*-curve analysis; *z* (right skewness) = Test statistic for *p*-curve right skewness; *z* (flatness) = Test statistic for degree of *p*-curve 'flatness'; *p*-uniform* = van Aert and van Assen's (2018) *p*-uniform* analysis; τ^2 = Estimate of 'true' variance in population from *p*-uniform* analysis; $\chi^2_{p\text{-uni.*}}$ = Likelihood ratio test of publication bias from *p*-uniform* analysis; 3PSM = Vevea and Hedges' (2005) three-parameter selection method analysis; χ^2_{3PSM} = Likelihood ratio test of publication bias from 3PSM analysis; HL = health literacy; SEF = self-efficacy; KN = knowledge; RP = risk perceptions; AT = attitudes; BEH = behavior; ST = status.
*** $p < .001$ ** $p < .01$ * $p < .05$.

Table D4

Standardized Parameter Estimates for Multi-Level Meta-Analytic Structural Equation Model for the Proposed Model Sensitivity Analysis Excluding Comprehension Health Literacy Measures, Health Risk Behaviors, and Samples from Higher Education

Effect	Total Sample			Comparison group: Excluded Comprehension HL measures			Comparison group: Excluded associations with health risk behaviors			Comparison group: Excluded associations coming from samples with better education		
	β	95% CI		β	95% CI		β	95% CI		β	95% CI	
		LL	UL		LL	UL		LL	UL		LL	UL
Direct effects												
HL→SEF	.219^{***e}	.187	.251	.281^{***e}	.238	.324	.216***	.183	.248	.176***	.140	.213
HL→KN	.290^{***ef}	.256	.325	.374^{***e}	.319	.429	.288***	.253	.324	.230^{***f}	.195	.265
HL→RP	.166***	.082	.250	.208***	.111	.305	.159***	.068	.251	.123**	.043	.204
HL→AT	.158***	.113	.202	.204***	.144	.264	.158***	.112	.203	.124***	.074	.174
HL→BEH	.062***	.037	.087	.049*	.007	.091	.064***	.038	.091	.057***	.033	.081
SEF→BEH	.214***	.169	.258	.224***	.162	.285	.226***	.180	.271	.147***	.092	.203
KN→BEH	.045	-.010	.101	.119*	.022	.217	.044	-.013	.101	.049	-.009	.108
RP→BEH	.020	-.072	.112	.040	-.064	.143	.018	-.076	.112	.017	-.069	.102
AT→BEH	.121***	.067	.176	.142***	.068	.215	.118***	.062	.173	.072*	.006	.138
HL→ST	.071**	.028	.113	.083*	.019	.147	.068**	.025	.111	.062***	.026	.098
SEF→ST	.028	-.035	.091	.014	-.070	.098	.026	-.039	.091	.041	-.032	.114
KN→ST	.010	-.071	.092	.032	-.110	.174	.008	-.075	.091	.009	-.074	.091
RP→ST	.193	-.055	.441	.228	-.042	.499	.197	-.057	.451	.170	-.060	.399
AT→ST	.022	-.062	.106	.043	-.055	.142	.023	-.062	.108	.034	-.089	.156
Indirect effects												
HL→SEF→BEH	.047^{***f}	.034	.059	.063***	.042	.084	.049***	.035	.062	.026^{***f}	.014	.038
HL→SEF→ST	.006	-.008	.020	.004	-.020	.028	.006	-.008	.020	.007	-.006	.020
HL→KN→BEH	.013	-.003	.029	.045*	.007	.082	.013	-.004	.029	.011	-.002	.025
HL→KN→ST	.003	-.021	.027	.012	-.041	.065	.002	-.022	.026	.002	-.017	.021
HL→RP→BEH	.003	-.012	.019	.008	-.014	.030	.003	-.012	.018	.002	-.009	.013
HL→RP→ST	.032	-.013	.077	.048	-.014	.109	.031	-.013	.076	.021	-.011	.053
HL→AT→BEH	.019***	.009	.030	.029**	.011	.047	.019***	.008	.029	.009	-.000	.018
HL→AT→ST	.003	-.010	.017	.009	-.012	.029	.004	-.010	.017	.004	-.011	.020

Sums of indirect effects												
HL→BEH[a]	.082^{***ef}	.059	.106	.145^{***e}	.102	.187	.083***	.059	.106	.048^{***f}	.030	.067
HL→ST[b]	.045*	.006	.084	.072*	.013	.132	.043*	.004	.082	.034*	.003	.066
Total effects												
HL→BEH[c]	.144^{***ef}	.125	.163	.194^{***e}	.164	.224	.147***	.127	.167	.105^{***f}	.087	.123
HL→ST[d]	.115***	.094	.137	.156***	.122	.189	.111***	.089	.133	.096***	.076	.116
Correlations												
SEF↔KN	.150**	.066	.233	.233***	.115	.351	.149**	.065	.234	.141***	.055	.228
SEF↔RP	.185***	.090	.280	.230***	.130	.329	.187***	.090	.283	.155***	.063	.246
SEF↔AT	.342***	.302	.383	.373***	.327	.419	.342***	.301	.384	.334***	.276	.391
KN↔RP	.068	-.028	.164	.105*	.004	.206	.070	-.028	.168	.043	-.049	.134
KN ↔ AT	.150***	.077	.222	.205***	.105	.306	.150***	.076	.224	.116**	.042	.189
RP ↔AT	.196***	.127	.265	.245***	.173	.318	.197***	.127	.267	.163***	.097	.230
BEH ↔ ST	.056***	.024	.089	.066***	.022	.110	.047**	.012	.083	.040*	.005	.075

Note. Model parameters are adjusted for the following covariates: age, gender, sample type (student vs. non-student), sample type (clinical vs. non-clinical), study quality, and study design. [a]Sum of indirect effects of health literacy on behavior through all variables; [b]Sum of indirect effects of health literacy on status through all variables [c]Total effect of health literacy on behavior; [d]Total effect of health literacy on status. [ef]Superscripted letters next to parameter estimates indicate statistically significantly different ($p < .05$) estimates using Schenker and Gentleman's (2001) 'standard method' based on confidence intervals β = Standardized parameter estimate; 95% CI = 95% confidence interval; LL = Lower limit of 95% CI. UL = Upper limit of 95% Ci; β_{diff} = Difference in standardized path coefficient; HL = health literacy; SEF = self-efficacy; KN = knowledge; RP = risk perceptions; AT = attitudes; BEH = behavior; ST = status.

$^{***}p < .001$ $^{**}p < .01$ $^{*}p < .05$