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A Meta-analysis of Sex Differences in Human Navigation Skills

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Abstract

There are inconsistent reports regarding behavioral sex differences in the human navigation literature. This meta-analysis quantifies the overall magnitude of sex differences in large-scale navigation skills in a variety of paradigms and populations, and examines potential moderators, using 694 effect sizes from 266 studies and a multilevel analytic approach. Overall, male participants outperform female participants, with a small to medium effect size (d= 0.34 to 0.38). The type of task, the type of dependent variable and the testing environment significantly contribute to variability in effect sizes, although there are only a few situations in which differences are either non-existent or very large. Pointing and recall tasks (and the deviation scores associated with them) show larger sex differences than distance estimation tasks or learning to criterion. Studies with children younger than 13 years showed much smaller effect sizes (d = .15) than older age groups. We discuss the implications of these findings for understanding sex differences in human spatial navigation and identify avenues for future navigation research.

Keywords: Meta-analysis, Sex difference, Navigation, Spatial Skills

A Meta-analysis of Sex Differences in Human Navigation Skills

Wayfinding or goal-directed navigation is important for the survival of most mobile species. Against that backdrop, it may seem surprising that humans differ in their navigation skills. Nevertheless, there is considerable individual variation in wayfinding accuracy and confidence, across a variety of experimental paradigms (Newcombe, 2018). We do not yet fully understand the correlates and causes of such individual variation, but sex of participants may be one dimension that matters. There are frequently-cited instances of male advantage in the literature (Dabbs, Chang, Strong & Milun, 1998; Gagnon, et al., 2018; Lawton, 1994; Lawton & Kallai, 2002). However, there are also reports of no sex differences (Driscoll, Hamilton, Yeo, Brooks & Sutherland, 2005; Herman, Kail & Siegel, 1979; O'Laughlin & Brubaker, 1998; Saucier, et al., 2002; Schmitzer-Torbert, 2007) and even studies showing a female advantage on navigation tasks under certain conditions (Burigat & Chittaro, 2007). These variations in results raise the question whether sex differences exist in human spatial navigation. However, in the popular press at least, it is common to see headlines such as *"Study says that men have the better sense of direction"* (Gregoire, 2015). This apparent contradiction suggests that a meta-analysis is needed to bring together the scattered literature, integrating reports with varying sample sizes and demographic characteristics, and a wide range of methodologies (testing environments, experimental procedures, use of technology, learning perspectives, and outcome measures).

Previous reviews do not address the core question of quantifying behavioral sex differences in human navigation and examining potential moderators, although they do provide valuable information. The most relevant prior effort is a narrative literature review, in which Coluccia and Louse (2004) found that, while more than 50% of papers did not find significant sex differences, the remainder found better performance by males and no studies reported females doing better. This pattern of evidence was suggestive of a male advantage, but in the absence of a systematic meta-analysis, it is impossible to know for sure, let alone to estimate the size of sex differences and the role of potential moderators in any effects. In addition, in the years since the Collucia and Louse review, there has been a great deal more navigation research. For example, the paper by Burigat and Chittaro (2007) showing a female advantage came out later.

There are two other relevant reviews, both of which are quantitative, although they address somewhat different questions. Jonasson (2005) conducted a meta-analysis of sex differences in rodent navigation, which can be seen as relevant to human differences given our common mammalian heritage. The analysis showed that sex differences in rodents varied with rearing environment, training protocols, and navigation task. Crucially, there was evidence of species variation, suggesting that there is no basic mammalian pattern. Mice actually demonstrated a small female advantage in the water maze task.

In another review relevant to our purpose, Boccia, Nemmi and Guariglia (2014) conducted a meta-analysis of sixty-six fMRI studies of the neural substrates involved in human navigation. They found interesting sex-linked variations in brain activation moderated by environment familiarity and ego- and allo- centric strategies. However, their review did not address the question of behavioral sex differences in navigation accuracy.

Accordingly, our purpose was to provide a comprehensive meta-analysis of behavioral sex differences in human spatial navigation. We aimed to quantify the overall magnitude of sex differences and examine potential moderators of the effects. To conduct this synthesis, we began with defining spatial navigation and then specified potential moderators.

Defining Wayfinding

There are a wide variety of cognitive processes involved in navigation, and experimenters have developed many different small- and large-scale paradigms and self-report measures to investigate individual differences (Wiener, Büchner, & Hölscher, 2009). There does not seem to be an agreed upon definition of what constitutes "spatial navigation". Coluccia and Louse (2004) defined navigation as a “complex of all the skills used for locating themselves with respect to a point of reference or an absolute system of coordinates.” However, this definition encompasses spatial processes at different scales (see Montello, 1993, 2010), despite substantial evidence that navigation in large-scale environments is fundamentally different from small-scale tasks in which all objects are inter-visible (Hegarty, Montello, Richardson, Ishikawa & Lovelace, 2006; Learmonth, Newcombe, Sheridan & Jones, 2008; Montello, 1993; Padilla, Creem-Regehr, Stefanucci & Cashdan, 2017).

For the purpose of the present meta-analysis, we defined navigation as skills involved in encoding spatial relations at environmental scale and transforming them to orient and navigate in environmental space. This definition includes spatial navigation with external representations (e.g. maps) but excludes reorientation tasks conducted in small spaces and small-scale mazes with target locations visible from a single vantage point. The only exception to the *scale* criterion for our review was the virtual water maze task (Astur et al., 1998), based on the Morris water maze task (Morris, 1981). This task is a well-accepted measure in the animal spatial cognition literature, where it has been shown to engage hippocampal processes that support cognitive mapping (Astur, Taylor, Mamelak, Philpott, & Sutherland, 2002). It has been widely used to study individual differences in the use of proximal and distal cues and has a known neural substrate implicated in navigation (Daugherty, Bender, Yuan, & Raz, 2015; Packard &

McGaugh, 1996). Further, the hidden platform task occludes the target to be reached and thus can be arguably included within the environment scale definition.

Potential Moderators

A systematic approach to moderator identification is likely to decrease the risk of Type 1 error in meta-analytic results (Lipsey & Wilson, 2001). Accordingly, we identified empirically-supported or theoretically-relevant factors *a priori* for consideration in the moderator analysis. Table 1 lists the measure-level variables that we identified for later coding. Below, we discuss the empirical and theoretical basis that led us to select these factors as potential moderators.

Task Goal. There are large variations in the task goal used to assess a participant's navigation skills. We list these task goals in 8 distinct categories (see Table 1). These eight categories may demonstrate large, small, or negligible sex differences, depending on the cognitive processes involved in completing the task goal. For example, Jansen-Osmann, Schmid and Heil (2007) found no sex difference on a route recall task, whereas map reading showed a large male advantage. In contrast, Allen and Wittenborg (1998) found a significant male advantage for route recall, but not for a distance task. This type of inconsistency across studies suggests that inclusion of task goals, as a moderator is important. In addition, task goals form the basic level from which all other task requirements are defined, and thus we used this moderator as the basic unit of analysis in subgroup analyses.

Perspective. An important difference in navigation tasks pertains to the type of visual representation of the environment –route or survey. In a route perspective, individuals experience the environment from a first-person perspective i.e. they locate target objects in relation to their own position. In contrast, in a survey perspective, individuals see the entire spatial layout from a bird's eye view. The inclusion of perspective as a moderator is particularly important in light of research suggesting that men show a preference for a Euclidean orientation strategy using cardinal directions and distances, but that women prefer a landmark strategy that relies on a sequence of turns and proximal cues (Dabbs, Chang, Strong & Milun, 1998; Lawton, 1994; Lawton & Kallai, 2002). This raises the possibility that men and women may differentially benefit from a particular perspective. There are also navigation studies that use a combination of route and survey perspectives and we categorized these studies into a third group. At a more global, theoretical level, perspective can be seen as a central defining component of spatial navigation, possibly because a change in perspective is a component of many navigation tasks (Wolbers & Hegarty, 2010). The importance of perspective as a moderator therefore manifests itself both at the empirical and theoretical level.

Outcome Measure. Outcome measures are often presented as reflecting different dimensions of performance. For example, in mental rotation, Lohman (1986) presented response time as reflecting speed of processing, whereas accuracy was believed to reflect level of ability. From this perspective, findings of a larger male advantage with accuracy than with response time in a spatial navigation task by Malinowksi and Gillespie (2001) emphasizes sex differences in level of ability. In the context of spatial navigation, methods of scoring other than accuracy and response time have also been used to quantify performance. With this in mind, we therefore categorized outcome measures into four categories –accuracy, degrees of deviation, distance, and response time. Examining potential variations in the magnitude of sex differences in outcome measures is crucial to assess current navigation metrics and biases built into them and how these might affect the magnitude of sex differences.

Route Direction. Depending on task goals and outcome measures, participants may need to navigate routes in the same direction as initially learned or in opposite directions. Potential variations in sex differences based on route direction could be indicative of differences in working memory and strategy flexibility. For example, individuals who depend on a rigid sequence of cues and turns may perform better in the forward direction than in the reversal condition. Given the male advantage in visual-spatial working memory (Voyer, Voyer, & Saint Aubin, 2017), the magnitude of sex difference might be larger during route reversal as a result of the added working memory load. Hence, we included route directions as a potential moderator and categorized movement into three groups –forward, backward, and free choice.

Route Selection. In the research we retrieved in the literature, participants were often asked to select a specific route to meet the task goal. These route selection options could be categorized into three groups –free choice, exact way, and shortcut. Empirical findings from Choi, McKillop, Ward, and L'Hirondelle (2006) showed that asking participants to use a shortcut can produce a male advantage, whereas following the exact way that was learned can produce a female advantage. Furthermore, Boone, Gong, and Hegarty (2018) reported that men are more likely than women to use shortcuts whereas women prefer the learned route. Therefore, we included route selection as a moderator in our analysis.

Timing. Research suggests that anxiety and self-doubt negatively influence the ability to encode important spatial features and consequently navigation performance (Saucier, et al., 2002). Women generally report higher spatial anxiety than men (Huang & Voyer, 2017; Lawton, 1994; Lawton & Kallai, 2002) and lower self-confidence in spatial tasks (Huang & Voyer, 2017; O'Laughlin & Brubaker, 1998). This suggests that women may be affected differentially by the imposition of time constraints. For example, it is possible that the male advantage in spatial navigation could be larger under time constraints compared to unconstrained conditions, as has been reported for mental rotation (Voyer, 2011). Hence, we included timing conditions as a potential moderator with two categories –untimed and timed.

Cues. Environments may also differ in the amount and diversity of visual cues available in them. Visual cues used to orient and navigate can be broadly divided into two main categories –proximal and distal (Chai & Jacobs, 2010; Knierim & Hamilton, 2011; O'Keefe & Nadel, 1978; Sandstrom, Kauffman & Huettel, 1998; Vorhees & Williams, 2006). Proximal and distal cues can be differentiated by the effect on parallax when individuals change their location in an environment with the latter cue type providing a more stable bearing than the former (Knierim & Hamilton, 2011). Most work manipulating the role of visual cues, however, has been restricted to small-scale navigation paradigms with few exceptions (Padilla, et al., 2017), even though large scale environments are also obviously rich in both proximal and distal cues. Existing research suggests a male superiority in environments with limited or directional landmark cues (Astur et al., 2004; Barkley & Gabriel, 2007;Canovas, Garcia & Cimadevilla, 2011; Moffat et al., 1998) and no sex differences in environments rich with proximal cues (Astur, et al., 2004; Saucier et al., 2002). Sex differences in human visual cue processing, mentioned by many authors (Astur, Ortiz & Sutherland, 1998; Barkley & Gabriel, 2007; Chai & Jacobs, 2009; 2010; Choi et al., 2006; Sandstrom, Kauffman & Huettel, 1998) provide strong empirical support for the inclusion of cues as a moderator of sex differences in navigation.

The role of distal and proximal cues in spatial navigation also has theoretical implications as these cues are seen as central to many navigation tasks, likely as a result of the much documented link between the use of such cues and hippocampal functioning (Poulter, Hartley, & Lever, 2018). Therefore, a result showing an effect of cues on the magnitude of sex differences in spatial navigation could raise the possibility of differentiated hippocampal functions in men and women.

Environment. The environment experienced by the participant while navigating can be seen as reflecting variation in the actual scale of the surroundings. Specifically, we categorized the environment as indoor, outdoor, or a combination of indoor-outdoor to refer to a limited, unlimited, or mixed area scale environment, respectively. More importantly, recall that although some researchers might consider them small-scale tasks, water maze tasks were included in our sample as they essentially provide the richness of large-scale tasks within a limited area by means of a manipulation of distal and proximal cues (Poulter et al., 2018). Therefore, this type of task formed a fourth environment category. In view of the argument that water maze tasks provide the clearest available evidence for sex differences in spatial navigation strategy selection (Boone et al., 2018), it is critical for us to consider this type of tasks as a central component of the environment moderator.

Familiarity. Navigation tasks can be conducted in environments that are either learned specifically for the purpose of testing (e.g. Nazareth, et al., 2018; Jansen-Osmann, Schmid & Heil, 2007) or that are already familiar to the participant (Meilinger, Frankenstein, & Bulthoff, 2013). Boccia, Nemmi, and Guariglia (2014) found that different neural correlates were involved in the processing of familiar and learned environments. It is therefore not surprising that Abu-Obeid (1998) found a significant male advantage in a new environment but not in a familiar one. Accordingly, we included familiarity as a potential moderator of sex differences in navigation.

Testing Medium. Coluccia and Louse (2004) reported that males outperformed females in about 57% of the research using “simulated” (i.e., virtual) environments, very similar to the 59% found for real environments. However, this value dropped to 42% for maps. More importantly, virtual and real environment showed no cases where females outperformed males, whereas this figure was around 18% for maps. Therefore, we aimed to determine whether Coluccia and Louse's findings on this moderator would be reflected in smaller sex differences for map-like tasks compared to virtual or real environments in our comprehensive quantitative review. Accordingly, we categorized testing medium into virtual, real, and symbolic groups – where symbolic referred to the use of a map or similar medium.

Feedback and Hints. There is evidence in the cognition literature of sex differences in attitudes and responses to failures and achievements (Dweck, 1986)**.** Although not examined frequently in the navigation literature, the inclusion of feedback and/or hints from guides as moderators accounts for important differences in men and women's response to performance feedback (Lenney, 1977) and their ability to use the feedback constructively for spatial updating. We therefore considered feedback and hints as two separate moderators. Feedback had two categories –immediate feedback and no-feedback. Hints had two categories –hints and no-hints –based on whether participants were given hints during the task goal.

Device Assistance. We know that device assistance from a map provides a survey perspective of the environment and consequently may provide an additional support to individuals –primarily women –who rely on a route strategy (Dabbs, Chang, Strong & Milun, 1998; Lawton, 1994; Lawton & Kallai, 2002) as described in more detail in the section on perspective. Hence, device assistance was used as a potential moderator with two categories – device and no-device.

Learning Intervals. Learning intervals were broken down into three categories – immediate (no gap between learning and testing phases), short (less than 24 hours between both phases), and long (more than 24 hours gap). Forgetting occurs over time, as a century of memory research shows, but spatial memory also seems to undergo consolidation during wakeful rest or sleep (Skaggs & McNaughton, 1996), in which it may actually strengthen. We are unaware of data suggesting that such “replay” differs by sex, but it seemed prudent to examine the question in our analysis, given the importance of these processes in the literature.

Age. There is gradual age-related change in navigation skills in children between 6 and 12 years of age (e.g., Acredolo, Pick, & Olsen, 1975; Allen, Kirasic, Siegel, & Herman, 1979; Heth, Cornell, & Alberts, 1997; Laurance, Learmonth, Nadel, & Jacobs, 2003; Overman, Pate, Moore, & Peuster, 1996) with spatial representations maturing near adolescence (Liben, Myers, Christensen, & Bower, 2013). Further, the large literature on the influence of hormone levels on spatial skills (Brake & Lacasse, 2018; Lisofsky, et al., 2016; Puts, McDaniel, Jordan & Breedlove, 2008) highlights the importance of participant age during testing (e.g. puberty, pregnancy, menopause, etc.). Thus, in addition to the task-related variations, we investigated the moderating influence of participant age in sex differences in navigation skills.

Current Meta-Analysis

The main aim of the current meta-analysis was to provide a summary of sex differences found in navigation research. To this end, we conducted an exhaustive search for relevant published and unpublished data collected in different countries with different sample populations and using different navigation paradigms. To our knowledge, no meta-analysis specifically quantifying human sex differences in navigation has been published to date and we believe that the current meta-analysis serves to fill that gap in the navigation literature. It is important to clarify that the current meta-analysis excludes self-report measures of navigation skills as well as any navigation studies involving small-scale paradigms in which the entire testing environment can be viewed from a single vantage point. We constrained the meta-analysis to include only studies with typical populations to avoid a potential confound. Further, published research that failed to include numerical values for male and female sex differences and for which the corresponding author was unable to provide these data were excluded from the meta-analysis.

Not surprisingly, many of the studies we retrieve included several outcome measures relevant to our research questions or provided non-independent measurements of their participants under different experimental conditions relevant to the potential moderators we identified. In the context of fixed effects, random effects, or mixed effects meta-analysis, such non-independent effect sizes would violate of the assumptions underlying these types of analyses (Borenstein, Hedges, Higgins, & Rothstein, 2009) and make the results uninterpretable. Accordingly, for all data analyses, we used cutting edge multilevel meta-analysis as this method is particularly well-suited to handle the hierarchical nature of a meta-analytic data and non-independent effect sizes (Raudenbush & Bryk, 2002).

Method

Literature Search and Study Selection

A primary search was conducted in databases of PsycINFO, PsycARTICLES, and ERIC using various Boolean combinations of the search terms: *wayfinding, spatial, navigation, orientation, maps*, *representation*, *cognition* and *environment.* The search included all available records from the year 1803 (default lower limit in the search engine) to October 2017. We refrained from using *sex/gender differences* in our initial search to prevent prematurely excluding papers that did not have sex/gender differences as their central theme. Our filters excluded patents, reviews, books, magazine articles, and any non-peer-reviewed sources. These searches resulted in 10,663 non-overlapping hits, which was initially reduced to 1164 with the help of our inclusion criteria detailed below. Foreign language articles including an English abstract were also included in the analyses. Theses and dissertations were considered as possible sources of unpublished material but were excluded if the same data had been published. In such cases, only the published version was included in the meta-analysis. In addition, requests for unpublished data announcements were posted to the following listservs - Cognitive Development Society (CDS), Spatial Learning Network (SILC), and Canadian Society for Brain, Behavior and Cognitive Science (CSBBCS). Altogether, we received 47 responses to our listserv announcement, although most of those were for published work.

Next, we adhered to the rules in Figure 1 to exclude articles that did not meet our inclusion criteria but had not been excluded by our automated search engine filters. This process involved two of the four authors (a postdoctoral research fellow and a doctoral student) carefully reading through the title, abstract and on occasion, the entire article to determine eligibility. These additional exclusions were papers that presented studies on non-humans, robotics, unmanned devices, and self-report measures as well as tasks that involved line orientation, object location in a room/table/virtual environment, web navigation, language, haptic orientation, tactile, grating, locomotion, optic flow, categorization, spatial frequency, grasping, and reach planning, etc. that did not fit our definition of spatial navigation. Studies that had either male-only or female-only human participants, as well as special populations (for example brain damaged, hearing, or visually impaired individuals) were excluded from our sample, although data from healthy control groups were included. Finally, papers that did not present original research (e.g. review papers) were excluded from the analyses. The next step was to contact authors of articles that cleared our screening process, but that did not report the information required for us to compute effect sizes relevant to sex differences. Papers from authors who did not respond to our emails or who no longer had access to the data were excluded from the meta-analysis.

Our final sample had 694 effects sizes drawn from 266 samples. Out of the total effect sizes, 80 came from unpublished research in English (70 from dissertations, 10 from one unpublished paper). For the remainder, 614 effect sizes were from papers published in English and no papers came from work published in other languages. Furthermore, 293 out of the 694 effect sizes (42.2%) originated from the United States, 135 effect sizes (19.5%) were from Germany, 73 were from Canada (10.5%), and 64 were from the United Kingdom (9.2%). The remaining effect sizes (18.6%) were from a variety of other countries. The final sample of studies included in the meta-analysis is presented in Table 2.

Inclusion Criteria

The following criteria were used to determine the inclusion eligibility of a study in the meta-analysis.

1. The study should involve empirical research with non-clinical, male AND female human populations. For papers that investigated both non-human and human subjects, we included data for the human subjects only. For papers that included a healthy control when investigating clinical/special populations, we included data for the healthy controls only.
2. The study should include at least one objective navigation performance outcome in a task that met our definition of spatial navigation (presented in the introduction). Importantly, this meant that studies using only self-reports/surveys as measures of navigation performance were excluded.

3. The navigation paradigm should be categorized at an "environmental" scale (see Montello (1993) for a description of scales). At an environmental scale, a participant needs to move some distance within the space in order to obtain information about the spatial properties of the real or virtual environment i.e. all spatial information cannot be obtained from a single vantage point in the environment. The only exception to this rule was the water maze task (see for example, Chamizo, Artigas, Sansa & Banterla, 2011), as justified in the introduction.

Coding of Study Variables

As a starting point, we developed a coding template that captured crucial methodological aspects of the studies along with the moderators of interest. Our coding template had categories for a number of variables not necessarily considered as moderators to provide as complete a picture as possible for each study, with an eye on later data interpretation. Therefore, the coding template involved the following study characteristics: Authors, year of publication, author ID, sample ID (a crucial variable for multilevel analysis), publication status, mean age of sample, experiment number, sample origin, number of males, number of females, study location, task goals, testing medium, outcome measure(s), route direction, timing conditions, perspective, locomotion, route direction, environment, familiarity, test interval, hints , feedback, device assistance, cues, and the calculated effect size(s). From this larger set, we considered the variables at sample-level and measure-level detailed in the introduction section to identify factors that might moderate sex differences in wayfinding/navigation skills. Sample-level variables reflect variables inherent to the samples themselves, such as mean age. Measures-level variables are those that are inherent to spatial navigation tasks, such as medium and outcome measure.

Sample-level variables.

Undergraduate students represented 53.5% of the total effect sizes and children represented 9.7% of the total effect sizes. The remaining effect sizes represented a wide range of participant ages, justifying our use of mean age of the participants the moderator of interest as a continuous variable and a categorical variable (less than 13, 13 to 17, 18 to 29, 30 to 50, 50 and older).

We also considered the sample level variable year of publication. This variable is easily obtained and is routinely considered in meta-analyses of cognitive sex differences as a means to investigate Feingold's (1988) claim that cognitive sex differences are decreasing in magnitude in recent years.

Measure-level variables. Table 1 presents a list of measure-level variables along with their respective categories. We have also included examples to clarify our classification process. In total, we had 14 measure-level variables consisting mostly of 2 to 3 groupings each. The task goals variable had eight categories, which was the highest number of categories in any variable. This large number of task goals testifies to the wide range of skills measured in the navigation literature.

To ensure coding validity, the detailed coding template mentioned earlier was used as a strong guideline. As an initial step before final coding, two of the authors of the present report (Coder 2 experienced in meta-analyses; Coder 1 experienced in navigation research and fully trained in meta-analytic coding by Coder 2) independently coded 25 studies accounting for 59 effects sizes for a total of 1711 entries. This coding process involved 29 variables (again, not all considered in moderator analyses): authors, year of publication, author ID, sample ID (a crucial variable for multilevel analysis), publication status, mean age of sample, experiment number, sample origin, number of males, number of females, study location, task goals, testing medium, outcome measure, route direction, timing conditions, perspective, locomotion, route selection, environment, familiarity, learning interval, guide assistance, feedback, device assistance, cues and the calculated effect size. This independent coding resulted in 173 disagreements, representing 1538 agreements over 1711 entries (29 variables x 59 effect sizes), for a .899 agreement rate (Cohen's *Kappa* = .798). The two coders had extensive discussions to elucidate points of disagreement and Coder 1 then proceeded with coding the remainder of the studies. At completion of coding, Coder 2 independently coded a new set of 50 studies (accounting for 77 effect sizes) from the final sample. In this case, the total of 2233 entries (29 variables x 77 effect sizes) produced only 9 disagreements, resulting in an inter-rater reliability of 99.6% (2224 agreements/2233 total entries**;** Cohen's *Kappa* = .992). This high inter-rater reliability clearly reflects the validity of the final coding.

Measure of effect size. The effect size measure was the standardized mean difference calculated as the mean for males minus that for females divided by the pooled standard deviation (Cohen's *d*; Cohen, 1988). The assumption is that men would perform better than women based on the literature presented so far. Thus, a positive effect size reflects a male advantage and a negative effect sizes reflect a female advantage in spatial orientation tasks. The effect size calculation was based on Cohen's (1988) formula when means and standard deviations were available, which was the case for 372 out of the 694 effect sizes (53.6%). The remaining cases were available with an inferential statistic (typically *t*-test, *p, r,* or *F*), thus the formulae presented by Lipsey and Wilson (2001) were used. In all cases, effect sizes were computed by the calculator provided on David Wilson's webpage (http://mason.gmu.edu/~dwilsonb/downloads/ES_Calculator.xls). Following recommendations by Hedges and Becker (1986), a small sample correction was applied to all effect sizes. When an effect size was not significant and no means or inferential statistics values were presented, authors were contacted by e-mail for more information. Out of the 19 authors who were contacted for that purpose, 6 replied and provided usable data. For the remainder, we kept an effect size of zero to avoid excluding relevant work, as seen in Table 2. Note however, that in some of the case in the table, zero was the actual effect size value.

Data Analysis

As is a typical goal of most meta-analyses focusing on sex differences, we aimed to quantify the overall magnitude of sex differences in spatial navigation and to identify variables that might moderate these sex differences. A valid examination of specific tasks and potential moderators required us to retrieve multiple effect sizes that are non-independent. Using these effect sizes in a fixed or random effects meta-analysis would violate the assumption that effect sizes should be independent (Borenstein et al., 2009) and this would distort the statistical analyses (Bateman & Jones, 2003). Accordingly, we relied on the multilevel linear modeling (MLM) approach to meta-analysis as it does not require independence of effect sizes and it easily handles the type of hierarchical design represented in meta-analysis (Raudenbush & Bryk, 2002). As the standard error calculated for each effect size in a meta-analysis reflects an estimate of the variance for individual effect sizes (see Borenstein et al., 2009), multilevel meta-analysis represents a “variance-known” hierarchical linear model resulting in the precision weighted estimates of effect sizes typical of meta-analytic results (Raudenbush & Bryk, 2002).

As a starting point, and similar to the approach used by Voyer, Voyer, and Saint Aubin (2017), we computed an overall analysis and moderator analysis on the whole sample. The overall multilevel analysis was computed by examining the data organized in two levels: effect sizes nested within samples. This overall structure reflected 694 effect sizes (Level 1) nested within 266 samples (Level 2). This large number of Level 1 and Level 2 units had the advantage to maximize power for the identification of significant moderators and to provide a more complete documentation of the overall findings in the available data. The variables task, year of publication, mean age of the sample, age coded categorically, testing medium, outcome measure, route direction, timing conditions, perspective, route selection, environment, familiarity, learning interval, hints, feedback, device assistance, and cues were considered in the moderator analysis.

As a second step, after demonstrating that the different tasks differed at some basic level (as reflected in the finding that they produced effect sizes of different magnitude), we performed a moderator analysis separately for each task. This additional set of analyses was required to recognize the fact that some of the moderators might be confounded with task. For example, in most cases, pointing tasks generally produce a deviation score as an outcome variable. These analyses also used the multilevel approach considering that all the task groupings included non-independent effect sizes.

All meta-analytic computations were performed by with the *metafor* package in the R statistical software (Viechtbauer, 2010). Effect sizes were treated as random effects whereas moderators were treated as fixed effects. As previously mentioned, the observed values obtained in this approach reflect precision weighted estimates of effect sizes (Raudenbush & Bryk, 2002). In addition, significance testing for multilevel models used robust standard error for added precision as they can be easily obtained with the *robust* command in the *metafor* package. However, as a small number of level 2 clusters (i.e., samples) can bias the calculation of robust standard errors, the appropriate correction built-in the *robust* procedure in *metafor* was implemented. Note that, with *robust*, an F test is reported (instead of the more common between-groups Q test) when robust standard errors are used.

Categorical independent variables were dummy coded into *k* - 1 dichotomous vectors (where *k* represents the number of categories) for consideration in the analysis whereas continuous moderators were mean-centered. In all moderator analyses, moderators were examined one at a time in models as there was no *a priori* basis to justify the examination of multi-factor models or interactions. In addition, only effects significant with $p < .05$ are presented in the results section. This means that any moderator that is not mentioned in the results was non-significant.

Results

A preliminary analysis was conducted to identify outliers. Following recommendations by Tabachnick and Fidell (2007), we defined outliers as effect sizes values that were more than 3.29 standard deviations away from the grand mean. Five outliers were identified based on this criterion. However, as such a number of outliers should be expected in a comprehensive sample, they were preserved as is for the sake of completeness, although they are identified by a star (*) in Table 1. The final sample, therefore, consisted of 694 effect sizes drawn from 266 independent samples, reflecting combined results from 9435 males and 9570 females.

Overall Meta-analysis

Overall sex differences in spatial navigation. A null model where the test of significance for the intercept is examined (Raudenbush & Bryk, 2002) provided data on the overall magnitude of sex differences in spatial navigation based on the current sample of studies. This analysis produced a mean estimated *d* of 0.341 (95% confidence interval (CI) = 0.302 to 0.380), indicating that males significantly outperformed females on spatial navigation tasks, $z = 17.05$, $p < .001$. Having considered this initial finding, it is important to remember that, when authors reported sex differences as non-significant but provided no information for effect size coding, we entered an effect size of zero for these studies. Of course, we contacted authors to obtain clarifications but were still left with 62 cases where the effect size was coded as zero because of the lack of additional data. Accordingly, the estimate presented above might underestimate the actual magnitude of sex differences in spatial navigation. With this in mind, we removed these 62 effect sizes and conducted a second overall analysis. In this analysis, we found a mean estimated d of 0.381 (95% CI = 0.340 to 0.423). Therefore, it might be more appropriate to state that the true estimate of sex difference in spatial navigation is found within a range from 0.341 to 0.381. In any case, the remainder of the analyses preserved all 694 effect sizes in an attempt to provide a report on the complete data set. Regardless of which sample is used, however, results also showed that the overall effect was heterogeneous, $Q(693) = 1473.11$, $p < .001$ (for the complete data set). This suggests that the overall estimate of effect size is not representative of the sample of effect sizes. Accordingly, the examination of potential moderators might account for this variability.

Moderators of sex differences in the overall sample. The moderator analysis revealed that task goal accounted for significant variance in effect sizes, $F(7, 258) = 4.38$, $p < .001$. Estimated effect sizes for this variable are presented in Table 3. The finding that none of the 95% confidence intervals contain zero indicates that a significant male advantage was observed for all task categories. In addition, multiple comparisons among means based on the robust standard errors and using the Tukey HSD method at the .05 level showed that recall and pointing tasks produced significantly larger effects than distance, learning, and verbal instructions tasks. No other differences achieved significance (all p's > .057).

Outcome measures was also a significant moderator of the effect sizes, $F(3, 262) = 7.04$, $p < .001$, with estimated effect sizes presented again in Table 3. As we have seen in all cases so far, none of the confidence intervals contained zero, indicating a significant male advantage in all categories. Tukey HSD multiple comparisons showed that deviation scores produced significantly larger effects than accuracy and distance measures, whereas response time produced larger effects than distance. No other differences achieved significance (all p's > .11).

Timing condition was also found to contribute significantly to variance in effect sizes, $F(1, 264) = 4.54$, $p = .034$, with estimated effect sizes also presented in Table 3. Examination of Table 3 indicates that, based on confidence intervals, both timed and untimed administration produce a significant male advantage, although it appears that the sex differences are larger for timed than for untimed tasks.

Environment produced a significant effect, $F(3, 262) = 4.01$, $p = .008$, with estimated effect sizes presented in Table 3. As none of the confidence intervals contained zero, a significant male advantage was found in all categories. Tukey HSD multiple comparisons showed that water mazes and combination of indoor-outdoor environments produced significantly larger effects than studies that used exclusively indoor or outdoor environments. No other differences achieved significance (smallest $p = .56$).

Finally, even though mean age of the participants as a continuous variable failed to account for significant variance ($p = .94$), age defined categorically produced a significant contribution to variance, $F(4, 261) = 4.74$, $p = .001$. Once more, the estimated mean effect sizes are presented in Table 3. Again, none of the confidence intervals contained zero, indicating a significant male advantage in all age categories. Tukey HSD multiple comparisons showed that studies sampling participants below the age of 13 produced significantly smaller effects than participants in all other age groups. In addition, the 30 to 49 category produced a smaller effect than the 13 to 17 category. No other differences achieved significance (all p's > .07).

Task Subgroup Analysis

As a starting point to the task subgroup analyses, we examined the overall homogeneity statistic within each subgroup to ensure that there was significant heterogeneity in the effect sizes that required explanation by moderators before proceeding. Results of this analysis showed that learning and distance tasks goals produced homogeneous effect sizes (smallest $p = .330$). Accordingly, the effect sizes presented in Table 3 for these two tasks goals can be considered representative of the state of affairs. However, for the remaining tasks, significant heterogeneity was observed (largest $p = .015$). Accordingly, moderator analyses proceeded separately for recall/recognition, cardinal directions, pointing, landmarks, maps, and verbal tasks, as presented in the following sections. However, to provide a clearer picture of what specific moderators accounted for significant variability, the results are structured as a function of moderator in what follows.

Perspective. Results showed that perspective was a significant moderator only in landmark position tasks, $F(2, 11) =9.21$, $p = .001$. Estimated means, presented in Table 4, show that only the route perspective category produced a significant male advantage. Tukey HSD comparisons showed that a route perspective produced larger effects than a combination of route-survey perspectives. No other comparisons produced significant differences among the mean estimated effect sizes (smallest $p = .24$).

Outcome Measure. Outcome measure was a significant moderator for all the tasks goals examined in the subgroup analysis (largest $p = .006$), with the estimates presented in Table 5. On pointing tasks, all the categories except response time indicated a significant male advantage. Tukey HSD comparisons showed that a deviation measures produced larger sex differences than response time and distance measures. No other differences achieved significance (smallest $p = .054$).

For recall/recognition tasks, the estimates indicated a significant male advantage in all categories. Tukey HSD comparisons showed that response time measures produced a significantly larger effect than accuracy and distance measures. No other differences achieved significance (smallest p = .25).

For cardinal direction tasks, all the categories except response time indicated a significant male advantage. Tukey HSD comparisons showed that accuracy and deviation measures produced larger sex differences than response time measures. No other differences achieved significance ($p = .56$).

For map tasks, the estimates presented in Table 5 indicated a significant male advantage on accuracy and deviations scores but not on distance and response time measures. Tukey HSD comparisons showed that deviation measures produced significantly larger effects than distance measures. No other differences achieved significance (smallest $p = .071$).

Estimates relevant to landmark position tasks showed that only the "other" category, combining one each for distance and response time measures, produced no significant male advantage, despite seemingly large effects. Tukey HSD comparisons showed a larger effect for deviation than accuracy measures. There were no other significant differences among the effect sizes (smallest $p = .15$).

Finally, on verbal instructions tasks, accuracy and response time measures indicated a significant male advantage whereas deviation and distance scores did not. Tukey HSD comparisons showed that accuracy and response time produced larger sex differences than distance measures. No other differences achieved significance (smallest $p = .22$).

Route Direction. Route direction was a significant moderator of effect sizes for pointing tasks, $F(2, 68) = 3.19$, $p = .048$ and verbal instructions tasks, $F(1, 13) = 19.93$, $p < .001$, with estimates presented in Table 6. For pointing, results showed a significant male advantage when participants went forward on the learned route or when such instructions were not applicable, but not for the backward route. Tukey HSD comparisons showed that a backward route produced significantly smaller effects than the "not applicable" category. No other difference achieved significance (smallest $p = .09$).

For verbal instruction tasks, the estimates presented in Table 6 indicated a significant male advantage for the two categories represented. Direct interpretation of the estimated mean seen in Table 6 suggests that sex differences were larger when route direction was not applicable compared to when the forward direction was followed.

Route Selection. Route selection was only a significant moderator in cardinal direction tasks, $F(3, 10) = 361.61$, $p < .001$. Relevant estimates, seen in Table 7, indicate that the male advantage was not significant only when a free choice was allowed. Tukey HSD multiple comparisons showed that shortcuts produced significantly larger effects than in all other groups. Free choice and exact way also produced smaller effects than when this moderator was not applicable. No other differences achieved significance (all p's > .055).

Timing Condition. Timing conditions was a significant moderator in map tasks, $F(1, 29) = 8.16$, $p = .008$ and verbal instructions tasks, $F(1, 13) = 34.18$ $p < .001$, with estimates presented in Table 8. For map tasks, the results reflected the overall finding that, although the male advantage was significant regardless of timing conditions, it was significantly larger when a timed administration was used. In contrast, on verbal instructions tasks, timed conditions resulted in a female advantage, whereas untimed conditions produced a male advantage.

Environment. Environment was a significant moderator of effect sizes in pointing tasks, $F(2, 68) = 9.60$, $p < .001$ and cardinal direction tasks, $F(2, 11) = 18.34$, $p < .001$, with estimates presented in Table 9. In both tasks goals, the male advantage was significant regardless of environmental conditions. For pointing, Tukey HSD comparisons showed that testing in both environments (indoor-outdoor) produced significantly larger effects than testing indoor or outdoor singly. No other difference achieved significance (smallest $p = .51$).

For cardinal direction tasks, Tukey HSD comparisons showed that water maze environments produced significantly larger sex differences than indoor or outdoor environments. The difference between these last two categories did not achieve significance ($p = .65$).

Familiarity. Familiarity was only a significant moderator for cardinal direction tasks, $F(2, 11) = 22.57$, $p < .001$, with the estimates presented in Table 10.and a significant male advantage was found for all categories. Tukey HSD comparisons showed that familiar locations produced larger sex differences than unfamiliar ones, whereas remaining differences did not achieve significance (smallest $p = .07$).

Feedback. The presence of feedback was a significant moderator for pointing tasks, $F(2, 28) = 9.68$, $p < .001$ and map tasks, $F(2, 28) = 32.56$, $p < .001$. Estimates are presented in Table 11. For pointing, the estimated effect sizes indicated a significant male advantage in all categories. Tukey HSD comparisons showed that immediate feedback and the "not reported" category produced significantly larger effects than no feedback. The difference between the first two categories did not achieve significance ($p = .43$).

For map tasks, a significant male advantage was found under immediate or no feedback but not for the "not reported" categories. Tukey HSD comparisons showed that immediate feedback produced significantly larger effects than no feedback or the "not reported" category. The difference between these last two categories did not achieve significance (p = .97).

Learning Interval. Learning interval only produced a significant contribution to variance in recall/recognition tasks, $F(3, 127) = 4.03$, p = .009. As seen in the estimates presented in Table 12, only immediate testing produced a significant male advantage when a delay applied. Studies where the interval was not applicable also produced a significant male advantage. Formal Tukey HSD comparisons showed that effects in long time intervals were significantly smaller than those in immediate interval or the “not applicable” case. No other differences achieved significance (smallest p = .20).

Age. Age defined categorically was also a significant moderator for pointing tasks, $F(3, 67) = 6.82$, p = .007 and landmark position tasks, $F(2, 22) = 7.53$, p = .003. Estimated mean effect sizes are presented in Table 13. For pointing, results indicated a significant male advantage in all the represented age categories except 30 to 49. Tukey HSD multiple comparisons showed that the 13 to 17 category produced significantly larger effects than all other groups. In addition, the less than 13 category produced a smaller effect than the 18 to 29 category. No other differences achieved significance (all p's > .16).

In landmark position tasks, all the represented age categories showed a significant male advantage. Tukey HSD comparisons showed a significantly larger effect for the 18 to 29 and 30 to 49 age samples than for samples below the age of 13. The 18 to 29 and 30 to 49 groupings did not differ from each other (p = .71).

Publication Bias and the File Drawer Problem

Despite our best efforts to obtain unpublished work, the present meta-analysis consists mostly of data obtained from published studies. In such a case, it is often assumed that the final sample might not be representative of the entire population of studies in existence (Rosenthal, 1979). Such a situation raises the possible influence of the “file-drawer problem” (Sterling, 1959), suggesting that studies producing non-significant results or in the unexpected direction (a female advantage in our case) have a lower probability of publication. This putative publication bias has the potential to affect any meta-analytic results so that by including mostly published studies, meta-analytic findings might exaggerate the magnitude of the effect under consideration.

The simplest way to examine the potential influence of the file-drawer problem is to compare the mean estimated effect sizes for samples obtained from published and unpublished research. We therefore proceeded with such an analysis in the overall sample. We also divided research intro three rather than two categories. Of course, whether a data source was clearly published or unpublished formed two of the categories. However, theses and dissertation were considered as a third category because their status is uncertain in relation to the file-drawer problem. Specifically, one reason why they are not published might simply be that the author of the thesis did not pursue publication. This resulted in 614 published effect sizes (239 samples), 70 effect sizes from theses (24 samples), and only 10 effect sizes from unpublished sources (3 samples). With this in mind, the analysis using publication status as moderator showed no significant influence of publication status, $F(2, 263) = 0.72$, $p = .488$. This suggests no evidence of a publication bias in the present sample.

One might sensibly argue that the small number of unpublished studies that we were able to obtain makes our examination of publication status as a moderator less convincing that one might wish. Based on this argument, and despite potential drawbacks, the Egger, Davey Smith, Schneider, and Minder (1997) approach was used as a further way to test a potential publication bias in the present sample. This method makes the assumption that studies with a small sample and a small effect size are less likely to get published (Borenstein et al., 2009). Therefore, in the presence of publication bias, plotting precision (the inverse of the standard error; y-axis) against effect size (x-axis) would produce an asymmetrical distribution with few values on the bottom left-hand side of the plot, where small samples and negative effects would belong. Accordingly, the present data are shown in such a funnel plot in Figure 2. A visual inspection of Figure 2 reveals no sign of asymmetry. However, visual examination of the plot is not sufficient and Egger et al have formalized this process mathematically.

Specifically, the Egger et al. (1997) method allows examination of a possible publication bias by regressing the standard normal deviate for the effect size on precision. If there is no publication bias, the regression line should run through the origin and the intercept of the regression equation should not be significantly different from zero. Egger et al. recommended a significance level of .10 to maximize power. Following the approach proposed by Viechtbauer (see http://stats.stackexchange.com/questions/155693/metafor-package-bias-and-sensitivity-diagnostics), the inverse SE was used as a moderator in the multilevel analysis with the standard normal deviate for the effect sizes as outcome variable. Results of the Egger et al. test showed that the intercept was not significantly larger than zero at $p < .10$, with an intercept estimate of 0.065 (90% CI: -0.242, 0.375). Therefore, the Egger's et al. approach failed to support the presence of a publication bias in our data.

Discussion

The present meta-analysis aimed to summarize the available literature on sex differences in human spatial navigation and to examine potential moderators of these effects. The results of the analyses are summarized in Table 14. These results should be seen as a guide to forward thinking in this area, although it is important to remember that, because of their quasiexperimental nature, meta-analytic results do not allow causal conclusions. Accordingly, our discussion provides speculations intended to stimulate empirical assessment in future work.

Overall Results

The overall effect for our 694 effect sizes was estimated as *d* of 0.34 (up to 0.38 if effects sizes coded as zero are omitted). In Cohen's (1988) classification, this effect would be considered small to medium. Interestingly, it is in line with the overall effect reported by Voyer, Voyer, and Bryden (1995) in their examination of small-scale spatial ability sex differences (overall *d* of 0.37). Furthermore, results showed that a publication bias is unlikely to account for the present findings. To put these estimates in context, consider that for a *d* of 0.34, the distribution of men and women in spatial navigation overlaps by approximately 86%, which, at first glance, might seem to be a large overlap. However, it also means that about 64% of men score above the mean of women, and thus the difference is arguably not negligible. Navigation training in regular schooling or in informal activities might be helpful to narrow sex differences, in view of the malleability of spatial abilities more generally (Uttal et al., 2013), although navigation-specific training needs development. The goal of such training would be not only to narrow the sex gap but also to benefit individuals of both sexes in the long term.

Moderator Analyses

The discussion of moderator analyses builds on Table 14. Readers should refer to Tables 3 to 13 for the relevant summary values.

Task goal. Task goal was a significant moderator of sex differences in navigation skills. Although the numerically largest effects were found in cardinal direction tasks (based on a relatively small number of effect sizes; see Table 3), statistical results showed only that recall and pointing tasks produced significantly larger effects than distance, learning, and verbal instructions tasks, with no other differences achieving significance. The smaller sex difference for distance tasks might reflect a floor effect as both men and women tend to perform poorly on such tasks as a result of their inherent difficulty (Newcombe, 1985). For verbal instructions, the smaller sex difference might reflect the female advantage in language tasks and courses (Voyer & Voyer, 2014), providing them with some amount of compensation in relation to men's performance. Finally, for learning tasks, although the male advantage is significant, the reduced magnitude of the effect size might reflect the possibility that women can catch up with men in paradigms that allow for learning.

Outcome measure. Outcome measure was a significant moderator of sex differences in navigation skills in the overall analysis (see Table 3). In addition, it was a significant moderator for all task goals considered in the subgroup analysis (see Table 5). For all task goals except for verbal instructions, deviation scores produced the largest male advantage, perhaps because deviation scores provide an unusually sensitive measure of precision and accuracy. For verbal instructions, accuracy and response time produced the largest male advantage. Although distance measures did not produce a significant sex difference under verbal instructions, the fact that they reflect a trend favoring women is intriguing, especially considering that this is one of only three effect sizes with a negative sign in the tables of results. Conclusions on this finding are limited by the small number of relevant effect sizes ($k = 3$; see Table 5). However, the investigation of distance measures with verbal instructions tasks might provide a fruitful avenue in future work to better understand why women might process navigation tasks efficiently in this context.

Route direction. Route direction was a significant moderator for pointing and verbal instruction task goals (see Table 6). However, the results with route direction are not particularly informative because the reverse route condition was not used as manipulation with verbal instructions. For pointing, a similar problem arises, with only 5 of 107 studies using a reversed direction. The findings show that sex differences are small and not significant under such conditions. One possible way to account for this finding is that the additional cognitive load required for a route followed in the reversed direction might reach a point where it even exceeds the men's ability to handle the extra information, resulting in floor effects.

Timing condition. Timing condition was a significant moderator of sex differences in navigation skills in the overall sample (Table 3). It was also significant in maps and verbal instructions tasks (Table 8). Except for verbal instructions, the male advantage was larger under timed than untimed conditions. The role of timing condition might suggest the presence of sex differences in speed of processing for complex spatial information. However, it is important to keep in mind that timed tasks accounted for only 16% of effect sizes in the overall sample (111 out of 694) and only 8% for map tasks (5 out of 62). Furthermore, the findings for verbal instructions are the opposite of what would be expected, with a significant female advantage observed for timed tasks, and a significant male advantage for untimed conditions. The findings for verbal instructions are questionable, however, because all four effect sizes for the timed condition come from the same sample in one study (Ishikawa & Kiyomoto, 2008). It is also important to consider that all effect sizes for distance and pointing were untimed, whereas for other categories the percentage of timed effect sizes was as follows: recall/recognition = 29.5%; cardinal directions = 27.8%; landmark position = 13.9%; learning = 3.6%; and verbal instructions = 12.5%. The small number of effect sizes from timed tasks in most of these task categories suggests that it is premature to draw strong conclusions concerning the role of timing conditions on sex differences in spatial navigation.

Environment. Environment was a significant moderator of sex differences in the overall sample as well as for pointing tasks (Tables 3 and 9). Sex differences were largest when testing involved a combination of indoor and outdoor environments. Water maze tasks stood out for producing larger sex differences than indoor environments or outdoor environments. There were no significant differences in effects between the water maze and the combined indoor-outdoor environments.

The large sex differences in combined indoor-outdoor environments might reflect the complexity of such tasks, adding to instances of high task complexity promoting larger sex differences in spatial tasks (Coluccia & Louse, 2004; Heil & Jansen-Osmann, 2008). Environments combining indoor and outdoor settings likely involve switching between egocentric and allocentric wayfinding strategies. Therefore, large sex differences in this context might partly reflect the male advantage in the ability to alternate between strategies (Wang & Carr, 2014).

Feedback. Feedback significantly moderated task goals, specifically for maps and pointing tasks (Table 11). Immediate feedback increased the magnitude of the sex difference. However, the finding that the largest effect for the pointing tasks is for the “not reported” category undermines this conclusion. In fact, it is clear that more research manipulating feedback is required considering that studies with immediate feedback reflected only 6.5% of effect sizes for maps and 7.4% for pointing.

Age. Age was a significant moderator of sex differences in the overall sample (Table 3) as well as in pointing and landmark position tasks (Table 12). It is readily apparent from the data presented in the tables that the less than 13 years age group produced the smallest effect sizes, with a clear increase in magnitude for the 13 to 17 years category. Considering that adolescence is a time for increased independent navigational range (Anooshian & Young, 1981) with sex differences in how far and frequently children travel away from home, experiential and social norms may play a role in promoting sex differences in navigation skills in the latter age group. However, it is important to note that the 18 to 29 years old group is over-represented in the retrieved literature, reflecting 70.5% of the effect sizes examined here (see Table 3). The 13 to 17 years old group is interesting because it produced the largest effect size presented in Table 3; however, it is also the grouping with the smallest sample (k = 24). These data emphasize the need for more lifespan developmental research on spatial navigation.

Moderators significant in only one task. Finally a number of moderators only accounted for significant variance for one of the task categories. For instance, perspective accounted for significant variance only in landmark position tasks (Table 4.) However, this finding might once again reflect a limited number of studies and does not warrant a lengthy discussion.

Route selection only achieved significance for cardinal direction (Table 7), showing that the male advantage was largest when a shortcut was required as part of the task response. In fact, the effect size of 1.07 for that category is the largest in all our tables. Speculatively, the use of a shortcut might require deeper processing of the route and results in a better cognitive map, suggesting that higher depth of processing advantages males. However, this reflects another case of a result based on a small number of effect sizes (k = 2). The most parsimonious conclusion here is therefore that this is a finding that requires replication in many more studies before efforts are expanded to explain it.

Familiarity with the testing environment moderated cardinal directions (Table 10), showing a significantly larger male advantage for familiar compared to new locations. This finding could be a side effect of the very small number of effect sizes ($k = 2$) for familiar settings in cardinal direction tasks.

Finally, learning interval was a significant moderator only for recall/recognition tasks (Table 12). Longer time intervals did not produce a significant male advantage, whereas immediate time intervals and testing where learning interval was not relevant did. We can speculate that, for longer intervals, the memory load exceeded even the male's abilities and produced a floor effect. Short time intervals did not produce a significant male advantage despite a medium effect size ($d = 0.42$). However, this category had a very broad confidence interval as a result of imprecise estimates accounted for by small sample sizes (see the Head & Isom, 2010, and Tippet et al., 2009 listings in Table 2). Nevertheless, in terms of actual magnitude, short intervals produced similar effects to what we found with immediate recall, thereby supporting the memory load account to some extent.

Non-significant Moderators of Special Importance

Although we found that a large of number of variables were significant moderators of sex differences in spatial navigation, some of the moderators failed to achieve significance despite our expectations. A few of those are particularly noteworthy because of their theoretical or practical implications. Specifically, despite the theoretical importance often assigned to cue types (proximal, distal; Padilla, Creem-Regehr, Stefanucci & Cashdan, 2016), this moderator was not significant. This finding contradicts the assumption of differential hippocampal function in men and women in processing environmental cues. This finding is consistent with our earlier finding related to the environment moderator. Specifically, it is reasonable to assume that an indoor environment (e.g. closed basement maze) may offer more proximal cues and fewer distal cues in comparison to an outdoor environment (e.g. university campus). Given that there were no significant differences in effects found between indoor or outdoor testing environments, the null effect of cues should not come as a surprise. However, the significantly larger sex differences in combined indoor-outdoor settings may point to sex differences in flexibility in cue processing rather than the ability to use one or the other cue and should be further investigated.

It is also noteworthy that year of publication failed to account for significant variability in effect sizes both in the overall sample and in the separate analysis for each task goals. On the surface, this suggests that the magnitude of sex differences in spatial navigation is unaffected by social changes associated with year of publication (e.g., Feingold, 1988). However, in considering this finding, it is also crucial to keep in mind that year of publication reflected a limited range in our sample, from 1977 to 2018, despite our search parameters including research published since 1803. This range limitation would have adverse effects on the likelihood of obtaining a significant relation between year of publication and the magnitude of effect sizes, as is always the case in correlational designs (Tabachnick & Fidell, 2007). Accordingly, it would be premature to draw definite conclusions on the current null finding for the moderating effect of year of publication on sex differences in spatial navigation.

Limitations

Of course, any comprehensive meta-analysis is not without limitations. In particular, throughout the discussion section we mentioned moderator categories where there were too few effect sizes to allow solid conclusions. All these cases reflect areas that require more research and should encourage researchers to direct their efforts to elucidate factors accounting for sex differences in human spatial navigation. In particular, more studies examining cardinal direction and distance task goals might be warranted considering that these are the categories where there are the fewest effect sizes in our sample (see Table 3). Similarly, it might be worthwhile to conduct more studies comparing timed and untimed conditions in the same experiment.

Future research should also consider manipulating the amount of feedback provided to participants and examine sex differences in improvement in navigation performance that may result from this manipulation. The inability of low-performers to use feedback to self-correct one's cognitive map of the environment may present an opportunity for training interventions. Finally, large-scale navigation research has been abundantly tested with undergraduate psychology students who represent not only a very specific demographic but also a specific specific stage in neural development. The emergence of sex difference around the age of 13 emphasizes the need for more developmental research in the 13-17 year age group.

The fact that we were only able to find a small number of effect sizes from clearly unpublished work (k = 10) is also a limitation of our analysis, although it is a very common problem for meta-analysis. We found statistical reassurance in the findings that publication status was not a significant moderator and the Egger et al.'s (1997) test produced no evidence of publication bias. These finding are most likely a consequence of our sampling of much research that did not aim primarily at examining sex differences in spatial navigation. Accordingly, we are quite confident that our results are a valid reflection of the current state of affairs for sex differences in human spatial navigation.

Conclusions

In conclusion, the present meta-analysis provided the first comprehensive quantitative review of sex differences in human spatial navigation. Overall, the take home message from our results is that sex differences are small to moderate and do not vary that much, with few exceptions. It is particularly noteworthy that the effect sizes were generally small for children.

An important observation arising from our results is that, in many cases, significant effects of moderators, especially when occurring in task subgroups, were compromised by small numbers of effect sizes. When such findings were theoretically unanticipated and did not have clear interpretations, they should be seen only as potentially intriguing but preliminary. Another caveat is that some of the effects of moderators may arise in cases where testing conditions or task factors promoted floor or ceiling effects, and these were often compounded by the presence of few effect sizes in the sample. Such findings create "effects" that are theoretically uninteresting and may make a male advantage either more or less pronounced.

We have emphasized in the discussion the cases that require more empirical research either on their own right or to address issues relevant to small sample sizes or floor/ceiling effects. In this way, we hope that the research presented here will allow researchers to investigate promising avenues in their future work on spatial navigation and in their efforts to document how performance in such tasks is affected by sex.

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Table 1

Coding Scheme for Moderators in the Present Meta-Analysis

Moderator	Categories
Task Goal	(1) *Pointing to target* (e.g. point to a learned/familiar target: Pointing) (2) *Retracing learned route* by recall or recognition (e.g. maze exit, walk to a target location: Recall / recognition) (3) *Orienteering with cardinal directions* (e.g. orienteering based on N/S/E/W: Cardinal directions) (4) *Estimating distance* (e.g. estimate the distance to a target building: Distance) (5) *Positioning targets or landmarks* (e.g. map arrangement/model-building: Landmark Position) (6) *Reading maps* (e.g. navigate by reading a map: Maps) (7) *Navigating with verbal instructions* (e.g. navigate with verbal directions: Verbal Instructions) (8) *Reaching learning criterion* (Learning)
Perspective	(1) *Route* (e.g. walking through a city) (2) *Survey* (e.g. flying over a city, reading a map) (3) *Both* (e.g. using a map to walk through a city)
Outcome Measure	(1) *Accuracy* (e.g. number of correct turns during route recall) (2) *Degrees of Deviation* (e.g. degree error in pointing to a target location) (3) *Distance* (e.g. distance traveled on a particular route) (4) *Response Time* (e.g. time taken to reach a target location)
Route Direction	(1) *Forward* (e.g. move towards a learned/familiar target) (2) *Backward* (e.g. go back to the starting locations i.e. opposite to the

	learning direction) (3) *Free choice*
Route Selection	(1) *Free Choice* (e.g. any route to find the target location) (2) *Exact way* (e.g. same learned path to target location) (3) *Shortcut* (e.g. most direct way to the target location)
Timing Condition	(1) *Untimed* (e.g. unlimited time for task completion) (2) *Timed* (e.g. limited time for task completion)
Cues	(1) *Distal* (e.g. non-target salient landmarks that cannot be directly reached through learned routes) (2) *Proximal* (e.g. non-target salient landmarks that may be reached through learned routes or through non-significant detours)
Environment	(1) *Indoor* (e.g. routes in a building basement) (2) *Outdoor* (e.g. routes in a city) (3) *Indoor-Outdoor* (e.g. routes through a building basement and into an open campus/field) *(4) Water maze*
Familiarity	(1) *New* (e.g. find maze exit with no prior learning/learning criterion) (2) *Learned* (e.g. repeated learning in an environment before testing) (3) *Familiar* (e.g. point to a local landmark)
Testing Medium	(1) *Real* (e.g. routes in a campus/city) (2) *Virtual* (e.g. routes/mazes on a computer screen) (3) *Symbolic* (e.g. routes on a map/model)
Feedback	(1) *Immediate* (e.g. target location revealed in each trial) (2) *No-feedback* (e.g. No indication of performance)
Hints	(1) *Hints* (e.g. hints provided during testing trials) (2) *No-hints* (e.g. no hints provided during testing)
Device Assistance	(1) *No-device* (e.g. no assistive device during testing) (2) *Device* (e.g. compass/map during testing)

Learning Interval	(1) *Immediate* (e.g. testing begins after learning criterion is met) (2) *Short* (e.g. testing begins within 24 hours of learning) (3) *Long* (e.g. testing begins after 24 hours of learning)

Note: In all moderators, the categories "not applicable" or "not reported" were also added when relevant.

Table 2

Studies Included in the Present Analysis

Authors	Year	*N*m	*N*f	Age	Task	Per	Out	Dir	Sel	Time	Env	Fee	Fam	Int	d
Abu-Obeid	1998	193	134	20	R	B	A	NA	NA	T	O	No	F	I	0.17
Abu-Obeid	1998	101	70	20	R	B	A	NA	NA	T	O	No	N	I	1.01
Acevedo et al	2010	26	24	8.5	R	R	RT	Le	S	T	O	No	Le	I	0.68
Acevedo et al	2010	26	24	8.5	R	R	A	Le	S	T	O	No	Le	I	0.87
Allahyar	2003	40	40	19.5	Le	R	RT	Le	F	T	I	No	N	NA	0.76
Allahyar	2003	13	15	19	P	R	A	Le	NA	U	I	No	N	NA	0.76
Allahyar	2003	13	15	19	P	R	RT	Le	NA	U	I	No	N	NA	0.76
Allahyar	2003	40	40	19	R	R	D	Le	S	U	I	No	N	NA	0.54
Allen & Willenborg	1998	24	24	20	D	B	D	Le	Le	U	O	No	Le	I	0
Allen & Willenborg	1998	24	24	20	R	B	RT	Le	Le	U	O	No	Le	I	0
Allen & Willenborg	1998	24	24	20	R	B	A	Le	Le	U	O	No	Le	I	0.72
Allison et al	2017	37	35	21.6	Le	R	De	Le	NA	U	B	No	Le	I	0.63
Allison et al	2017	37	35	21.6	Le	R	RT	Le	NA	U	B	No	Le	I	0.82
Allison et al	2017	31	59	21.9	Le	R	De	Le	NA	U	B	No	Le	I	0.51
Allison et al	2017	37	123	20.4	Le	R	De	Le	NA	U	B	No	Le	I	0.22
Astur et al	2016	79	84	19.1	La	B	A	Le	NA	U	I	No	Le	I	-0.09
Astur et al	2016	79	84	19.1	La	B	A	Le	NA	U	I	No	Le	I	-0.08
Astur et al	2016	79	84	19.1	R	B	RT	Le	NA	U	I	No	Le	I	0.06
Astur et al	2016	79	84	19.1	R	B	D	Le	NA	U	I	No	Le	I	0.17
Astur et al	2016	79	84	19.1	R	B	RT	Le	NA	U	I	No	Le	I	0.4
Bakdash	2010	21	21	18.5	R	R	A	Le	Le	U	O	No	Le	NA	0.32
Bakdash	2010	34	33	19.5	P	R	De	Le	NA	U	O	No	Le	NA	1.39
Bakdash	2010	34	33	19.5	M	R	A	Le	NA	U	O	No	Le	NA	2.32*
Bakdash	2010	21	21	18.5	M	R	A	Le	NA	U	O	No	Le	NA	0.83
Barrash	1994	40	40	48	Le	R	A	Ba	Le	U	I	Yes	Le	I	0.16
Barton et al	2014	24	24	20.7	R	R	D	Ba	S	U	O	No	N	I	0.02
Baskaya et al	2004	58	56	20	M	S	A	NA	NA	U	I	No	Le	I	-0.08

Basten et al	2012	23	27	22	M	S	A	Le	NA	U	O	No	F	I	0.57
Basten et al	2012	39	42	26	M	S	A	Le	NA	U	O	No	F	I	0.44
Blacker et al	2017	33	42	21	P	R	De	Le	NA	U	O	No	Le	I	0.04
Blacker et al	2017	33	42	21	P	R	De	Le	NA	U	O	No	Le	I	0.09
Blacker et al	2017	33	42	21	P	R	De	Le	NA	U	O	No	Le	I	0.14
Blacker et al	2017	33	42	21	La	R	A	Le	NA	U	O	No	Le	I	0.29
Blanch et al	2004	13	12	22.5	R	S	A	NA	NA	U	O	No	Le	I	0.5
Blanch et al	2004	13	12	22.5	R	R	A	NA	NA	U	O	No	Le	I	0.91
Boone et al	2018	28	40	20	R	R	D	Le	S	T	O	No	Le	I	0.67
Boone et al	2018	28	40	20	R	R	RT	Le	S	T	O	No	Le	I	0.97
Boone et al	2018	18	18	20	R	R	RT	Le	S	T	O	No	Le	I	0.46
Boone et al	2018	18	18	20	R	R	D	Le	S	T	O	No	Le	I	0.81
Boone et al	2018	18	18	20	R	R	RT	Le	S	T	O	No	Le	I	0.46
Boone et al	2018	18	18	20	R	R	D	Le	S	T	O	No	Le	I	0.88
Bosco et al.	2004	53	54	22.5	R	B	A	Le	Le	U	O	No	Le	I	0.25
Bosco et al.	2004	53	54	22.5	Le	B	A	NA	NA	U	O	No	Le	I	0.37
Bosco et al.	2004	53	54	22.5	R	B	A	NA	NA	U	O	No	Le	I	0.17
Broadbent et al	2014	40	24	7.7	R	R	A	Le	Le	U	I	Yes	Le	I	0.31
Broadbent et al	2014	40	24	7.7	R	R	A	Le	NA	U	I	Yes	Le	I	0.23
Broadbent et al	2014	38	24	7.7	R	R	A	Le	NA	U	I	Yes	Le	I	0.41
Broadbent et al	2015	22	26	7.7	R	R	A	Le	NA	U	I	No	Le	I	-0.23
Broadbent et al	2015	22	26	7.7	R	R	A	Le	NA	U	I	No	Le	I	-0.18
Broadbent et al	2015	22	26	7.7	R	R	A	Le	NA	U	I	No	Le	I	0.03
Brunye et al	2012	12	12	19.8	R	B	A	Le	S	U	O	No	Le	I	0
Brunye et al	2012	12	12	19.8	R	B	RT	Le	S	U	O	No	Le	I	0.2
Brunye et al	2012	12	12	19.8	R	B	A	Le	S	U	O	No	Le	I	0.43
Brunye et al	2012	12	12	19.8	R	B	RT	Le	S	U	O	No	Le	I	1.66
Brunye et al	2012	12	12	19.8	R	B	A	Le	S	U	O	No	Le	I	0
Brunye et al	2012	12	12	19.8	R	B	RT	Le	S	U	O	No	Le	I	0.1
Brunye et al	2012	12	12	19.8	R	B	A	Le	S	U	O	No	Le	I	-0.14
Brunye et al	2012	12	12	19.8	R	B	RT	Le	S	U	O	No	Le	I	-0.04
Burigat&Chittaro	2007	16	8	23.7	R	B	RT	Le	S	U	O	No	Le	I	0.08

Burigat&Chittaro	2007	16	8	23.7	R	B	RT	Le	S	U	O	No	Le	I	0.61
Burigat&Chittaro	2007	16	8	23.7	R	B	RT	Le	S	U	O	No	Le	I	0.72
Burigat&Chittaro	2007	16	8	23.7	R	B	RT	Le	S	U	O	No	Le	I	0.73
Burigat&Chittaro	2007	17	7	32.3	R	B	RT	Le	S	U	O	No	Le	I	-1.15
Burigat&Chittaro	2007	17	7	32.3	R	B	RT	Le	S	U	O	No	Le	I	-0.42
Burigat&Chittaro	2007	17	7	32.3	R	B	RT	Le	S	U	O	No	Le	I	-0.35
Burigat&Chittaro	2007	17	7	32.3	R	B	RT	Le	S	U	O	No	Le	I	0.02
Burkitt et al	2007	18	19	19.8	R	R	RT	Le	S	T	I	No	Le	I	0.07
Burkitt et al	2007	18	19	19.8	R	R	RT	Le	S	T	I	No	Le	I	0.36
Burkitt et al	2007	18	18	19.8	R	R	RT	Le	S	T	I	No	Le	I	-0.24
Burkitt et al	2007	18	18	19.8	R	R	RT	Le	S	T	I	No	Le	I	1.04
Burte & Montello	2017	34	44	20	R	R	A	Le	Le	U	O	No	Le	I	0.19
Burte & Montello	2017	34	44	20	R	R	A	Le	Le	U	O	No	Le	I	0.33
Burte & Montello	2017	34	44	20	R	R	A	Le	Le	U	O	No	Le	I	0.47
Burte & Montello	2017	34	44	20	P	R	De	Le	NA	U	O	No	Le	I	0.57
Burte & Montello	2017	34	44	20	D	R	D	Le	S	U	O	No	Le	I	0.08
Cashdan et al	2012	29	34	30	P	R	De	Le	S	U	O	No	F	I	0.44
Castelli et al.	2008	20	20	24.5	Le	R	RT	Ba	Le	U	O	Yes	Le	I	0.32
Castelli et al.	2008	20	20	24.5	Le	R	A	Ba	Le	U	O	Yes	Le	I	0.33
Castelli et al.	2008	20	20	24.5	P	R	De	NA	NA	U	O	No	F	I	0.71
Castelli et al.	2008	20	20	24.5	La	R	D	NA	NA	U	O	No	F	I	1.26
Chai & Jacobs	2012	41	41	19.8	R	R	De	Le	S	T	O	Yes	Le	I	0.69
Chai & Jacobs	2012	41	41	19.8	R	R	De	Le	S	T	O	Yes	Le	I	-0.31
Chamizo et al	2011	20	20	21.5	R	R	A	Le	F	T	I	Yes	N	I	0.64
Chamizo et al	2011	20	20	21.5	R	R	A	Le	F	T	I	Yes	N	I	0.7
Chamizo et al	2011	33	37	22	R	R	A	Le	F	T	I	Yes	N	I	0.44
Chamizo et al	2011	33	37	22	R	R	A	Le	F	T	I	Yes	N	I	0.51
Chen et al.	2009	20	20	21.8	R	R	RT	NA	NA	U	I	Yes	Le	L	-0.09
Chen et al.	2009	20	20	21.8	R	S	RT	NA	NA	U	I	Yes	Le	L	0.18
Choi et al.	2006	15	20	22.5	R	R	A	Ba	F	U	I	No	Le	NA	0.14
Choi et al.	2006	15	20	22.5	R	R	D	Ba	F	U	I	No	Le	NA	0.45
Choi et al.	2006	15	20	22.5	R	R	D	Ba	Le	U	I	Yes	Le	NA	-0.55

Choi et al.	2006	15	20	22.5	R	R	A	Ba	S	U	I	No	Le	NA	0.39
Choi et al.	2006	15	20	22.5	R	R	D	Ba	S	U	I	No	Le	NA	0.72
Colluccia et al.	2007	48	48	22.3	M	B	A	NA	Le	T	O	No	Le	I	0.42
Colluccia et al.	2007	48	48	22.3	M	B	A	NA	Le	T	O	No	Le	I	0.51
Corbin	2014	19	11	20.5	V	R	A	Le	Le	U	I	No	N	I	0.04
Corbin	2014	19	11	20.5	V	R	RT	Le	Le	U	I	No	N	I	0.29
Corbin	2014	19	11	20.5	M	R	A	Le	Le	U	I	No	N	I	0
Corbin	2014	19	11	20.5	M	R	A	Le	Le	U	I	No	N	I	0.28
Cornell et al	1992	30	30	6	R	R	D	Ba	Le	U	O	Yes	Le	I	0
Cornell et al	1992	30	30	11.5	R	R	D	Ba	Le	U	O	Yes	Le	I	0
Cornell et al	1992	30	30	35.5	R	R	D	Ba	Le	U	O	Yes	Le	I	-0.52
Cornell et al.	1989	36	36	5.92	Le	R	A	Ba	Le	U	O	Yes	Le	I	0
Cornell et al.	1989	36	36	5.92	Le	R	D	Ba	Le	U	O	Yes	Le	I	0
Cornell et al.	1989	36	36	11.9	Le	R	A	Ba	Le	U	O	Yes	Le	I	0
Cornell et al.	1989	36	36	11.9	Le	R	D	Ba	Le	U	O	Yes	Le	I	0
Cubukcu & Nasar	2005	95	65	33	R	R	A	Le	NA	U	O	No	Le	I	0.1
Cubukcu & Nasar	2005	95	65	33	P	R	De	Le	S	U	O	No	Le	I	0.43
Cubukcu & Nasar	2005	95	65	33	R	R	De	NA	S	U	O	No	Le	I	0.73
Cutmore et al.	2000	24	24	21	M	S	D	Le	NA	U	I	No	Le	I	0.84
Cutmore et al.	2000	24	24	21	R	R	A	Le	NA	T	I	No	Le	I	0.87
Dahmani et al.	2012	32	34	23.2	R	R	A	NA	S	T	O	No	Le	I	-0.22
Dahmani et al.	2012	32	34	23.2	R	R	RT	NA	S	T	O	No	Le	I	0.53
Dahmani et al.	2012	32	34	23.2	R	R	D	NA	S	T	O	No	Le	I	0.59
Daugherty & Raz	2017	68	145	51.2	R	R	D	Le	NA	U	W	Yes	Le	I	0.03
Daugherty & Raz	2017	68	145	51.2	R	R	D	Le	NA	U	W	Yes	Le	I	0.33
Daugherty & Raz	2017	68	145	51.2	R	R	A	Le	NA	U	W	Yes	Le	I	0.42
Daugherty & Raz	2017	68	145	51.2	R	R	D	Le	NA	U	W	Yes	Le	I	0.68
Davies	2002	18	18	39	M	S	RT	NA	NA	U	O	No	N	NA	0
Devlin & Bernstein	1995	126	151	31.7	Le	R	RT	NA	Le	U	O	Yes	Le	I	0
Devlin & Bernstein	1995	126	151	31.7	Le	R	A	NA	Le	U	O	Yes	Le	I	0.34
Devlin & Bernstein	1997	43	43	32	Le	B	A	NA	Le	T	O	Yes	Le	I	0
Devlin & Bernstein	1997	43	43	32	Le	B	RT	NA	Le	T	O	Yes	Le	I	0.49

Driscoll et al	2005	33	37	50.3	R	R	RT	Le	F	T	I	Yes	N	I	0
Driscoll et al	2005	33	37	50.3	R	R	RT	Le	F	T	I	Yes	N	I	0.54
Driscoll et al	2005	33	37	50.3	R	R	RT	Le	F	T	I	Yes	N	I	0.82
Driscoll et al	2005	16	16	45.5	R	R	RT	Le	F	T	I	Yes	N	I	0.81
Farran et al (a)	2012	21	19	7.8	Le	R	A	Le	NA	U	I	No	Le	I	0.02
Farran et al (a)	2012	21	19	7.8	Le	R	RT	Le	NA	U	I	No	Le	I	0.15
Farran et al	2016	12	20	8.1	Le	R	A	Le	F	U	I	Yes	Le	I	-0.27
Farran et al	2016	12	20	8.1	Le	R	A	Le	F	U	I	Yes	Le	I	-0.24
Farran et al	2016	12	20	8.1	Le	R	A	Le	F	U	I	Yes	Le	I	0.51
Farran et al	2016	12	20	8.1	Le	R	A	Le	F	U	I	Yes	Le	I	0.54
Farran et al	2015	43	50	8.6	Le	R	A	Le	F	U	I	Yes	Le	I	0.2
Farran et al	2015	43	50	8.6	Le	R	A	Le	F	U	I	Yes	Le	I	0.23
Farranr et al	2015	43	50	8.6	Le	R	A	Le	F	U	I	Yes	Le	I	0.55
Farran et al	2015	43	50	8.6	Le	R	A	Le	F	U	I	Yes	Le	I	0.64
Farran et al (b)	2012	10	10	6	Le	R	A	Le	NA	U	I	No	Le	I	-0.07
Farran et al (b)	2012	10	10	6	Le	R	A	Le	NA	U	I	No	Le	I	-0.07
Farran et al (b)	2012	10	10	6	Le	R	A	Le	NA	U	I	No	Le	I	0.23
Farran et al (b)	2012	10	10	6	Le	R	A	Le	NA	U	I	No	Le	I	0.52
Farran et al (b)	2012	11	9	8.7	Le	R	A	Le	NA	U	I	No	Le	I	-0.42
Farran et al (b)	2012	11	9	8.7	Le	R	A	Le	NA	U	I	No	Le	I	-0.4
Farran et al (b)	2012	11	9	8.7	Le	R	A	Le	NA	U	I	No	Le	I	0.03
Farran et al (b)	2012	11	9	8.7	Le	R	A	Le	NA	U	I	No	Le	I	0.04
Ferguson et al	2015	85	157	21	C	S	A	Le	NA	T	O	No	N	I	0.53
Ferguson et al	2015	116	137	34	C	S	A	Le	NA	T	O	No	N	I	0.63
Gagnon et al	2018	46	60	21.7	P	R	A	Le	S	U	O	No	N	I	0.1
Gagnon et al	2018	46	60	21.7	P	R	A	Le	S	U	O	No	N	I	0.34
Gagnon et al	2018	46	60	21.7	P	R	A	Le	S	U	O	No	N	I	0.55
Gagnon et al	2018	46	60	21.7	R	R	A	Le	S	U	O	No	N	I	0.77
Gagnon et al	2016	42	36	22.6	P	R	De	Le	S	U	O	No	Le	I	0.47
Galati et al	2017	12	12	20	R	R	RT	Le	S	U	O	Yes	Le	I	0.61
Galati Weisberg et al	2015	7	29	20	R	R	RT	Le	Le	U	O	Yes	Le	I	0.32
Galea & Kimura	1993	49	48	21.9	Le	S	A	Le	Le	U	O	Yes	Le	I	0.36

Galea & Kimura	1993	49	48	21.9	Le	S	A	Le	Le	U	O	Yes	Le	I	0.4
Galea & Kimura	1993	49	48	21.9	Le	S	RT	Le	Le	U	O	Yes	Le	I	0.48
Glicksohn et al.	1998	15	11	42	P	S	De	Ba	NA	U	O	No	F	I	0
Glicksohn et al.	1998	15	11	42	P	S	De	Le	NA	U	O	No	F	I	0
Glicksohn et al.	1998	14	23	42	P	S	De	Ba	NA	U	O	No	F	I	0
Glicksohn et al.	1998	14	23	42	P	S	De	Le	NA	U	O	No	F	I	0
Goldiez	2004	10	10	25.7	P	R	De	Le	F	U	I	No	Le	NA	0
Goldiez	2004	50	50	29.8	P	R	De	Le	F	U	I	No	Le	NA	0
Goldiez	2004	10	10	25.7	P	R	D	Le	F	U	I	No	Le	NA	0
Goldiez	2004	50	50	29.8	P	R	D	Le	F	U	I	No	Le	NA	0
Goldiez	2004	10	10	25.7	C	R	De	Le	F	U	I	No	Le	NA	-0.13
Goldiez	2004	50	50	29.8	C	R	De	Le	F	U	I	No	Le	NA	0.34
Goldiez	2004	50	50	29.8	R	R	RT	Le	F	U	I	No	Le	NA	0
Goldiez	2004	10	10	25.7	R	R	De	Le	F	U	I	No	Le	NA	0
Goldiez	2004	50	50	29.8	R	R	De	Le	F	U	I	No	Le	NA	0
Goldiez	2004	10	10	25.7	R	R	RT	Le	F	U	I	No	Le	NA	0.79
Gron et al	2000	12	12	26.0	R	R	RT	Le	F	U	I	No	N	NA	1.85
Grubel et al	2017	9	11	21.8	R	R	RT	Le	S	U	O	No	Le	I	0.27
Grubel et al	2017	9	11	21.8	R	R	A	Le	S	U	O	No	Le	I	0.92
Grubel et al	2017	9	11	21.8	R	R	A	Le	S	U	O	No	N	I	-0.92
Grubel et al	2017	9	11	21.8	R	R	RT	Le	S	U	O	No	N	I	-0.27
Gugerty & Brooks	2004	79	25	19	P	S	A	NA	NA	U	O	Yes	N	I	0.69
Hamburger & Röser	2014	5	25	21.7	Le	R	A	Le	Le	U	I	No	Le	I	0
Hamburger & Röser	2014	4	16	26.8	Le	R	A	Le	Le	U	O	No	Le	I	0
Hamilton/Sutherland	1999	25	41	22.5	R	R	A	Le	F	T	I	Yes	N	I	0
Hardt et al	2009	32	32	20.4	R	R	RT	Le	NA	T	I	No	Le	I	0
Hardt et al	2009	32	32	20.4	R	R	RT	Le	NA	T	I	No	Le	I	0.74
Hardt et al	2009	52	68	20.4	R	R	A	Le	NA	T	I	No	Le	I	0
Hardt et al	2009	52	68	20.4	R	R	RT	Le	NA	T	I	No	Le	I	0.54
Hardt et al	2009	20	24	19.3	R	R	A	Le	NA	T	I	No	Le	I	0
Hardt et al	2009	20	24	19.3	R	R	A	Le	NA	T	I	No	Le	I	0.38
Hardt et al	2009	20	24	19.3	R	R	RT	Le	NA	T	I	No	Le	I	1.23

Harrison	2000	53	131	66.3	Le	R	A	Le	F	U	I	No	Le	NA	0.12
Harrison	2000	53	131	66.3	Le	R	RT	Le	F	U	I	No	Le	NA	0.17
Harrison	2000	19	39	20.3	Le	R	RT	Le	F	U	I	No	Le	NA	0.03
Harrison	2000	19	39	20.3	Le	R	A	Le	F	U	I	No	Le	NA	0.3
Harrison	2000	53	131	66.3	R	R	RT	Le	F	U	I	No	Le	NA	0.7
Harrison	2000	53	131	66.3	R	R	A	Le	F	U	I	No	Le	NA	0.71
Harrison	2000	19	39	20.3	R	R	A	Le	F	U	I	No	Le	NA	0
Harrison	2000	19	39	20.3	R	R	RT	Le	F	U	I	No	Le	NA	0.23
Harrison	2000	53	131	66.3	M	R	A	NA	NA	U	I	No	Le	NA	0.59
Harrison	2000	19	39	20.3	M	R	A	NA	NA	U	I	No	Le	NA	0.35
Head & Isom	2010	6	5	20	Le	R	D	Le	F	U	I	Yes	N	S	0.23
Head & Isom	2010	9	17	20	Le	R	D	Le	F	U	I	Yes	N	S	0.5
Head & Isom	2010	9	7	20	R	R	D	Le	S	U	I	Yes	N	S	-0.05
Head & Isom	2010	11	20	20	R	R	D	Le	S	U	I	Yes	N	S	0.06
Hedge et al	2017	25	30	20	La	B	A	Le	NA	U	I	No	Le	I	0.04
Hedge et al	2017	25	30	20	R	R	A	Le	NA	U	I	No	Le	I	0.04
Hedge et al	2017	25	30	20	R	R	A	Le	NA	U	I	No	Le	I	0.19
Hedge et al	2017	25	30	20	R	R	A	Le	NA	U	I	No	Le	I	0.63
Hegarty et al.	2006	83	135	22	P	R	De	NA	NA	U	I	No	Le	I	0.43
Hegarty et al.	2006	83	135	22	P	R	De	NA	NA	U	I	No	Le	I	0.52
Hegarty et al.	2006	83	135	22	P	R	De	NA	NA	U	I	No	Le	I	0.61
Hegarty et al.	2006	83	135	22	M	R	A	NA	NA	U	I	No	Le	I	0.21
Hegarty et al.	2006	83	135	22	M	R	A	NA	NA	U	I	No	Le	I	0.33
Hegarty et al.	2006	83	135	22	M	R	A	NA	NA	U	I	No	Le	I	0.33
Hegarty et al.	2006	83	135	22	D	R	D	NA	NA	U	I	No	Le	I	0.18
Hegarty et al.	2006	83	135	22	D	R	D	NA	NA	U	I	No	Le	I	0.33
Hegarty et al.	2006	83	135	22	D	R	D	NA	NA	U	I	No	Le	I	0.39
Hegarty et al	2002	16	9	20	P	R	De	Ba	NA	U	O	No	N	I	0.04
Hegarty et al	2002	57	47	19	La	R	De	Le	NA	U	O	No	F	I	0.29
Hegarty et al	2002	56	48	19	La	R	De	Le	NA	U	O	No	F	I	0.89
Hemmer et al	2015	164	164	10	C	R	A	Le	Le	T	O	No	N	I	0.48
Heth et al.	1997	40	40	10.2	P	R	A	Ba	F	U	O	No	Le	I	0

Holding & Holding	1989	12	12	20	P	S	RT	NA	NA	U	O	No	Le	I	0
Holding & Holding	1989	12	12	20	P	S	De	NA	NA	U	O	No	Le	I	0.99
Holding & Holding	1989	12	12	20	D	S	D	NA	NA	U	O	No	Le	I	0
Holding & Holding	1989	12	12	20	D	S	D	NA	NA	U	O	No	Le	I	1.48
holscher et al	2009	16	16	23	R	B	A	Le	F	U	I	Yes	F	I	0.71
Holscher et al	2011	12	12	25.5	V	B	A	Le	S	U	O	No	F	NA	0
Holscher et al	2011	12	12	25.5	V	B	D	Le	S	U	O	No	F	NA	0
Holscher et al	2011	12	12	25.5	V	B	A	Le	S	U	O	No	F	NA	0.72
Holscher et al	2011	12	12	25.5	V	B	A	Le	S	U	O	No	F	NA	0.91
Honda & Nihei	2004	24	24	20	V	R	A	Le	Le	U	O	Yes	N	NA	-0.66
Honda & Nihei	2004	24	24	20	V	R	A	Le	Le	U	O	Yes	N	NA	0.86
Hund	2016	93	99	20	R	R	RT	Le	S	U	I	No	Le	I	0.29
Hund & Gill	2014	74	62	21.0	V	B	A	Le	NA	U	I	No	F	NA	-0.11
Hund & Gill	2014	74	62	21.0	V	B	RT	Le	NA	U	I	No	F	NA	-0.06
Hund & Gill	2014	74	62	21.0	P	B	De	Le	NA	U	I	No	F	NA	0.11
Hund & Minarik	2000	32	32	21.5	V	S	A	Le	Le	U	O	No	Le	I	-0.34
Hund & Minarik	2000	32	32	21.5	V	S	RT	Le	Le	U	O	No	Le	I	0.1
Hund & Minarik	2000	44	46	20.9	V	S	A	Le	Le	U	O	No	Le	I	0.1
Hund & Minarik	2000	44	46	20.9	V	S	RT	Le	Le	U	O	No	Le	I	0.44
Hund & Nazarczuk	2009	36	36	20	V	B	RT	Le	Le	U	I	No	Le	I	-0.1
Hund & Nazarczuk	2009	36	36	20	V	B	A	Le	Le	U	I	No	Le	I	0.33
Hund & Padgitt	2010	36	39	19.7	P	S	De	NA	NA	U	I	No	F	I	0.32
Ishikawa & Kiyomoto	2008	7	25	19.8	V	R	RT	Le	F	T	O	No	N	I	0.43
Ishikawa & Kiyomoto	2008	7	25	19.8	V	R	D	Le	5	T	O	No	N	I	-0.51
Ishikawa & Kiyomoto	2008	7	25	19.8	V	R	De	Le	5	T	O	No	N	I	-0.41
Ishikawa & Kiyomoto	2008	7	25	19.8	V	R	D	Le	5	T	O	No	N	I	-0.35
Ishikawa & Takahashi	2013	12	12	22.3	R	B	D	NA	F	U	O	No	F	I	0.03
Ishikawa & Takahashi	2013	12	12	22.3	R	B	RT	NA	F	U	O	No	F	I	0.07
Ishikawa & Takahashi	2013	12	12	22.3	R	B	D	NA	F	U	O	No	F	I	0.07
Ishikawa & Takahashi	2013	12	12	22.3	R	B	D	NA	F	U	O	No	F	I	0.19
Ishikawa & Takahashi	2013	12	12	22.3	R	B	RT	NA	F	U	O	No	F	I	0.32
Ishikawa & Takahashi	2013	12	12	22.3	R	B	RT	NA	F	U	O	No	F	I	0.37

Ishikawa & Takahashi	2013	12	12	21.8	R	B	RT	NA	F	U	O	No	F	I	0.87
Ishikawa & Takahashi	2013	12	12	21.8	R	B	RT	NA	F	U	O	No	F	I	0.9
Ishikawa & Takahashi	2013	12	12	21.8	R	B	RT	NA	F	U	O	No	F	I	0.91
Ishikawa et al	2008	4	18	20.4	R	R	RT	Le	F	T	O	No	N	I	-1.52*
Ishikawa et al	2008	4	18	20.4	R	R	A	Le	F	T	O	No	N	I	0.63
Ishikawa et al	2008	4	18	20.4	R	R	D	Le	F	T	O	No	N	I	0.98
Ishikawa et al	2008	4	18	20.4	R	R	A	Le	F	T	O	No	N	I	1.19
Ishikawa et al	2008	4	19	20.4	R	R	RT	Le	F	T	O	No	N	I	-0.14
Ishikawa et al	2008	4	19	20.4	R	R	D	Le	F	T	O	No	N	I	0.55
Ishikawa et al	2008	4	19	20.4	R	R	A	Le	F	T	O	No	N	I	0.74
Ishikawa et al	2008	4	19	20.4	R	R	A	Le	F	T	O	No	N	I	0.85
Ishikawa et al	2008	3	18	20.4	R	R	A	Le	F	T	O	No	N	I	-0.25
Ishikawa et al	2008	3	18	20.4	R	R	D	Le	F	T	O	No	N	I	-0.17
Ishikawa et al	2008	3	18	20.4	R	R	A	Le	F	T	O	No	N	I	0.34
Ishikawa et al	2008	3	18	20.4	R	R	RT	Le	F	T	O	No	N	I	0.37
Ishikawa & Montello	2006	11	13	20.2	P	R	De	Le	NA	U	O	No	N	L	1.15
Ishikawa & Montello	2006	11	13	20.2	M	R	A	NA	NA	U	O	No	N	L	1.22
Ishikawa & Montello	2006	11	13	20.2	D	R	D	NA	NA	U	O	No	N	L	0.21
Jansen et al	2010	10	10	22.9	Le	R	A	Le	Le	U	I	No	N	I	0.63
Jansen et al	2010	10	10	45.2	Le	R	A	Le	Le	U	I	No	N	I	0.41
Jansen et al	2010	10	10	65.2	Le	R	A	Le	Le	U	I	No	N	I	0.31
Jansen-Osmann & Wiedenbauer	2004	7	13	7.8	Le	R	A	Le	Le	U	I	No	N	I	0.24
Jansen-Osmann & Wiedenbauer	2004	10	10	11.8	Le	R	A	Le	Le	U	I	No	N	I	0.32
Jansen-Osmann & Wiedenbauer	2004	27	27	29.5	Le	R	A	Le	Le	U	I	No	N	I	0
Jansen-Osmann &	2004	7	13	7.8	R	R	D	Le	Le	U	I	No	N	I	0.42

Wiedenbauer															
Jansen-Osmann & Wiedenbauer	2004	7	13	7.8	R	R	A	Le	Le	U	I	No	N	I	0.85
Jansen-Osmann & Wiedenbauer	2004	10	10	11.8	R	R	D	Le	Le	U	I	No	N	I	0.66
Jansen-Osmann & Wiedenbauer	2004	10	10	11.8	R	R	A	Le	Le	U	I	No	N	I	0.94
Jansen-Osmann & Wiedenbauer	2004	27	27	29.5	R	R	D	Le	Le	U	I	No	N	I	-0.46
Jansen-Osmann & Wiedenbauer	2004	27	27	29.5	R	R	A	Le	Le	U	I	No	N	I	-0.27
Jansen-Osmann et al	2007	30	30	14.4	M	R	D	NA	NA	U	I	No	Le	I	0.62
Jansen-Osmann et al	2007	30	30	14.4	M	S	A	NA	NA	U	I	No	Le	I	0.77
Jansen-Osmann et al	2007	30	30	14.4	R	R	A	NA	S	U	I	No	Le	I	0
Jansen-Osmann et al	2007	10	10	7.85	R	R	A	NA	S	U	I	No	Le	I	0.2
Jansen-Osmann et al	2007	10	10	11.2	R	R	A	NA	S	U	I	No	Le	I	0.74
Jansen-Osmann et al	2007	10	10	24.1	R	R	A	NA	S	U	I	No	Le	I	0.17
JansenOsmann & Fuchs	2006	15	15	7.8	R	R	A	NA	S	U	I	No	Le	I	-0.23
JansenOsmann & Fuchs	2006	15	15	7.8	R	R	De	NA	S	U	I	No	Le	I	0.01
JansenOsmann & Fuchs	2006	15	15	12.2	R	R	De	NA	S	U	I	No	Le	I	0.42
JansenOsmann &	2006	15	15	12.2	R	R	A	NA	S	U	I	No	Le	I	0.44

Fuchs															
JansenOsmann & Fuchs	2006	15	15	25.9	R	R	De	NA	S	U	I	No	Le	I	0.02
JansenOsmann & Fuchs	2006	15	15	25.9	R	R	A	NA	S	U	I	No	Le	I	0.83
Kirasic et al	1984	24	24	20	P	S	De	Le	NA	U	O	No	F	NA	0
Kirasic et al	1984	24	24	20	P	R	De	Le	NA	U	O	No	F	NA	0
Kirasic et al	1984	24	24	20	P	R	A	Le	NA	U	O	No	F	NA	0.58
Kirasic et al	1984	24	24	20	D	S	D	Le	NA	U	O	No	F	NA	0
Kirasic et al	1984	24	24	20	D	R	D	Le	NA	U	O	No	F	NA	0
Kober & Neuper	2011	13	14	24.6	R	R	D	Le	S	U	I	No	Le	I	0.32
Kober & Neuper	2011	13	14	24.6	R	R	A	Le	S	U	I	No	Le	I	0.45
Kong et al	2017	73	117	20.3	La	R	A	Le	NA	U	I	No	Le	I	0.77
Konig et al	2017	26	43	23.7	C	R	A	Le	NA	U	O	No	F	I	1.07
Konig et al	2017	26	43	23.7	C	R	A	Le	NA	U	O	No	F	I	1.14
Korthauer et al	2017	36	39	21.6	R	R	A	Le	S	U	W	Yes	Le	I	0.41
Korthauer et al	2017	36	39	21.6	R	R	A	Le	S	U	W	Yes	Le	I	0.42
Korthauer et al	2017	36	39	21.6	R	R	D	Le	S	U	W	Yes	Le	I	0.53
Korthauer et al	2017	36	39	21.6	R	R	RT	Le	S	U	W	Yes	Le	I	0.58
Korthauer et al	2017	36	39	21.6	R	R	RT	Le	S	U	W	Yes	Le	I	0.79
Kozlowski&Bryant	1977	28	17	20	P	R	De	Le	NA	U	O	No	F	NA	0.55
Kushigian	1998	39	51	35.5	R	R	RT	Le	F	U	I	No	Le	NA	0.91
Kushigian	1998	39	51	35.5	R	R	RT	Le	S	U	I	No	Le	NA	0.51
Lawton	1997	104	174	23.3	P	R	RT	Le	NA	U	I	No	Le	I	0.2
Lawton	1997	104	174	23.3	P	R	De	Le	NA	U	I	No	Le	I	0.4
Lawton et al.	1996	20	55	28.7	Le	R	RT	Ba	F	U	I	No	Le	I	0
Lawton et al.	1996	20	55	28.7	P	R	De	NA	NA	U	I	No	N	I	0.75
Lawton & Morrin	1999	96	123	22.6	P	R	De	Le	NA	U	I	No	N	I	0.64
Lawton & Morrin	1999	67	115	22.6	P	R	De	Le	NA	U	I	Yes	N	I	0.43
Lehnung et al	2001	74	79	7.7	P	R	De	Le	NA	U	I	No	N	I	0

Lehnung et al	2001	74	79	7.7	La	R	A	Le	NA	U	I	No	N	I	0
Liben et al	2013	19	21	9.6	R	B	A	NA	F	U	O	No	N	I	0.27
Liben et al	2013	19	21	9.6	R	B	D	NA	F	U	O	No	N	I	0.41
Liben et al	2013	19	21	9.6	R	B	A	NA	F	U	O	No	N	I	0.44
Liben et al	2013	19	21	9.6	R	R	A	NA	F	T	O	No	N	I	0.67
Liben et al	2013	19	21	9.6	R	B	De	NA	F	U	O	No	N	I	0.71
Lingwood	2015	179	169	31	Le	R	A	Le	Le	U	I	No	N	I	0.17
Lingwood	2015	59	49	27	Le	R	A	Le	Le	U	I	No	N	I	-0.17
Lingwood	2015	10	10	26.5	Le	R	A	Le	Le	U	I	No	N	I	0.63
Lingwood	2015	10	10	26.5	Le	R	A	Le	Le	U	I	No	N	I	0.65
Lingwood	2015	10	10	27	Le	R	A	Le	Le	U	I	No	N	I	-0.63
Lingwood	2015	10	10	27	Le	R	A	Le	Le	U	I	No	N	I	0
Lingwood	2015	10	10	24.9	Le	R	A	Le	Le	U	I	No	N	I	-0.25
Lingwood	2015	10	10	24.9	Le	R	A	Le	Le	U	I	No	N	I	0
Lingwood	2015	18	22	20.5	Le	R	A	Le	Le	U	I	No	N	I	-0.16
Lingwood	2015	18	22	20.5	Le	R	A	Le	Le	U	I	No	N	I	0.18
Lingwood	2015	9	11	22.6	Le	R	A	Le	Le	U	I	No	N	I	0.8
Lingwood	2015	9	11	22.6	D	R	D	Le	Le	U	I	No	N	I	0.26
Liu et al	2011	382	252	39.2	R	R	A	Ba	Le	U	O	No	N	NA	0.38
Liu et al	2011	382	252	39.2	La	R	A	Le	NA	U	O	No	N	NA	0.21
Liu et al	2011	382	252	39.2	R	R	A	Le	S	U	O	No	N	NA	0.27
Liu, et al	2011	382	252	39.2	R	R	A	NA	Le	U	O	No	N	NA	0
Liu, et al	2011	382	252	39.2	C	R	A	NA	NA	U	O	No	N	NA	0
Livingston-Lee et al	2014	16	21	27.5	R	R	A	Le	S	T	I	No	N	I	0
Livingston-Lee et al	2014	16	21	27.5	R	R	A	Le	S	T	I	No	N	I	0.19
Lovden et al	2007	16	16	24.8	Le	B	D	Le	S	U	I	Yes	N	I	0.97
Malinowksi/Gillepsie	2001	818	124	19.7	C	R	RT	NA	NA	T	O	No	Le	S	0.38
Malinowksi/Gillepsie	2001	818	124	19.7	C	R	A	NA	NA	T	O	No	Le	S	0.8
Marchette et al	2011	29	29	20	P	R	De	Le	NA	U	O	No	F	NA	0
McGuiness & Sparks	1983	50	50	20	R	B	A	NA	NA	U	O	No	F	NA	0.36
McGuinnes & Sparks	1983	18	18	19.3	M	S	D	NA	NA	U	O	No	F	NA	-0.77
McGuinnes & Sparks	1983	18	18	19.3	M	S	A	NA	NA	U	O	No	F	NA	0.74

McGuinnes & Sparks	1983	18	18	19.3	M	S	A	NA	NA	U	O	No	F	NA	1.73
Meilinger er al	2014	9	9	25	P	R	RT	Le	NA	U	I	No	N	NA	0
Meilinger er al	2014	9	9	25	P	R	De	Le	NA	U	I	No	N	NA	0
Meilinger er al	2014	10	10	25	P	R	RT	Le	NA	U	I	No	N	NA	0.4
Meilinger er al	2014	10	10	25	P	R	De	Le	NA	U	I	No	N	NA	1.94*
Meilinger er al	2014	9	9	25	Le	R	RT	Le	NA	U	I	No	N	NA	0
Meilinger er al	2014	9	9	25	Le	R	A	Le	NA	U	I	No	N	NA	0.53
Meilinger er al	2014	9	9	25	C	R	RT	Le	NA	U	I	No	N	NA	0.5
Meilinger er al	2014	10	10	25	C	R	RT	Le	NA	U	I	No	N	NA	0.7
Meilinger er al	2013	13	10	28.5	R	B	A	Le	NA	U	O	No	F	NA	0
Meilinger er al	2013	13	10	28.5	R	B	RT	Le	NA	U	O	No	F	NA	0
Meilinger et al	2007	13	5	28.6	M	B	A	NA	F	U	I	No	N	I	0.61
Meilinger et al	2007	13	5	28.6	M	B	A	NA	F	U	I	No	N	I	0.97
Meilinger et al	2007	9	9	27.4	M	B	D	NA	F	U	I	No	N	I	-1.97*
Meilinger et al	2007	9	9	27.4	M	B	RT	NA	F	U	I	No	N	I	-1.47*
Meilinger et al	2007	9	9	27.4	M	B	A	NA	F	U	I	No	N	I	-1.31*
Meilinger et al	2007	9	9	27.4	M	B	A	NA	F	U	I	No	N	I	0.6
Meilinger et al	2007	9	9	27.4	M	B	A	NA	F	U	I	No	N	I	0.87
Meilinger et al	2015	20	16	28.2	P	R	RT	Le	S	U	I	No	N	I	0.02
Meilinger et al	2015	20	16	28.2	P	R	De	Le	S	U	I	No	N	I	0.51
Meilinger et al	2015	7	8	28.2	P	R	RT	Le	S	U	I	No	N	I	-0.55
Meilinger et al	2015	7	8	28.2	P	R	De	Le	S	U	I	No	N	I	0.3
Meilinger et al	2016	34	26	30	La	S	A	Le	NA	U	O	No	F	I	-0.18
Meilinger et al	2009	12	12	24	R	R	A	Le	Le	U	O	No	Le	I	0.81
Meilinge et al	2009	12	12	24	La	R	A	Le	NA	U	O	No	Le	I	-0.18
Meilinger et al	2009	12	12	24	La	R	RT	Le	NA	U	O	No	Le	I	0.13
Meilinger et al	2008	12	12	24	R	R	A	Le	F	U	O	No	Le	I	0.66
Meilinger et al	2008	9	9	24	C	R	A	NA	NA	U	O	No	N	I	0.04
Meilinger et al	2016	5	7	26.1	P	R	RT	Le	Le	U	I	No	Le	I	0.06
Meilinger et al	2016	5	7	26.1	P	R	De	Le	Le	U	I	No	Le	I	0.47
Meilinger et al	2015	15	18	24	P	R	RT	Le	F	U	I	No	Le	I	-0.17
Meilinge et al	2015	15	18	24	P	R	De	Le	F	U	I	No	Le	I	0.55

Meilinger et al	2015	15	18	24	C	R	RT	Le	F	U	I	No	Le	I	-0.2
Meilinger et al	2016	6	9	26	Le	R	RT	Le	Le	U	I	No	Le	I	0.53
Meilinge et al	2016	6	9	24	Le	R	A	Le	Le	U	I	No	Le	I	0.66
Meilinger et al	2016	13	11	24	Le	R	RT	Le	Le	U	I	No	Le	I	0.49
Meilinger et al	2016	13	11	24	Le	R	A	Le	Le	U	I	No	Le	I	0.56
Meneghetti et al	2012	10	10	25	Le	R	A	NA	Le	U	O	No	N	I	0.52
Meneghetti et al	2012	10	10	25	Le	S	A	NA	Le	U	O	No	N	I	0.81
Meneghetti et al	2012	10	10	65	Le	S	A	NA	Le	U	O	No	N	I	0.14
Meneghetti et al	2012	10	10	65	Le	R	A	NA	Le	U	O	No	N	I	0.21
Merrill et al	2016	80	73	9.6	Le	R	A	Le	Le	U	I	Yes	Le	I	0.07
Merrill et al	2016	80	73	9.6	Le	R	A	Le	Le	U	I	Yes	Le	I	0.07
Merrill et al	2016	80	73	9.6	La	R	A	Le	Le	U	I	Yes	Le	I	0.04
Merrill et al	2016	80	73	9.6	R	R	A	Ba	Le	U	I	Yes	Le	I	0.06
Moffat et al	1998	40	34	19.9	M	R	RT	Le	Le	T	O	No	N	I	0.93
Moffat et al	1998	40	34	19.9	R	R	A	Le	Le	T	I	No	N	I	-0.11
Moffat et al	1998	40	34	19.9	R	R	A	Le	Le	T	I	No	N	I	1.38
Moffat et al	1998	40	34	19.9	R	R	RT	Le	Le	T	I	No	N	I	1.59
Moffat et al	2007	34	34	46.5	R	R	D	Le	S	T	I	Yes	N	I	0
Montello	1991	42	18	22.5	P	R	RT	Le	NA	U	O	No	F	I	0.13
Montello	1991	42	18	22.5	P	R	De	Le	NA	U	O	No	F	I	0.33
Montello et al	1999	36	43	47	M	R	A	Le	Le	U	O	No	N	I	-0.22
Montello et al	1999	36	43	47	M	R	D	Le	Le	U	O	No	N	I	-0.09
Montello et al	1999	36	43	47	M	R	D	Le	Le	U	O	No	N	I	-0.04
Montello et al	1999	36	43	47	M	R	A	Le	Le	U	O	No	N	I	0
Montello et al	1999	36	43	47	M	R	D	Le	Le	U	O	No	N	I	0.04
Montello et al	1999	36	43	47	M	R	A	Le	Le	U	O	No	N	I	0.09
Montello et al	1999	36	43	47	M	R	A	Le	Le	U	O	No	N	I	0.2
Montello et al	1999	36	43	47	M	R	De	Le	Le	U	O	No	N	I	0.23
Montello et al	1999	36	43	47	M	R	D	Le	Le	U	O	No	N	I	0.58
Montello et al	1999	36	43	47	M	R	De	Le	Le	U	O	No	N	I	0.68
Montello et al	2016	24	24	20	P	R	RT	Le	NA	U	I	No	Le	I	-0.22
Montello et al	2016	24	24	20	P	R	De	Le	NA	U	I	No	Le	I	1.14

Montello & Pick	1993	13	11	20	P	R	De	Le	NA	U	B	Yes	Le	I	0.31
Montello & Pick	1993	13	11	20	P	R	De	Le	NA	U	B	Yes	Le	I	0.37
Montello & Pick	1993	13	11	20	P	R	RT	Le	NA	U	B	Yes	Le	I	0.5
Montello & Pick	1993	13	11	20	P	R	RT	Le	NA	U	B	Yes	Le	I	0.84
Montello & Pick	1993	13	11	20	P	R	RT	Le	NA	U	B	Yes	Le	I	1.17
Montello & Pick	1993	12	10	20	P	R	De	Le	NA	U	B	Yes	Le	I	1.5
Munzer & Stahl	2011	13	13	24.5	Le	S	A	Le	Le	U	I	Yes	N	I	0
Munzer & Stahl	2011	13	13	24.5	Le	S	A	Le	Le	U	I	Yes	N	I	0.22
Munzer & Stahl	2011	13	13	24.5	Le	S	A	Le	Le	U	I	Yes	N	I	0.4
Munzer & Stahl	2011	13	13	24.5	Le	S	A	Le	Le	U	I	Yes	N	I	0.56
Munzer & Stahl	2011	13	13	24.5	Le	R	A	Le	Le	U	I	Yes	N	I	-0.2
Munzer & Stahl	2011	13	13	24.5	Le	R	RT	Le	Le	U	I	Yes	N	I	0.17
Munzer & Stahl	2011	13	13	24.5	Le	R	A	Le	Le	U	I	Yes	N	I	0.35
Munzer & Stahl	2011	13	13	24.5	Le	R	A	Le	Le	U	I	Yes	N	I	0.53
Munzer & Stahl	2011	13	13	24.5	Le	R	A	Le	Le	U	I	Yes	N	I	0
Munzer & Stahl	2011	13	13	24.5	Le	R	A	Le	Le	U	I	Yes	N	I	0.31
Munzer & Stahl	2011	13	13	24.5	Le	R	A	Le	Le	U	I	Yes	N	I	0.44
Munzer & Stahl	2011	13	13	24.5	Le	R	RT	Le	Le	U	I	Yes	N	I	0.53
Munzer et al	2012	14	14	17.7	V	R	A	Le	Le	U	O	Yes	N	I	0.39
Munzer et al	2012	12	12	17.1	V	R	A	Le	Le	U	O	Yes	N	I	0.21
Munzer et al	2012	12	12	17.1	V	R	A	Le	Le	U	O	Yes	N	I	0.63
Munzer et al	2012	14	14	17.7	M	R	A	Le	Le	U	O	Yes	N	I	1.27
Munzer et al	2012	14	14	17.7	C	R	A	Le	Le	U	O	Yes	N	I	0.43
Munzer et al	2012	14	14	17.7	P	R	De	Le	NA	U	O	NR	Le	I	0.41
Munzer et al	2012	14	14	17.7	P	R	De	Le	NA	U	O	NR	Le	I	1.01
Munzer et al	2012	14	14	17.7	P	R	De	Le	NA	U	O	NR	Le	I	0.81
Munzer et al	2012	12	12	17.1	P	R	De	Le	NA	U	O	NR	Le	I	0.28
Munzer et al	2012	12	12	17.1	P	R	De	Le	NA	U	O	NR	Le	I	1.1
Munzer et al	2012	14	14	17.7	M	R	A	Le	NA	U	O	NR	Le	I	0.35
Munzer et al	2012	14	14	17.7	M	R	A	Le	NA	U	O	NR	Le	I	0.86
Munzer et al	2012	14	14	17.7	M	R	A	Le	NA	U	O	NR	Le	I	0.08
Munzer et al	2012	12	12	17.1	M	R	A	Le	NA	U	O	NR	Le	I	-0.22

Munzer et al	2012	12	12	17.1	M	R	A	Le	NA	U	O	NR	Le	I	0.9
Munzer et al	2012	14	14	17.7	R	R	A	Le	NA	U	O	NR	Le	I	0.5
Munzer et al	2012	14	14	17.7	R	R	A	Le	NA	U	O	NR	Le	I	0.29
Munzer et al	2012	14	14	17.7	R	R	A	Le	NA	U	O	NR	Le	I	0.55
Munzer et al	2012	12	12	17.1	R	R	A	Le	NA	U	O	NR	Le	I	-0.16
Munzer et al	2012	12	12	17.1	R	R	A	Le	NA	U	O	NR	Le	I	0.92
Nazareth et al	2018	54	51	12.1	P	R	De	Le	S	U	O	No	Le	I	0.11
Nazareth et al	2018	54	51	12.1	P	R	De	Le	S	U	O	No	Le	I	0.43
Nazareth et al	2018	35	55	20	P	R	De	Le	S	U	O	No	Le	I	0.37
Nazareth et al	2018	35	55	20	P	R	De	Le	S	U	O	No	Le	I	0.37
Nazareth et al	2018	25	45	20	P	R	De	Le	S	U	O	No	Le	I	0.45
Nazareth et al	2018	25	45	20	P	R	De	Le	S	U	O	No	Le	I	0.46
Nazareth et al	2018	54	51	12.1	La	R	A	Le	S	U	O	No	Le	I	0.04
Nazareth et al	2018	25	45	20	La	R	A	Le	S	U	O	No	Le	I	0.2
Nazareth et al	2018	35	55	20	La	R	A	Le	S	U	O	No	Le	I	0.4
Neidhart et al	2010	52	42	5.4	P	R	De	Le	NA	U	O	No	N	I	0.21
Neidhart et al	2010	20	19	7.8	P	R	De	Le	NA	U	O	No	N	I	0.09
Nelligan	2017	39	47	20.1	R	R	A	Le	F	T	I	No	Le	NA	0.62
Nelligan	2017	39	47	20.1	R	R	A	Le	F	T	I	No	Le	NA	0.72
Nelligan	2017	21	21	19.9	R	R	A	Le	F	T	I	No	Le	NA	0.27
Nelligan	2017	47	52	20	R	R	A	Le	F	T	I	No	Le	NA	0.52
Nelligan	2017	39	47	20.1	R	R	A	Le	Le	T	I	No	Le	NA	0.81
Nelligan	2017	39	47	20.1	R	R	A	Ba	Le	T	I	No	Le	NA	0.85
Nelligan	2017	39	47	20.1	R	R	A	Le	S	T	I	No	Le	NA	0.67
New et al	2007	45	41	35	P	R	De	Le	NA	U	O	No	Le	I	-0.53
Ngo et al	2015	25	25	23	R	R	A	Le	F	T	O	No	Le	I	0.49
Ngo et al	2015	25	25	23	R	R	A	Le	F	T	O	No	Le	I	0.64
Nori et al	2009	20	20	24.3	R	R	RT	Ba	Le	T	O	Yes	N	I	-0.16
Nori et al	2009	20	20	24.3	R	R	A	Ba	Le	T	O	Yes	N	I	-0.04
Nori et al	2009	20	20	24.3	R	R	RT	Ba	Le	T	O	Yes	N	I	0.24
Nowak & Moffat	2011	46	60	23	R	R	D	Le	F	U	I	Yes	N	I	0.4
Nowak & Moffat	2011	44	72	23	R	R	RT	Le	F	U	O	Yes	N	I	0.89

Nowak & Moffat	2011	49	62	23	R	R	D	Le	S	U	I	Yes	N	I	0.57
Nowak & Moffat	2011	43	36	23	R	R	A	Le	S	U	I	Yes	N	I	1.18
Nowak et al	2014	29	29	22.8	La	S	A	Le	F	T	I	Yes	N	I	0.18
Nowak et al	2014	29	29	22.8	La	S	A	Le	F	T	I	Yes	N	I	0.36
Nowak et al	2014	29	29	22.8	R	R	D	Le	S	T	I	Yes	N	I	0.43
Nowak et al	2014	29	29	22.8	R	R	D	Le	S	T	I	Yes	N	I	0.5
Nowak et al	2014	29	29	22.8	R	R	A	Le	S	T	I	Yes	N	I	1
Nowak et al	2014	29	29	22.8	R	R	D	Le	S	T	I	Yes	N	I	1.09
Oberholzer	2017	5	8	24	V	R	A	Le	Le	U	O	No	N	L	-0.62
Oberholzer	2017	6	10	24	V	R	A	Le	Le	U	O	No	N	I	0.33
Oberholzer	2017	6	10	24	V	R	De	Le	Le	U	O	No	N	I	0.41
Oberholzer	2017	6	9	24	V	R	RT	Le	Le	U	O	No	N	I	0.43
Oberholzer	2017	5	8	24	V	R	De	Le	Le	U	O	No	N	L	0.79
Oberholzer	2017	5	11	24	M	R	A	Le	Le	U	O	No	N	I	-0.25
Oberholzer	2017	4	11	24	M	R	De	Le	Le	U	O	No	N	L	-0.05
Oberholzer	2017	5	11	24	M	R	RT	Le	Le	U	O	No	N	I	0.07
Oberholzer	2017	4	10	24	M	R	A	Le	Le	U	O	No	N	L	0.12
Oberholzer	2017	4	10	24	M	R	De	Le	Le	U	O	No	N	I	0.51
Ohnishi et al	2006	14	14	27.3	R	R	A	Le	NA	U	I	No	N	I	-0.17
Ohnishi et al	2006	14	14	27.3	R	R	A	Le	NA	U	I	No	N	I	-0.08
Padgitt & Hund	2012	40	44	20.2	V	R	A	NA	Le	U	I	No	N	I	0.43
Padgitt & Hund	2012	40	44	20.2	V	R	RT	NA	Le	U	I	No	N	I	0.43
Padilla et al	2017	54	54	23	R	R	A	NA	NA	U	O	No	N	I	0.48
Padilla et al	2017	54	54	23	R	R	A	NA	NA	U	O	No	N	I	0.32
Pazzaglia & Taylor	2007	24	27	20	P	B	A	NA	Le	U	O	No	Le	I	0.18
Pazzaglia & Taylor	2007	24	27	20	M	B	A	NA	Le	U	O	No	Le	I	0.3
Pazzaglia & Taylor	2007	24	27	20	M	B	A	NA	Le	U	O	No	Le	I	0.6
Pazzaglia & Taylor	2007	24	27	20	R	B	A	Le	Le	U	O	No	Le	I	0.52
Pingel	2010	28	37	19.8	R	B	D	Le	F	U	O	No	F	I	0.62
Piper et al	2011	151	136	36.5	R	R	D	Le	S	T	O	No	Le	I	0.3
Piper et al	2011	151	136	36.5	R	R	D	Le	S	T	O	No	Le	I	0.39
Postma	2012	59	56	50	R	R	D	Le	S	U	O	No	N	I	0.43

Purser	2012	38	29	8.1	Le	R	A	Le	Le	U	I	No	N	I	-0.42
Purser	2012	38	29	8.16	Le	R	A	Le	Le	U	I	No	N	I	-0.28
Purser	2014	19	20	8.87	Le	R	A	Le	Le	U	I	No	N	I	-0.28
Purser	2014	19	20	8.87	Le	R	A	Le	Le	U	I	No	N	I	-0.13
Rahman et al	2017	44	43	36	C	R	RT	Le	S	U	W	Yes	Le	I	0.82
Rahman et al	2017	44	43	36	C	R	De	Le	S	U	W	Yes	Le	I	1.38
Rahman et al	2017	44	43	36	R	R	D	Le	S	T	W	Yes	Le	I	-0.5
Rahman et al	2017	44	43	36	R	R	D	Le	S	U	W	Yes	Le	I	0.36
Rahman et al	2017	44	43	36	R	R	De	Le	S	U	W	Yes	Le	I	0.53
Rahman et al	2017	44	43	36	R	R	A	Le	S	U	W	Yes	Le	I	0.68
Rahman et al	2017	44	43	36	R	R	A	Le	S	T	W	Yes	Le	I	0.74
Rahman et al	2017	44	43	36	R	R	RT	Le	S	U	W	Yes	Le	I	0.76
Richardson et al	2011	15	17	22.9	P	R	De	Le	NA	U	I	No	N	I	0.44
Richardson et al	2011	15	17	22.9	P	R	RT	Le	NA	U	I	No	N	I	0.57
Richardson et al	2011	15	17	22.9	P	R	De	Le	NA	U	I	No	N	I	1.57
Richardson et al	2011	20	20	20.7	P	R	RT	Le	NA	U	O	No	N	I	-0.62
Richardson et al	2011	20	20	20.7	P	R	De	Le	NA	U	O	No	N	I	-0.15
Richardson et al	2011	20	20	20.7	P	R	RT	Le	NA	U	O	No	N	I	0.01
Richardson et al	2011	20	20	20.7	P	R	De	Le	NA	U	O	No	N	I	1.18
Richardson et al	1999	9	11	22.5	P	S	De	Le	NA	U	I	No	Le	I	0.78
Richardson et al	1999	9	11	22.5	P	B	De	Le	NA	U	I	No	Le	I	0.97
Richardson et al	1999	10	11	22.5	P	R	De	Le	NA	U	I	No	Le	I	-0.63
Richardson et al	1999	10	11	22.5	P	R	De	Le	NA	U	I	No	Le	I	0.97
Richardson et al	1999	11	9	22.5	P	R	De	Le	NA	U	I	No	Le	I	0.09
Richardson et al	1999	11	9	22.5	P	R	De	Le	NA	U	I	No	Le	I	0.38
Rizk-Jackson	2006	14	13	30.3	R	R	A	Le	S	T	O	No	Le	I	0.72
Rizk-Jackson	2006	14	13	30.3	R	R	A	Le	S	T	O	No	Le	I	1.24
Rizk-Jackson	2006	14	13	30.3	R	R	A	Le	S	T	O	No	Le	I	1.35
Rizk-Jackson	2006	14	13	30.3	R	R	RT	Le	S	T	O	No	Le	I	1.52
Rizk-Jackson	2006	14	13	30.3	R	R	RT	Le	S	T	O	No	Le	I	1.69
Rodgers et al	2012	40	46	53	R	R	D	Le	S	U	I	No	Le	I	0.12
Rodgers et al	2012	40	46	53	R	R	RT	Le	S	U	I	No	Le	I	0.19

Rodgers et al	2012	40	46	53	R	R	D	Le	S	U	I	No	Le	I	0.36
Ruddle et al	2011	28	28	27	Le	R	A	Le	Le	U	O	No	Le	I	-0.04
Ruddle et al	2011	28	28	27	Le	R	A	Le	Le	U	O	No	Le	I	0.16
Ruddle et al	2011	18	18	25	Le	R	A	Le	Le	U	O	No	Le	I	0.2
Sadalla & Montello	1989	21	25	20	P	R	De	NA	NA	U	I	No	Le	I	0
Sadalla & Montello	1989	21	25	20	P	R	De	NA	NA	U	I	No	Le	I	0.11
Sadalla & Montello	1989	21	25	20	P	R	De	NA	NA	U	I	No	Le	I	0.16
Sandberg et al	2001	19	17	6.5	M	B	A	Le	F	U	I	No	N	I	0.06
Sandberg et al	2001	19	17	6.5	R	B	A	Le	S	U	I	No	N	I	0
Sandstrom et al	1998	8	8	22	R	R	RT	Le	F	U	I	No	N	I	0
Sandstrom et al	1998	24	24	22	R	R	RT	Le	F	U	I	No	N	I	0
Sandstrom et al	1998	24	24	22	R	R	RT	Le	F	U	I	No	N	I	0.75
Sandstrom et al	1998	24	24	22	R	R	RT	Le	F	U	I	No	N	I	1.06
Sandstrom et al	1998	8	8	22	R	R	RT	Le	F	U	I	No	N	I	1.4
Sandstrom et al	1998	8	8	22	R	R	RT	Le	F	U	I	No	N	I	1.44
Sargent	2017	106	102	45	La	R	A	Le	NA	U	O	No	N	I	0.09
Saucier et al	2002	20	22	20.2	V	R	A	Le	Le	U	I	Yes	N	I	0.8
Schinazi et al	2013	9	7	22	P	R	De	Le	Le	U	O	No	Le	I	0
Schinazi et al	2013	9	7	22	P	R	De	Le	Le	U	O	No	Le	I	1.73
Schinazi et al	2013	9	7	22	M	R	A	Le	Le	U	O	No	Le	I	0
Schinazi et al	2013	9	7	22	D	R	D	Le	Le	U	O	No	Le	I	0
Schmitz	1997	54	45	10	R	R	A	Le	NA	U	I	No	Le	I	0.24
Schmitz	1997	54	45	13.5	R	R	RT	Le	NA	U	I	No	N	I	0.98
Schmitz	1999	15	17	30	R	R	A	Le	NA	U	I	No	N	I	0
Schmitz	1999	15	17	30	R	R	RT	Le	NA	U	I	No	N	I	0.7
Schmitz	1999	15	17	30	R	R	A	Le	NA	U	I	No	Le	I	0.9
Schmitzer-Torbert	2007	22	23	19.3	R	R	A	Le	F	U	I	Yes	Le	I	0.94
Schmitzer-Torbert	2007	22	23	19.3	R	R	A	Le	F	U	I	Yes	Le	I	1.44
Schmitzer-Torbert	2007	30	38	19.6	R	R	A	Le	F	U	I	No	Le	I	0.46
Schmitzer-Torbert	2007	30	38	19.6	R	R	A	Le	F	U	I	No	Le	I	0.7
Schmitzer-Torbert	2007	30	38	19.6	R	R	A	Le	F	U	I	No	Le	I	1.09
Schoenfeld	2010	29	29	38.8	P	R	De	Le	NA	U	O	No	Le	I	0.09

Schoenfeld	2010	29	29	38.8	La	R	A	Le	NA	T	O	No	Le	I	0.76
Sensibaug	2017	51	59	20	P	R	De	Le	NA	U	O	No	Le	I	0.36
Sensibaug	2017	51	59	20	P	R	De	Le	NA	U	O	No	Le	I	0.38
Sensibaug	2017	51	59	20	La	R	A	Le	NA	U	O	No	Le	I	0
Shore et al	2001	10	10	20	R	R	A	Le	NA	U	I	No	Le	I	0.94
Shore et al	2001	10	10	20	R	R	A	Le	NA	U	I	No	Le	I	0.94
Silverman et al	2000	46	65	21.9	P	R	De	Le	NA	U	O	No	Le	I	0.3
Silverman et al	2000	81	105	21.9	Le	R	RT	Ba	NA	U	I	No	Le	I	0.31
Silverman et al	2000	46	65	21.9	R	R	A	Ba	NA	U	O	No	Le	I	0.48
Silverman et al	2000	46	65	21.9	Le	R	D	Ba	S	U	O	No	Le	I	0.45
Sjölinder et al	2005	6	6	25.5	R	R	D	Le	NA	U	I	No	Le	I	-0.55
Sjölinder et al	2005	6	6	25.5	R	R	De	Le	NA	U	I	No	Le	I	-0.33
Sjölinder et al	2005	6	6	25.5	R	R	D	Le	NA	U	I	No	Le	I	-0.33
Sjölinder et al	2005	6	6	25.5	R	R	RT	Le	NA	U	I	No	Le	I	0.4
Sjölinder et al	2005	6	6	25.5	R	R	De	Le	NA	U	I	No	Le	I	0.01
Sjölinder et al	2005	6	6	25.5	R	R	D	Le	NA	U	I	No	Le	I	0.13
Sjölinder et al	2005	6	6	25.5	R	R	D	Le	NA	U	I	No	Le	I	0.2
Sjölinder et al	2005	6	6	25.5	R	R	RT	Le	NA	U	I	No	Le	I	0.22
Sjölinder et al	2005	6	6	66.8	R	R	D	Le	NA	U	I	No	Le	I	-0.29
Sjölinder et al	2005	6	6	66.8	R	R	D	Le	NA	U	I	No	Le	I	-0.19
Sjölinder et al	2005	6	6	66.8	R	R	De	Le	NA	U	I	No	Le	I	-0.1
Sjölinder et al	2005	6	6	66.8	R	R	RT	Le	NA	U	I	No	Le	I	0.53
Sjölinder et al	2005	6	6	66.8	R	R	D	Le	NA	U	I	No	Le	I	-0.65
Sjölinder et al	2005	6	6	66.8	R	R	De	Le	NA	U	I	No	Le	I	0.34
Sjölinder et al	2005	6	6	66.8	R	R	D	Le	NA	U	I	No	Le	I	0.36
Sjölinder et al	2005	6	6	66.8	R	R	RT	Le	NA	U	I	No	Le	I	0.56
Sugimoto & Kusumi	2014	26	18	21	M	S	A	NA	NA	U	O	No	N	I	-0.17
Sugimoto & Kusumi	2014	26	18	21	M	R	A	NA	NA	U	O	No	N	I	-0.07
Tan et al	2006	15	17	40.8	Le	R	RT	Le	S	U	O	No	Le	I	0.86
Tang et al	2009	68	39	31	R	R	RT	NA	NA	U	I	No	N	I	0.99
Tippett et al	2009	12	12	70	Le	R	RT	Le	NA	U	O	No	Le	S	0.27
Tippett et al	2009	12	12	70	R	R	RT	Le	NA	T	O	Yes	Le	S	0.91

Tippett et al	2009	12	12	70	R	R	RT	Le	NA	T	O	Yes	Le	S	1.02
Tlauka et al	2005	16	16	22.5	M	B	A	Le	Le	T	I	Yes	Le	I	0.88
Tlauka et al	2005	16	16	22.5	M	B	RT	Le	Le	T	I	Yes	Le	I	1.34
Tlauka et al	2005	16	16	22.5	P	B	De	Le	NA	U	I	Yes	Le	I	0.64
Tlauka et al	2005	16	16	22.5	P	B	RT	Le	NA	U	I	Yes	Le	I	0.71
Tlauka et al	2005	16	16	22.5	M	B	A	Le	NA	U	I	Yes	Le	I	0.62
Tlauka et al	2005	16	16	22.5	Le	B	RT	Le	NA	T	I	Yes	Le	I	0.62
Tlauka et al	2005	16	16	22.5	Le	B	RT	Ba	NA	U	I	Yes	Le	I	0.65
Tlauka et al	2005	16	16	22.5	D	B	D	Le	NA	U	I	Yes	Le	I	0.5
van Gerven et al	2012	17	19	20	La	R	A	Le	F	U	I	Yes	N	I	0.15
van Gerven et al	2012	17	19	20	La	R	A	Le	F	U	I	Yes	N	I	0.58
van Gerven et al	2012	17	19	20	La	R	A	Le	F	U	I	Yes	N	I	1.02
van Gerven et al	2012	17	19	20	R	R	A	Le	F	U	I	Yes	N	I	0
van Gerven et al	2012	17	19	20	R	R	A	Le	F	U	I	Yes	N	I	0
van Gerven et al	2012	17	19	20	R	R	A	Le	F	U	I	Yes	N	I	0.28
van Gerven et al	2012	17	19	20	R	R	A	Le	F	U	I	Yes	N	I	0.56
van Gerven et al	2012	17	19	20	R	R	A	Le	F	U	I	Yes	N	I	0.67
van Gerven et al	2012	17	19	20	R	R	D	Le	F	U	I	Yes	N	I	0.77
van Gerven et al	2012	17	19	20	R	R	RT	Le	F	U	I	Yes	N	I	1.15
van Gerven et al	2012	17	19	20	R	R	A	Le	F	U	I	Yes	N	I	1.19
van Gerven et al	2012	17	19	20	R	R	RT	Le	F	U	I	Yes	N	I	1.63
van Gerven et al	2012	17	19	20	R	R	D	Le	S	U	I	Yes	N	I	0.52
van Gerven et al	2012	17	19	20	R	R	RT	Le	S	U	I	Yes	N	I	1.4
Vashro & Cashdan	2014	49	51	30	P	R	De	Le	S	U	O	No	F	I	0.52
Vashro et al	2015	61	57	30	P	R	De	Le	S	U	O	No	F	I	0.48
Ventura et al	2013	129	194	20	R	R	RT	Le	NA	T	I	No	Le	I	1
Ventura et al	2013	129	194	20	R	R	RT	Le	NA	T	O	No	Le	I	0.81
Verdine	2011	20	40	24.6	P	R	De	Le	S	U	O	No	Le	I	-0.32
Verdine	2011	20	40	24.6	P	B	De	Le	S	U	O	No	Le	I	0.6
von Stülpnagel et al	2013	43	39	23.0	P	R	De	Le	NA	U	O	No	Le	I	0
von Stülpnagel et al	2013	43	39	23.0	M	R	A	Le	NA	U	O	No	Le	I	0
von Stülpnagel et al	2013	43	39	23.0	La	R	A	Le	NA	U	O	No	Le	I	0

von Stülpnagel et al	2013	43	39	23.0	Le	R	RT	Le	S	U	O	No	Le	I	0.68
Waller & Greenauer	2007	42	42	19.1	P	R	De	Ba	F	U	I	No	Le	S	0.44
Waller & Greenauer	2007	42	42	19.1	La	R	A	Ba	F	U	I	No	Le	S	-0.1
Waller & Greenauer	2007	42	42	19.1	D	R	D	Ba	F	U	I	No	Le	S	0.37
Waller et al.	2001	12	12	20.1	P	R	De	NA	NA	U	I	No	Le	L	1.09
Waller et al.	2001	12	12	20.1	P	R	De	NA	NA	U	I	No	Le	L	1.79
Wang et al	2014	24	24	20	Le	R	A	Ba	Le	U	O	No	Le	I	0.04
Wang et al	2014	24	24	20	Le	R	A	Ba	Le	U	O	No	Le	I	0.04
Wang et al	2014	24	24	20	Le	R	A	Ba	Le	U	O	No	Le	I	-0.15
Wang et al	2014	24	24	20	Le	R	A	Ba	Le	U	O	No	Le	I	0.22
Ward et al.	1986	72	72	19	V	R	A	NA	NA	U	O	No	Le	I	0.48
Watson	1999	88	88	45	C	R	De	NA	NA	U	I	No	Le	NA	0.7
Watson	1999	88	88	45	R	R	A	Le	S	U	I	No	Le	NA	0.35
Weisberg/Newcombe	2014	19	26	20.8	P	R	De	Le	NA	U	O	No	Le	I	-0.1
Weisberg/Newcombe	2014	26	26	20	P	R	De	Le	NA	U	O	No	Le	I	-0.21
Weisberg/Newcombe	2014	19	26	20.8	La	R	A	Le	NA	U	O	No	Le	I	-0.04
Weisberg/Newcombe	2014	26	26	20	La	R	A	Le	NA	U	O	No	Le	I	0.28
Weisberg et al	2017	21	27	21.7	R	R	A	Le	Le	U	I	No	N	I	-0.46
Weisberg et al	2017	21	27	21.7	P	R	De	Le	NA	U	I	No	N	I	-0.29
Weisberg et al	2017	21	27	21.7	M	R	A	Le	NA	U	I	No	N	I	-0.27
Weisberg et al	2016	124	167	20	P	R	De	Le	NA	U	O	No	Le	I	0.42
Weisberg et al	2016	124	167	20	P	R	De	Le	NA	U	O	No	Le	I	0.54
Weisberg et al	2016	124	167	20	P	R	De	Le	NA	U	O	No	Le	I	0.55
Weisberg et al	2016	124	167	20	La	R	A	Le	NA	U	O	No	Le	I	0.27
Wenczel et al	2017	13	10	24.7	La	R	A	Le	Le	T	O	No	N	I	0.69
Wenczel et al	2017	13	10	24.7	La	R	A	Le	Le	T	O	No	N	I	1.45
Wiener & Mallot	2003	10	15	20	Le	R	A	Le	S	U	O	NR	Le	I	0.5
Wiener & Mallot	2003	16	14	20	Le	R	A	Le	S	U	O	NR	Le	I	0.85
Wiener & Mallot	2003	10	11	20	R	R	A	Le	S	U	O	NR	Le	I	0
Wiener & Mallot	2003	10	11	20	R	R	A	Le	S	U	O	NR	Le	I	0.18
Wiener & Mallot	2003	16	14	20	R	R	A	Le	S	U	O	NR	Le	I	0.66
Wiener et al	2013	24	23	47.3	Le	R	A	Le	Le	U	I	No	Le	I	0.03

Wiener et al	2012	21	19	35	P	R	A	Le	NA	U	I	No	Le	I	0.13
Wiener et al	2004	15	15	23.2	Le	R	D	NA	F	U	O	No	Le	I	0.46
Wiener et al	2004	15	15	23.2	R	R	D	NA	F	U	O	No	Le	I	0.69
Wiener et al	2004	20	20	24	Le	R	D	Le	S	U	O	No	Le	I	1.05
Wiener et al	2004	22	22	24.5	R	R	D	NA	S	U	O	No	N	I	0.48
Wiener et al	2004	20	20	24	R	R	D	Le	S	U	O	No	Le	I	0.35
Yasen et al	2015	81	88	20	R	R	RT	Le	S	T	O	Yes	Le	I	0.36
Yasen et al	2015	81	88	20	R	R	RT	Le	S	T	O	Yes	Le	I	0.58
Yuan et al	2014	47	93	48.5	R	R	D	Le	F	U	I	Yes	N	I	0.39
Yuan et al	2014	47	93	48.5	R	R	RT	Le	F	U	I	Yes	N	I	0.43
Yuan et al	2014	47	93	48.5	R	R	RT	Le	F	U	I	Yes	N	I	0.46
Yuan et al	2014	47	93	48.5	R	R	D	Le	F	U	I	Yes	N	I	0.55
Zancada et al	2015	11	49	40	La	R	A	Le	NA	U	O	No	Le	I	0.35
Zancada et al	2015	11	49	40	La	R	A	Le	NA	U	O	No	Le	I	0.5
Zancada et al	2015	11	49	40	La	R	A	Le	NA	U	O	No	Le	I	0.5
Zancada et al	2015	11	49	40	La	R	A	Le	NA	U	O	No	Le	I	0.63
Zancada et al	2015	11	49	40	R	R	A	Le	NA	U	O	No	Le	I	0.07
Zancada et al	2015	11	49	40	R	R	A	Le	NA	U	O	No	Le	I	0.19
Zancada et al	2015	11	49	40	R	R	D	Le	NA	U	O	No	Le	I	0.21
Zancada et al	2015	11	49	40	R	R	RT	Le	NA	U	O	No	Le	I	0.22
Zhong	2013	38	33	22.3	P	R	De	Le	Le	U	B	No	Le	I	0.38
Zhong	2013	38	33	22.3	P	R	De	Le	Le	U	B	No	Le	I	0.74
Zwergal et al	2016	12	12	54	R	R	A	Le	S	T	I	No	N	I	-0.45
Zwergal et al	2016	12	12	54	R	R	A	Le	S	T	I	No	N	I	0.84

Note: *Note:* Year = year of publication; *N*m = number of males; *N*f = number of females; Age = mean age of the sample; Task: R = Recall/recognition, C = Cardinal directions, La = Landmark position, P = Pointing, M = Map, D = Distance, Le = Learning, V = Verbal instruction; Per = Perspective: S = Survey, R = Route, B = Both; Out = Outcome variable: A = Accuracy, D = Distance, De = Deviation, RT =

Response time; Dir = Route direction: Le = Learned, B = Backward; Sel = Route selection: S = Shortcut, F = Free choice, Le = Learned; Time = Timing condition: T = Timed, U = Untimed; Env = Environment: O = Outdoor, I = Indoor, B = Both, W = Water maze; Fee = Feedback; Fam = Familiarity: F = Familiar, N = New, Le = Learned; Int = Learning interval: I = Immediate, S = Short, L = Long. In all cases, NA = Not applicable. An asterisk (*) after the *d* denotes an effect that would be considered an outlier based on the criteria proposed by Tabachnick and Fidell (2007). Apparent duplication of entries is accounted for by the coding of moderators that were not significant in the analysis or not analyzed.

Table 3

Summary for Significant Moderators in the Overall Meta-analysis

Moderator	Sample size (*k*)	Estimated mean *d*	95% confidence interval
Task Goal			
Pointing	122	0.365	0.294, 0.436
Recall/Recognition	298	0.386	0.332, 0.439
Cardinal directions	18	0.441	0.160, 0.722
Distance	14	0.229	0.140, 0.318
Landmark Position	36	0.285	0.176, 0.393
Maps	62	0.349	0.207, 0.491
Verbal Instructions	32	0.219	0.102, 0.335
Learning	112	0.247	0.164, 0.329
Outcome Measure			
Accuracy	326	0.307	0.254, 0.359
Deviation	123	0.440	0.375, 0.505
Distance	96	0.250	0.169, 0.331
Response time	149	0.388	0.302, 0.473
Timing Conditions			
Untimed	583	0.315	0.268, 0.362
Timed	111	0.459	0.347, 0.572
Environment			
Indoor	336	0.332	0.275, 0.389
Outdoor	329	0.336	0.283, 0.389
Indoor-Outdoor	12	0.546	0.383, 0.709
Water maze	17	0.488	0.380, 0.596
Age categories			
Below 13	69	0.145	0.055, 0.244
13 to 17	24	0.577	0.351, 0.803
18-29	489	0.365	0.317, 0.413
30-49	81	0.314	0.199, 0.430
50 and above	31	0.423	0.258, 0.588

Note: The table presents the number of effect sizes (*k*) and the mean weighted *d* for each moderator category with the 95% confidence interval (CI) in parentheses. The mean weighted effect size is significantly different from zero with $p < .05$ if the 95% CI for *d* does not include zero.

Table 4

Results of the Analysis for Perspective as a Moderator

		k	*d* (95% CI)
Task Goals	Categories		
Landmark Position	Route	30	0.29 (0.15,0.43)
	Survey	3	0.09 (-0.25,0.42)
	Both	3	-0.05 (-0.13,0.04)

Note: The table presents the number of effect sizes (*k*) and the mean weighted *d* for each moderator category with the 95% confidence interval (CI) in parentheses. The mean weighted effect size is significantly different from zero with $p < .05$ if the 95% CI for *d* does not include zero.

Table 5

Results of the Analysis for Outcome Measure as a Moderator

		Recall/Recognition	
Task Goal	Categories	*k*	*d* (95% CI)
Pointing	Accuracy	9	0.37 (0.16,0.58)
	Deviation	93	0.37 (0.28,0.46)
	Distance	2	0.22 (0.17,0.27)
	Response time	18	0.11 (-0.08,0.30)
Recall/Recognition	Accuracy	133	0.35 (0.27,0.43)
	Deviation	14	0.41 (0.20,0.63)
	Distance	60	0.28 (0.17,0.39)
	Response time	91	0.52 (0.42,0.63)
Cardinal Direction	Accuracy	9	0.57 (0.29,0.84)
	Deviation	4	0.69 (0.23,1.14)
	Response time	5	0.21 (-0.03,0.46)
Map	Accuracy	45	0.42 (0.21,0.63)
	Deviation	4	0.67 (0.39,0.95)
	Distance	8	0.23 (-0.29,0.74)
	Response time	5	0.40(-0.31,1.22)
Landmark Position	Accuracy	32	0.21 (0.08,0.33)
	Deviation	2	0.57 (0.45,0.69)
	Other	2*	0.77(-0.03,1.58)
Verbal Instructions	Accuracy	18	0.23 (0.02,0.43)
	Deviation	3	0.14 (-0.74,1.01)
	Distance	3	-0.27 (-0.57,0.03)
	Response time	8	0.23 (0.01,0.45)

Note: The table presents the number of effect sizes (*k*) and the mean weighted *d* for each moderator category with the 95% confidence interval (CI) in parentheses. The mean weighted effect size is significantly different from zero with $p < .05$ if the 95% CI for *d* does not include zero.

* Reflects one effect size each for distance and response time.

Table 6

Results of the Analysis for Route Direction as a Moderator

Task Goals	Categories	*k*	*d* (95% CI)
Pointing	Forward	102	0.33 (0.25,0.41)
	Backward	5	0.15 (-0.04,0.35)
	Not applicable	15	0.51 (0.30,0.71)
Verbal Instructions	Forward	29	0.12 (-0.04,0.27)
	Not applicable	3	0.45 (0.41,0.49)

Note: The table presents the number of effect sizes (*k*) and the mean weighted *d* for each moderator category with the 95% confidence interval (CI) in parentheses. The mean weighted effect size is significantly different from zero with $p < .05$ if the 95% CI for *d* does not include zero.

Table 7

Results of the Analysis for Route Selection as a Moderator

Task Goals	Categories	*k*	*d* (95% CI)
Cardinal Directions	Free choice	3	0.11 (-0.26,0.48)
	Exact way	2	0.46 (0.42,0.51)
	Shortcut	2	1.07 (0.70,1.44)
	Not applicable	11	0.53 (0.22,0.84)

Note: The table presents the number of effect sizes (*k*) and the mean weighted *d* for each moderator category with the 95% confidence interval (CI) in parentheses. The mean weighted effect size is significantly different from zero with $p < .05$ if the 95% CI for *d* does not include zero.

Table 8

Results of the Analysis for Timing Condition as a Moderator

Task Goals	Categories	*k*	*d* (95% CI)
Map	Untimed	57	0.37 (0.17,0.57)
	Timed	5	0.78 (0.51,1.05)
Verbal Instructions	Untimed	28	0.22 (0.07,0.38)
	Timed	4	-0.20 (-0.34,-0.06)

Note: The table presents the number of effect sizes (*k*) and the mean weighted *d* for each moderator category with the 95% confidence interval (CI) in parentheses. The mean weighted effect size is significantly different from zero with $p < .05$ if the 95% CI for *d* does not include zero.

Table 9

Results of the Analysis for Environment as a Moderator

Task Goals	Categories	*k*	*d* (95% CI)
Pointing	Indoor	50	0.36 (0.24,0.48)
	Outdoor	64	0.31 (0.22,0.40)
	Indoor-Outdoor	8	0.63 (0.51,0.75)
Cardinal Directions	Indoor	6	0.40 (0.04,0.76)
	Outdoor	10	0.50 (0.21,0.78)
	Water Maze	2	1.07 (0.72,1.42)

Note: The table presents the number of effect sizes (*k*) and the mean weighted *d* for each moderator category with the 95% confidence interval (CI) in parentheses. The mean weighted effect size is significantly different from zero with $p < .05$ if the 95% CI for *d* does not include zero.

Table 10

Results of the Analysis for Familiarity as a Moderator

Task Goals	Categories	*k*	*d* (95% CI)
Cardinal Direction	New	8	0.39 (0.13,0.47)
	Learned	8	0.58 (0.22,0.93)
	Familiar	2	1.09 (0.75,1.25)

Note: The table presents the number of effect sizes (*k*) and the mean weighted *d* for each moderator category with the 95% confidence interval (CI) in parentheses. The mean weighted effect size is significantly different from zero with $p < .05$ if the 95% CI for *d* does not include zero.

Table 11

Results of the Analysis for Feedback as a Moderator

Task Goals	Categories	*k*	*d* (95% CI)
Pointing	Immediate	9	0.59 (0.42,0.75)
	No-feedback	107	0.31 (0.23,0.39)
	Not reported	6	0.69 (0.49,0.88)
Map	Immediate	4	0.94 (0.81,1.07)
	No-feedback	53	0.38 (0.16,0.60)
	Not reported	5	0.37 (-0.01,0.79)

Note: The table presents the number of effect sizes (*k*) and the mean weighted *d* for each moderator category with the 95% confidence interval (CI) in parentheses. The mean weighted effect size is significantly different from zero with $p < .05$ if the 95% CI for *d* does not include zero.

Table 12

Results of the Analysis for Learning Interval as a Moderator

Task Goals	Categories	*k*	*d* (95% CI)
Recall/Recognition	Immediate	260	0.38 (0.32,0.45)
	Short	4	0.42 (-0.13,0.98)
	Long	2	0.04 (-0.14,0.23)
	Not applicable	32	0.41 (0.26,0.56)

Note: The table presents the number of effect sizes (*k*) and the mean weighted *d* for each moderator category with the 95% confidence interval (CI) in parentheses. The mean weighted effect size is significantly different from zero with $p < .05$ if the 95% CI for *d* does not include zero.

Table 13

Results of the Analysis for Age Categories as a Moderator

Task Goals	Categories	*k*	*d* (95% CI)
Pointing	Less than 13	6	0.12 (0.01,0.24)
	13 to 17	5	0.69 (0.41,0.97)
	18 to 29	100	0.37 (0.29,0.46)
	30 to 49	11	0.20 (-0.04,0.43)
Landmark Position	Less than 13	3	0.03 (0.001,0.05)
	18 to 29	14	0.27 (0.10,0.45)
	30 to 49	7	0.32 (0.09,0.55)

Note: The table presents the number of effect sizes (*k*) and the mean weighted *d* for each moderator category with the 95% confidence interval (CI) in parentheses. The mean weighted effect size is significantly different from zero with $p < .05$ if the 95% CI for *d* does not include zero.

Table 14

Summary of Results for Significant Moderators

Moderator	Significant on:	Comments
Perspective	Landmark Position	Only route view produced a significant male advantage, not survey or both combined.
Outcome Variable	Overall, Recall, Maps, Pointing, Cardinal Directions, Landmark Position, Verbal Instructions	Deviation measures generally larger than other scores, except on verbal. Aside from this finding, the specific pattern of difference among means varies depending on the task.
Route Direction	Pointing, Verbal	Significant male advantage found for retracing the learned route or when not applicable in pointing; not significant for learned route in verbal.
Route Selection	Cardinal Directions	Male advantage significant in all cases except for a free choice
Timing Conditions	Overall, Map, Verbal	Male advantage larger with timed rather than untimed conditions in overall and map, female advantage for timed in verbal
Environment	Overall, Pointing, Cardinal Directions	Sex effect significant in all categories. For pointing and overall, the "both" category produced larger effects than indoor and outdoor environments separately: for cardinal directions and overall, water maze also produced larger effects than

		single environments.
Familiarity	Cardinal Directions	Significant male advantage in all categories but larger for familiar than new locations.
Feedback	Maps, Pointing	Immediate feedback and "not reported" produced significantly larger effects than no feedback
Learning Interval	Recall	Immediate testing and studies where it was not relevant produced a significant male advantage, not longer time intervals.
Age Categories	Overall, Pointing, Landmark Position	Fine details vary across tasks but the <13 grouping tends to produce the smallest sex differences.

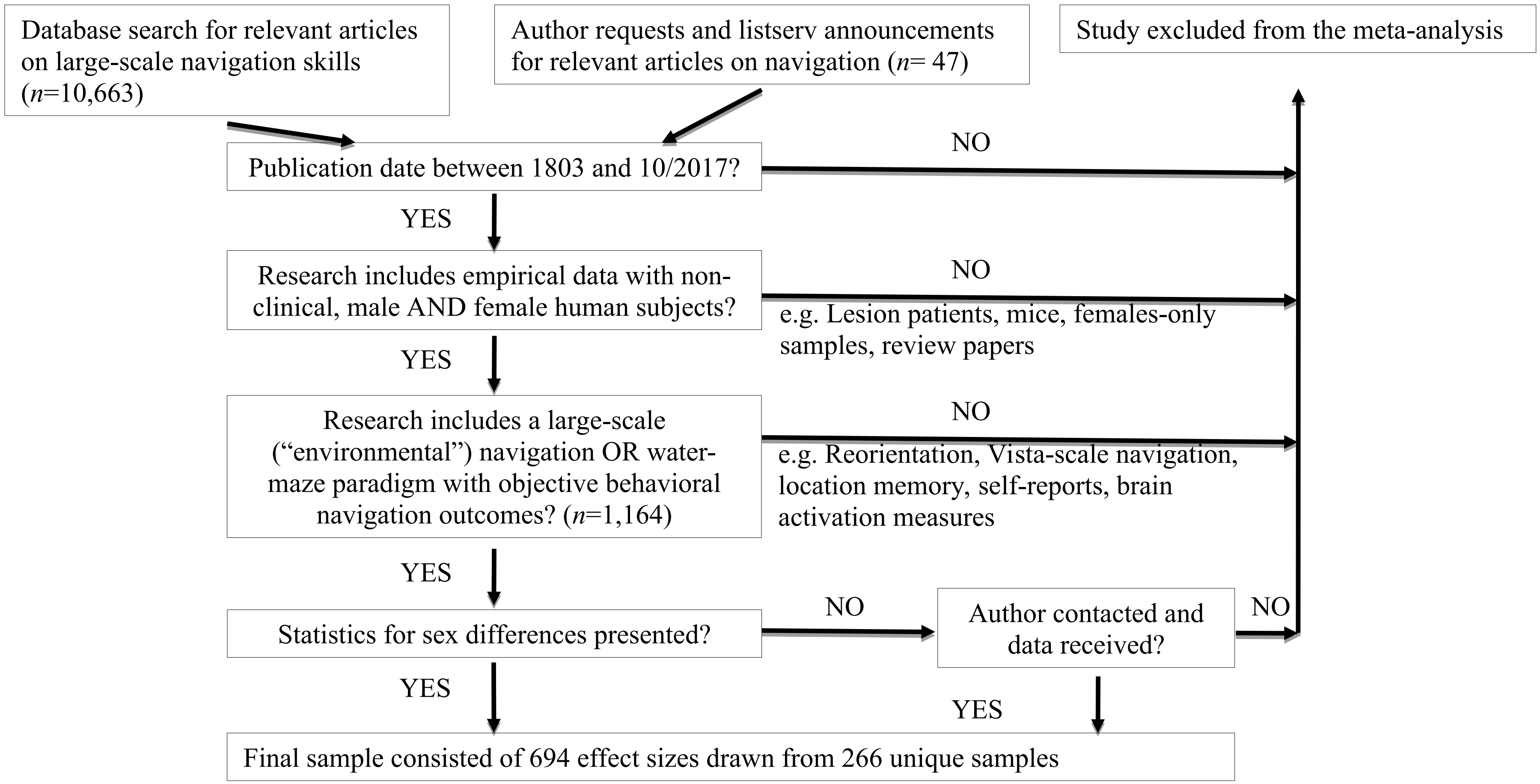

Figure 1. Flowchart illustrating the selection process of articles included in the meta-analysis.

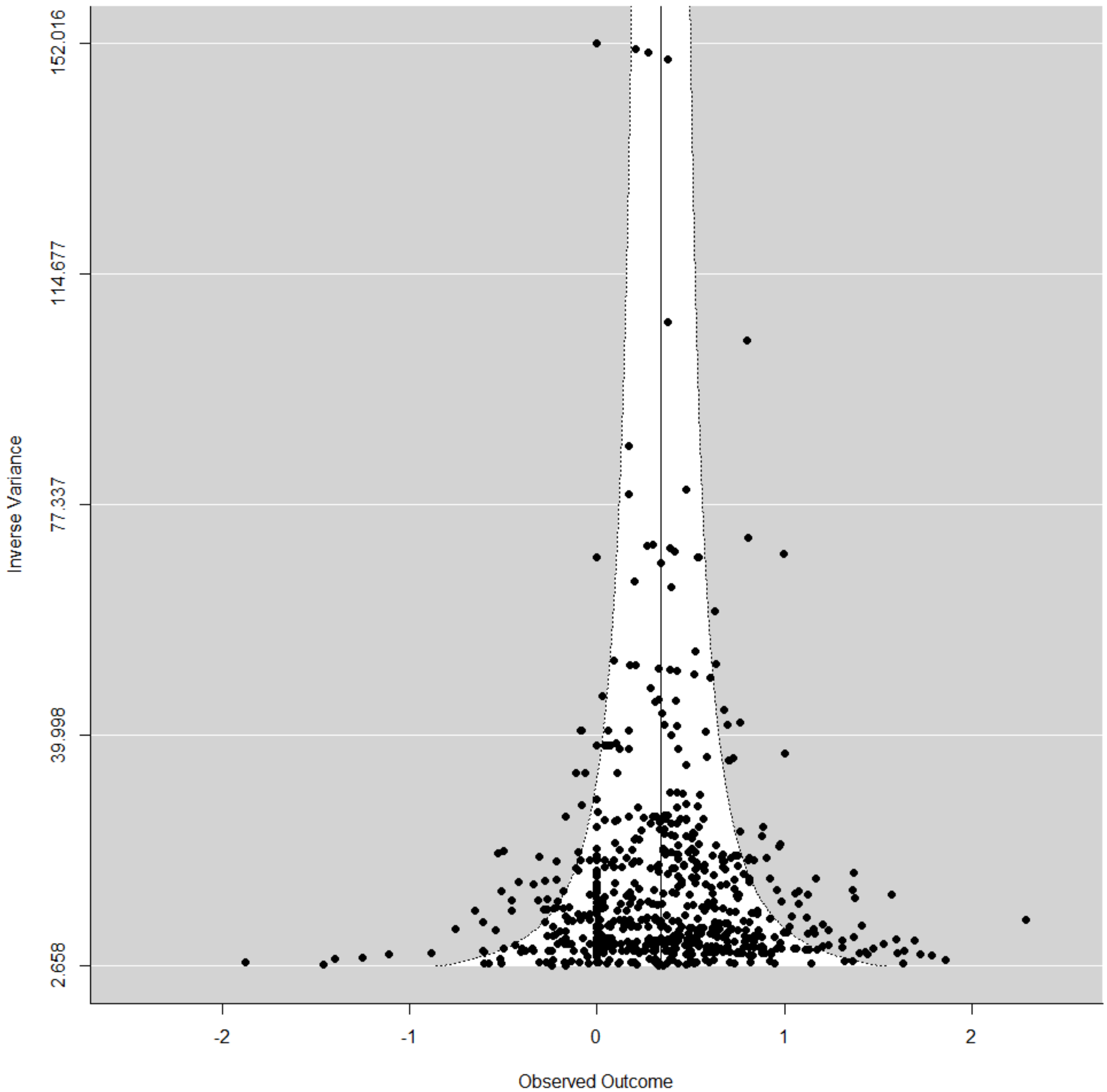

Figure 2. Funnel plot of precision (inverse variance) as a function of Cohen's *d* (observed outcome) for the whole sample.

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