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A Comparative Bayesian Meta-Analysis of Reaction Time-Based Tasks in Developmental Dyslexia

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Abstract

Dyslexic individuals exhibit slow reaction times (RTs) in Rapid Automatized Naming (RAN) tasks. Using hierarchical Bayesian meta-analysis, we asked whether slower processing in dyslexia extends beyond RAN to include RT-based motor-skills and nonverbal tasks (simple, choice, interference control). Following a systematic review, we identified studies comparing dyslexic and age-matched neurotypical groups on RT-based tasks. For RAN, we restricted study selection to letter-naming tasks (30 studies [k], 37 effects [m]), and found a large slowing effect in dyslexia (μ = 1.26). While slowing was also evident on motor-skills (k = 40, m = 100) and nonverbal RT-based tasks (k = 17, m = 43), effects were smaller in magnitude (μ = .58 for motor; μ = .42 for nonverbal RT) compared to RAN. Generalized slowing may be a nonspecific marker of developmental disorders including dyslexia, reflecting differences in neural connectivity and processing efficiency. Whether generalized slowing is implicated in poor reading requires examining variation in dyslexic cognitive profiles.

Keywords: dyslexia, reaction time, letter naming, rapid automatized naming, motor skills

Introduction

Developmental dyslexia is a neurodevelopmental disorder characterized by impaired phonological processing, which impedes learning of orthographic (spelling) patterns and the development of fluent and accurate word recognition and decoding skills (Seidenberg, 2017; Snowling, 2000). One task widely used to assess phonological processing in dyslexia is the Rapid Automatized Naming (RAN) task, where individuals name sets of familiar items (e.g., letters, digits, objects, or colors) as quickly and accurately as possible (Denckla, 1972; Fawcett & Nicolson, 1994). Performing a RAN task does not require any reading but relies on automaticity in retrieving phonological and articulatory representations of letter names, color names, and the like. In a meta-analysis examining RAN task performance in dyslexia (Araújo & Faísca, 2019), dyslexic groups exhibited slower naming speed when compared to age-matched neurotypical groups (d = 1.19, large effect), with similar findings across stimulus types (i.e., alphanumeric vs. pictures/colors). Deficits in RAN in dyslexia align with theoretical accounts emphasizing the importance of automaticity, control of attention, and executive functioning in the development of literacy skills (Smith-Spark & Gordon, 2022).

In addition to noting slow RAN performance in dyslexia, researchers have reported that some dyslexic individuals have difficulties performing motor skills that are largely routinized or automatic (Fawcett et al., 2001; Nicolson & Fawcett, 2011). Dyslexic individuals exhibit deficits relative to age-matched peers on a variety of nonverbal motor tasks, e.g., tapping fingers, inserting pegs into a grooved board, stringing beads, and copying shapes (Brookman et al., 2013; Fawcett et al., 2001; Niechwiej-Szwedo et al., 2017; Stanley & Watson, 1980). Such findings have led to interest in the role of the cerebellum, basal ganglia, and other subcortical structures in explaining these difficulties, and the question of whether differences in brain organization and functioning in dyslexia extend beyond the language network. Under the procedural deficit hypothesis, dyslexic individuals may show deficits in domain-general cognitive processes that underlie skill acquisition, sequence learning, and automaticity (Lum et al., 2013; Nicolson & Fawcett, 2011; Ullman et al., 2020). Support for this hypothesis comes from two meta-analyses: Obeid et al. (2022) found impaired motor skills in dyslexic groups compared to age-matched neurotypical comparison groups (d = .52, medium effect) while Rochelle and Talcott (2006) found impaired balance (d = .64, medium effect).

In the context of observed associations between motor coordination difficulties and dyslexia, researchers have suggested that poor procedural learning in dyslexia might contribute to generalized slowing, i.e., longer reaction times (RTs) across tasks (Stoodley & Stein, 2006). Aligning with this hypothesis, recent neuroimaging studies have linked reduced connectivity across cortical networks in dyslexic individuals with lesser degree of automaticity in performing routine tasks (Taskov & Dushanova, 2021) and with slower nonverbal processing speed (Horowitz-Kraus et al., 2023). In another study, dyslexic children showed decreased white matter tracts across the brain, which the authors linked to compromised reading skills (Lou et al., 2019). Taken together, these findings suggest that decreased density of white matter networks (i.e., neural underconnectivity) in dyslexia might extend beyond the language networks supporting phonological and orthographic processing, thereby influencing processing speed across disparate tasks.

This leads to the prediction that dyslexic groups will tend to respond more slowly than age-matched neurotypical

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groups across varied tasks. While the two prior meta-analyses of motor skills and balance in dyslexia included a variety of tasks (Obeid et al., 2022; Rochelle & Talcott, 2006), they did not focus specifically on time-based measures. Hence, this study aimed to synthesize existing literature, with a specific focus on timed responses. Some of the strongest evidence of generalized slowing in dyslexia would come from relatively simple non-verbal RT-based tasks (i.e., simple RT or choice RT tasks requiring button press responses to specific visual or auditory stimuli). This would be in keeping with in studies of generalized slowing in developmental language disorder utilizing RT-based tasks with minimal verbal demands (Kail, 1994; Zapparrata et al., 2023a). While the generalized slowing hypothesis has received some attention within the dyslexia literature, e.g., in studies using auditory choice RT paradigms (Nicholson, 1994), more of the dyslexia literature has used RT-based interference control tasks to study possible deficits in executive functioning (Smith-Spark & Gordon, 2022). While the interference control tasks used to study executive functioning in dyslexia are more complex than simple RT or choice RT tasks, these tasks often include baseline or congruent conditions suitable for extracting estimates of processing speed.

Research Objectives and Hypotheses

The current study aimed to investigate processing speed in developmental dyslexia across different task paradigms. For this aim, we conducted a systematic literature review to identify relevant studies, then ran separate hierarchical Bayesian meta-analyses for RAN tasks, time-based motor skills tasks (e.g., pegboard, bead-threading, drawing), and RT-based nonverbal tasks (simple RT, choice RT, interference control) to get estimates of mean differences in performance between dyslexic groups and age-matched neurotypical comparison groups (i.e., Hedges's *g*). After obtaining estimates of effect sizes for each task type, we used hierarchical Bayesian meta-regression analysis to determine whether effects were of similar magnitude for time-based motor tasks and nonverbal RT-based task paradigms as compared to the RAN tasks. We hypothesized that dyslexic groups would exhibit slow processing speed across task types, but that effects might be larger for RAN tasks requiring verbal responses, as compared to the motor-skills and nonverbal RT-based tasks utilizing button-press responses.

Method

The meta-analysis was preregistered in PROSPERO (Zapparrata et al., 2022). We conducted three systematic literature reviews using PROQUEST, ERIC EBSCO, and PubMed databases. To meet inclusion criteria, studies had to compare a group of dyslexic individuals with an age-matched neurotypical group on either a RAN letter-naming task, a time-based motor-skills task, or a relatively simple nonverbal RT task (simple, choice, interference control). Reports could include multiple studies (*k*) if the studies utilized independent dyslexic and comparison groups. Studies could also include multiple measures from the same participant groups, yielding dependent effects (*m*). Studies were assigned ID-codes to track dependencies within the dataset.

RAN Letter-Naming Tasks

The first systematic review consisted of RAN and other rapid naming tasks. The database search used Boolean combinations of the following keywords: *dyslexia, poor readers, naming, RAN*. From this initial search, we restricted study selection to reports utilizing RAN letter-naming tasks to increase uniformity of procedures. Studies required participants to name a series of letters as quickly and accurately as possible. Studies measured the total time required to read the letter sequence (Chung & Ho, 2010), counted the number of letters named in a specified amount of time (Gabay et al., 2020), or computed the rate of letters named per second (Boets et al., 2010). Note that six of the studies provided composite RAN scores (e.g., letter and digit RAN conditions), which we included in the dataset. Another study used Chinese characters and required syllable responses (Laio et al., 2015); this study was also included in the dataset. The systematic review of RAN tasks yielded 30 studies (*k*) with 37 effects (*m*); see Table 1 for a list of reports. The 30 selected studies involved a total of 777 dyslexic and 842 age-matched neurotypical participants.

Table 1: Reports included in the RAN meta-analysis.

Author Information	
Araujo et al. (2016)	Kim et al. (2014)
Badian (1996)	Krasowicz-Kupis et al. (2009)
Beidas et al. (2013)	Kraus & Horowitz-Kraus (2014)
Bexkens et al (2014)	Laasonen et al. (2012)
Boets et al. (2010)	Liao et al. (2015)
Breznitz & Mistra (2003)	Lindgrén & Laine (2010)
Chung & Ho (2010)	Mayseless & Breznitz (2010)
De Silva et al. (2020)	Meisinger et al. (2010)
Engelhardt et al. (2021)	Nicolson & Fawcett (1994)
Fawcett & Nicolson (1994)	Ransby & Swanson (2003)
Gabay et al. (2020)	Soriano & Miranda (2010)
Georgiou et al. (2018)	Soriano-Ferrer et al. (2014)
Horowitz-Kraus & Btreznitz (2011)	Suarez-Coalla & Cuetos (2015)
Jiménez et al. (2009)	van Witteloostuijn et al. (2021)

Time-based Motor-skills Tasks

The second systematic review consisted of time-based motor tasks. Database search terms included Boolean combinations of the following keywords: *dyslexia, reading disability, reading impairment, motor, dexterity, tapping, pegboard*. From the search results, we restricted study selection to tasks that measure speed, rate, or time required to complete a specified motor task.

Table 2: Reports included in the motor skills meta-analysis.

Author Information	
Alamorgot et al. (2020)	Pagliarini et. al. (2015)
Aman (1979)	Peter et al. (2011)
Arfé et al. (2020)	Ramus, Pidgeon, et. al (2003)
Bégel et al. (2022)	Ramus, Rosen, et al. (2003)
Brookman et al. (2013)	Rathcke & Lin (2021)
Carroll et al. (2016)	Rousselle & Wolff (1991)
Catts et al. (2002)	Savage & Frederickson (2006)
Chiarenza (1990)	Stanley & Watson (1980)
Fawcett et al. (1996)	Stark (2013)
Fawcett et al. (2001)	Stoodley et al. (2006)
Galli et al. (2019)	Stoodley & Stein (2006)
Irannejad & Savage (2012)	Suárez-Coalla, et al. (2020)
Klicpera et al. (1981)	Sumner et al. (2014)
Kwok & Ellis (2014)	van Daal et al. (1999)
Lam et al. (2011)	Velay et al. (2002)
Le Jan et al. (2011)	White et al. (2006)
Mather (2003)	Whitehouse (1983)
Menghini et al (2011)	Yang et al. (2022)
Niechwiej-Szwedo et al. (2017)	

Tapping tasks measured the speed or rate that participants tapped with one of their appendages, such as toes (Fawcett et al., 1996) or fingers (Bégel et al., 2022; Brookman et al., 2013). Other tasks measured the amount of time required to point to a target (Velay et al., 2002), or trace a maze with one's fingers (Aman, 1979).

Drawing tasks required participants to draw symbols and objects, and measured the time required to complete the assigned task (Galli et al., 2019; Stanley & Watson, 1980). Some tasks measured the time required for participants to write letters (Alamargot et al., 2020), words (Fawcett et al., 2001), or sentences (Arfé et al., 2020). Other time-based motor tasks involved manual dexterity and the movement or manipulation of physical objects. As examples, studies measured the time required to insert pegs into a series of holes (Niechwiej-Szwedo et al., 2017), or the number of beads threaded in a set amount of time (Fawcett et al., 2001).

The database search of time-based motor-skills tasks yielded 40 studies (*k*) with 100 effects (*m*); see Table 2 for a list of reports. The included studies provided data from 1058 dyslexic and 2099 age-matched neurotypical participants.

Nonverbal RT-based Tasks

The third systematic review consisted of RT-based processing speed tasks. This systematic review was conducted using Boolean searches with combinations of keywords: *dyslexia, poor readers, reaction time, RT, simple, choice, interference control*. From the initial search, we restricted selection to simple RT, choice RT, and interference control tasks requiring nonverbal (button-press) responses.

Table 3: Reports included in nonverbal RT meta-analysis.

Author Information	
Bexkens et al. (2014)	Lachmann et al. (2009)
Bonifacci & Snowling (2008)	Russeler et al. (2002)
Breznitx & Meyler (2003)	Sela (2014)
Erez & Pratt (1992)	Stoodley et al. (2008)
Gabay et al. (2020)	Taroyan et al (2006)
Horowitz-Kraus & Breznitz (2011)	Vender et al. (2019)
Judge et al. (2007)	Van Daal & Leij (1999)
Lachmann & Leeuwen (2008)	

Simple RT tasks required participants to make a nonverbal response to a specified target stimulus, e.g., press a mouse key for each occurrence of a target tone (Daal & Leij, 1999). Choice RT tasks presented two or more stimuli at the same time and required participants to select a specified target using a button press. In one such study (Sela, 2014), participants were instructed to press one of three buttons depending on whether they heard a tone, saw a rectangle, or heard a tone while seeing a rectangle. Another choice RT task asked participants to press a right-side button with their right hand when the target arrow pointed right, and a left-side button with their left hand when the target arrow pointed left (Bexkens et al., 2014). Some of the choice RT tasks presented letters as stimuli (Horowitz-Kraus & Breznitz, 2011).

To increase the pool of available studies, relatively simple interference control tasks were included in the pool of nonverbal RT-based tasks. The interference control tasks required participants to make a response in the context of a distractor or priming stimulus, and thus engage executive functions like response inhibition. Although the tasks varied in design, they all required a nonverbal response and had an RT-based dependent variable. As an example, Lachman and Leeuwan (2008) instructed participants to respond as quickly as possible using response keys to indicate whether pairs of stimuli were the same or different while also ignoring a surrounding shape. This task was done using letters, pseudo letters, and shapes as target stimuli.

The selected interference control tasks included variants of the Simon task, where participants had to respond to target stimuli while ignoring its spatial position (Gabay et al., 2020; Vender et al., 2019). Other studies used variants of the go/no-go task, with participants instructed to respond to target stimuli and withhold responses to non-target distractors (Erez & Pratt, 1992; Judge et al., 2007; Russeler et al. 2002; Stoodley et al., 2008; Taroyan et al., 2006).

The database search of nonverbal RT-based tasks yielded 17 (*k*) studies with 43 effects (*m*); see Table 3. The included studies provided data from 328 dyslexic and 341 age-matched neurotypical participants.

Combined Meta-analytic Sample

To compare effects across task paradigms (RAN, motor-skills, nonverbal RT), we merged the three datasets to create a combined sample of studies and effects. This final meta-analytic sample consisted of 84 studies (*k*) with 180 effects (*m*). The total sample comprised 2071 dyslexic and 3182 age-matched neurotypical participants.

Results

All datafiles and analysis code are available an Open Science Framework repository (Zapparrata et al., 2024; https://osf.io/ckjfn/). Overall effect sizes (μ) were calculated using hierarchical random-effects Bayesian meta-analytic modeling. This offers a flexible meta-analytic method to handle effect sizes with a nested structure, (i.e., statistical dependencies from multiple effects drawn from the same studies and participant groups; Pimontel et al., 2016). Bayesian meta-analysis allows researchers to generate posterior distributions (i.e., a range of plausible values) for each parameter of interest (e.g., overall effect size [μ], the mean estimate of Hedges's *g*).

This supports a more intuitive interpretation of meta-analytic results compared to what is possible with conventional (frequentist) meta-analytic methods (Tanner-Smith et al., 2016). Conventional meta-analysis relies on null hypothesis testing to decide whether a mean effect is statistically significant (e.g., p-value < .05), and generates a confidence interval (e.g., 95% CI) for the estimated mean effect. This CI has a non-intuitive interpretation (e.g., if the meta-analytic methods were replicated an infinite number of times with different study samples, 95% of the derived mean estimates would fall in this range) that is often misunderstood and misrepresented (Pimontel et al., 2016; Zapparrata, 2024).

In contrast, with a Bayesian approach, the researcher can generate exact probabilistic statements about the posterior distributions of parameters, such as the probability that the overall effect size [μ] is greater than 0 (Sutton & Abrams, 2001). For the associated credible interval (e.g., 95% CrI), the researcher can conclude that there is 95% probability that the true value of μ falls within the bounds of the interval. Similarly intuitive statements can be made about other parameters (e.g., between-study heterogeneity [τ], see below for further description).

The reported statistical analyses were run using the *Metafor* (Viechtbauer et al., 2010), *Robumeta* (Fisher et al., 2016), and *Rjags* (Plummer et al., 2022) packages in R, with commands added to determine exact probabilities of overall effects being greater than common benchmarks (i.e., .20 for a small effect, .50 for a medium effect, .80 for a large effect). Note that in our meta-analysis, positive effects indicate worse performance (longer RTs indicative of slower processing) in dyslexic groups compared to age-matched neurotypical comparison groups. Therefore, we also included a command to determine the probability of the overall effect sizes being positive (i.e., greater than 0).

As a first step, we ran separate models for each of the three meta-analytic datasets to determine the overall effect size (μ), the between-study standard deviation of effects (τ) for each task category (i.e., RAN, time-based motor skills, nonverbal RT), and the within-study variation (σ). The τ parameter provides an estimate of between-study variability in effects, interpreted as the standard deviation of effect size estimates across studies (Borenstein et al., 2017). In addition to τ, researchers may be interested in estimating within-study variation (σ) in hierarchical meta-analyses indexing multiple effect sizes nested within studies.

Figure 1 presents the funnel plots showing the distribution of effects by task category (RAN, motor skill, nonverbal RT). Figure 2 presents the posterior distributions for the effect size parameter (μ) for each of the three datasets. Table 4 presents effect size estimates and credible intervals for the three intercept-only models, along with probability statements about the magnitude of the overall effect (μ).

The meta-analytic model for RAN letter-naming studies ($k = 30$, $m = 37$) yielded an average estimate (μ) = 1.26 (95% *Credible Interval* [CrI] = 1.00; 1.52), with a 100% probability that $\mu > .80$ (large effect). Between-study heterogeneity of effects (τ) was estimated at .57 and within-study heterogeneity (σ) at .25. As a test for publication bias, we conducted Egger's test of funnel plot asymmetry. This revealed evidence of bias ($z = 2.23$, $p = .026$), indicating possible missing data in the lower left quadrant of the funnel plot (i.e., weak effects from small samples).

The model for time-based motor-skills tasks ($k = 40$, $m = 100$) yielded an effect size (μ) = .58 (95% CrI = 0.37; 0.79), with a 100% probability of $\mu > .20$ (small effect) and a 77% probability of $\mu > .50$ (medium effect). Between-studies heterogeneity (τ) was estimated as .51 and within-study heterogeneity (σ) as =.49. No evidence of publication bias was found ($z = 1.28$, $p = .199$).

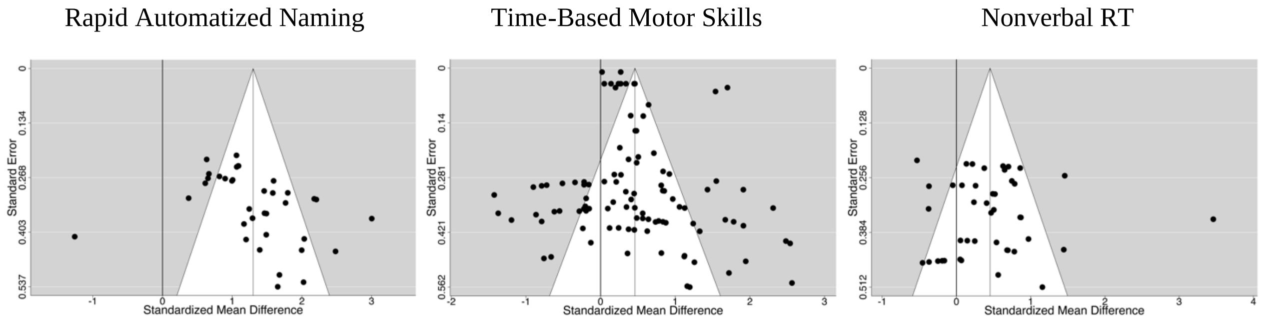

Figure 1. Funnel plots depicting the distribution of effects by task category

Table 4: Overall effect size (μ) with associated probability statements for each task paradigm

Task	μ	CrI	$P(\mu > 0)$	$P(\mu > .20)$	$P(\mu > .50)$	$P(\mu > .80)$
RAN (k = 30, m = 37)	1.26	[1.00; 1.52]	1.00	1.00	1.00	1.00
Motor Skills (k = 40, m= 100)	0.58	[0.37; 0.79]	1.00	1.00	.77	.02
Nonverbal RT (k = 17, m = 43)	0.42	[0.16; 0.68]	1.00	.95	.26	.00

The meta-analytic model for nonverbal RT-based tasks (k = 17, m = 43) yielded an effect size (μ) = .42 (95% CrI = 0.16; 0.68), with a 95% probability of $\mu > .20$ (small effect) and a 26% probability of $\mu > .50$ (medium effect). Between-studies heterogeneity (τ) was estimated as .32 and within-study heterogeneity (σ) as .51. No evidence of publication bias was found (z = –0.15, p = .883).

Table 5: Bayesian meta-regression comparing effect sizes across task categories (k = 84, m = 180)

Task	μ	β	τ	σ
			0.40	0.51
Intercept (RAN = reference)	1.22			
Motor Skills		–0.64		
Nonverbal RT		–0.73		

Next, we used Bayesian meta-regression to examine whether effect size estimates varied in magnitude across datasets (RAN, motor skills, nonverbal RT tasks). The RAN meta-analytic sample served as the reference category and was compared with effects drawn from time-based motor-skills and nonverbal RT tasks; see Table 5. The intercept represents the overall effect (μ) derived from RAN tasks. Each of the coefficients (β) can be interpreted as the change in effect by task category (time-based motor, nonverbal RT), when compared to estimates drawn from RAN tasks. While slower RTs were evident in dyslexia across task types, the group differences were larger in magnitude for effects drawn from RAN tasks as compared to motor-skills or nonverbal RT-based tasks.

Discussion

Recent neuroimaging studies suggest that neural underconnectivity may underlie reading difficulties observed in developmental dyslexia and that differences in processing efficiency may extend beyond the language network (Horowitz-Kraus et al., 2023; Taskov & Dushanova, 2021). Such findings are in keeping with prior work emphasizing impaired procedural learning and atypical development of cerebellar and subcortical pathways in dyslexia (Nicolson et al., 2001; Ullman et al., 2020). These theories implicate differences in domain-general processing in the broader dyslexia phenotype, which may lead to reduced processing speed or generalized slowing across tasks and domains.

The current meta-analytic study aimed to evaluate the generalized slowing hypothesis in dyslexia by examining performance on a wide range of time-based tasks. We started with RAN because this task is prominent in dyslexia research and may differentiate dyslexia from other learning disabilities (Denckla & Cutting, 1999; Denckla & Rudel, 1976). We then extended our meta-analysis to compare dyslexic and age-matched neurotypical groups on time-based motor skills and nonverbal RT-based tasks. Results indicated longer RTs in dyslexic groups across all task types, which we interpret as evidence of generalized slowing. Group differences were larger in magnitude for RAN tasks than for motor skills or nonverbal RT tasks, which might be attributed to verbal response requirements of RAN as compared to the varied motor requirements of time-based motor-skills and nonverbal RT tasks.

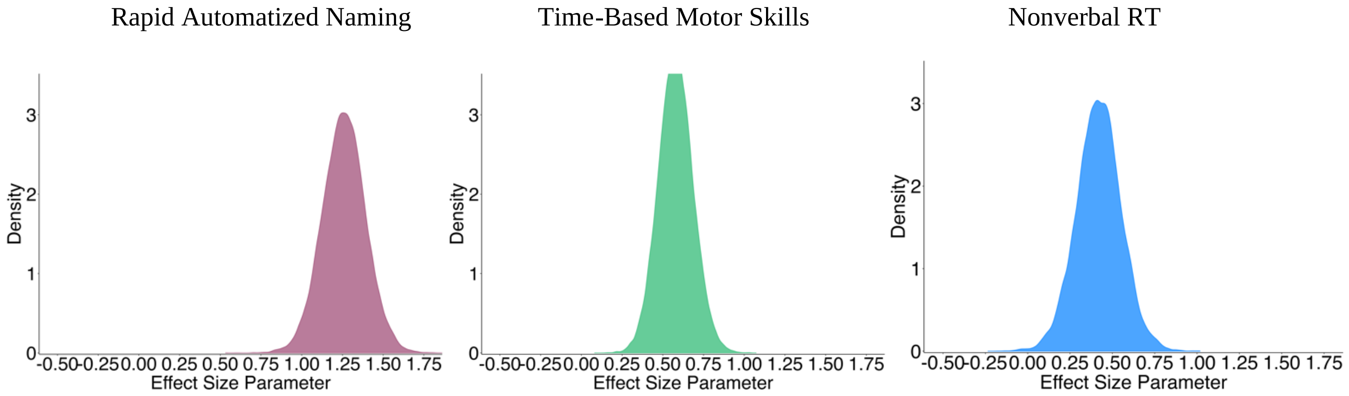

Figure 2. Posterior density plots of the overall effect size parameter (μ) by task category

Evidence of publication bias was present in the meta-analysis of dyslexic performance on RAN tasks, suggesting an underrepresentation of studies with smaller effects. Here we note that observing small differences between dyslexic and neurotypical groups on RAN tasks would be unexpected given the existing diagnostic criteria and well-documented phonological processing deficits associated with dyslexia (Seidenberg, 2017; Snowling, 2000). Perhaps more informatively, there was no evidence of publication bias in studies of time-based motor-skills and nonverbal RT tasks.

In addition to providing estimates by task category, the Bayesian approach allowed us to generate probabilistic statements about the posterior distributions of the effect size estimates by task type. Relative the other task categories, RAN tasks had the highest probability of a large effect ($\mu >$ .80). In contrast, for motor-skills and nonverbal RT tasks, we observed a large probability of a small effect ($\mu >$ .20).

Another benefit to utilizing the Bayesian approach is the precise estimation of τ, even in the presence of outliers. Other more conventional methods of meta-analysis describe the estimation of heterogeneity parameters as incidental to the analysis (Hedges et al., 2010; Tanner-Smith et al., 2016), whereas the Bayesian approach allows researchers to generate and visualize an entire posterior distribution for the τ parameter. Further, the Bayesian meta-analytic model is more flexible than conventional methods in the sense that researchers can specify a distribution for underlying effects that is more robust if extreme outliers are present (Plummer, 2022). For example, in a Bayesian meta-analytic model specification, it is common for a normal distribution to be specified as the underlying likelihood distribution of effects for parameters of interest. However, a *t*-distribution is known to be more robust in the presence of outliers (Lange, 1989). In the present study, outliers were detected upon visual inspection (Figure 1); however, they were not influential in the meta-analytic results. Researchers conducting meta-analyses on small datasets (possibly containing extreme outliers) should consider using a Bayesian approach with the underlying likelihood distribution specified to generate a precise τ parameter. Ultimately, the Bayesian approach offers flexibility in both the specification of the meta-analytic model and the interpretation of results when conducting meta-analyses on neurodevelopmental disorders.

Next, it is important to highlight that τ represents variation at a group-level. While the current group-level meta-analytic results indicate slower processing in dyslexia across task types, this should not be taken as evidence that all dyslexic individuals exhibit generalized slowing. With respect to motor skills, research indicates considerable individual differences in dyslexia. That is, motor impairments do not affect dyslexics uniformly and, moreover, do not account for their observed reading difficulties (Ramus et al., 2003). Similarly, not all individuals with dyslexia may show general slowing in nonverbal RT tasks as compared to age-matched peers (Bonifacci & Snowling, 2008). While there is some evidence tying visual processing speed to reading (Lobier et al., 2013; McLean et al., 2011), more research is needed to link processing speed deficits directly with observed reading difficulties in dyslexia.

While our findings indicate differences in domain-general processing speed in dyslexia, it is important to emphasize that generalized slowing may be a nonspecific marker of language delay that extends beyond dyslexia, e.g., reflecting differences in neural connectivity and processing efficiency in individuals with developmental language disorder (Zapparrata et al., 2023a). Further discussion of slower processing speed in relation to differences in cortical connectivity is seen in research on other developmental disorders, including autism (Just et al., 2012; Zapparrata et al., 2023b). Such findings indicate that generalized slowing and neural underconnectivity are not specific to dyslexia but may reflect differences in processing efficiency across developmental disabilities (Ullman et al., 2020).

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