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Original Research Article

Individual Differences in Germ Spreading Behaviors Among Children With Attention-Deficit/Hyperactivity Disorder: The Role of Executive Functioning

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Abstract

Objective Infectious diseases, such as coronavirus disease 2019 (COVID-19), are commonly transmitted by respiratory droplets and contact with contaminated surfaces. Individuals with attention-deficit/hyperactivity disorder (ADHD) are more likely to be infected with COVID-19 and experience more hospitalizations than individuals without ADHD. The current study investigated the role of ADHD symptomatology and executive functioning (EF) in germ spreading behavior frequency among young children with and without ADHD and parenting responses to these behaviors. **Methods** Participants included 53 children diagnosed with ADHD and 47 typically developing (TD) children between the ages of 4–5 years (76% male; Mage = 4.62; 86% Hispanic/Latinx). Parents and teachers reported on children's ADHD symptomatology and children completed three EF tasks. Germ spreading behavior frequency (direct contact of hand to face and toy in mouth) and parenting responses (verbal and nonverbal behaviors) were observed during a 5-min parent–child play situation. **Results** Negative binomial regression analyses indicated that both ADHD diagnostic status and poor metacognition predicted both higher rates of toy to mouth ($\beta = 1.94$, $p <$ .001; $\beta = 0.03$, $p = .004$) and face touching frequency ($\beta = 0.60$, $p = .03$; $\beta = 0.03$, $p = .004$), respectively. Additionally, poor attention and worse cognitive flexibility only predicted higher rates of toy to mouth frequency ($\beta = 0.09$, $p < .001$; $\beta = -0.04$, $p = .001$), respectively. **Conclusions** Young children with ADHD are at high risk for spreading germs via putting toys in their mouth and touching their face. Particularly, high levels of inattention and poor EF appear to be associated with higher rates of germ spreading behaviors.

Key words: attention-deficit/hyperactivity disorder; COVID-19; executive functioning; preschool.

Introduction

The coronavirus disease 2019 (COVID-19), caused by severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2), has rapidly spread to nearly every country around the world and has infected over 85 million people in the United States (CDC, 2022). Infectious diseases, such as influenza and COVID-19, can be transmitted via respiratory droplets (i.e., coughing, sneezing) and contact with fomites (i.e., contaminated objects and surfaces; Artasensi et al., 2021). The fomite viral load plays a crucial role in the length of time a surface is deemed contaminated and differs between diseases (Kampf et al., 2020; Singh et al., 2021). The persistence of infectious diseases also varies between settings, with daycare centers estimated to be high-risk for transmission and viral persistence on surfaces for up to several days (Kraay et al., 2021; Riddell et al., 2020). Recent work highlights how younger children with attention-deficit/hyperactivity disorder (ADHD) are more likely to be infected with COVID-19 (Merzon et al., 2021) and other illnesses, such as the common cold or upper respiratory infections (Zhou et al., 2017), than individuals without ADHD. In order to maximize prevention efforts and inform safety guidelines for at-risk groups, the current study investigated the role of diagnostic status, ADHD symptomatology, and executive functioning (EF) in germ spreading behavior frequency among young children with and without ADHD, and parenting factors in response to these behaviors.

ADHD and COVID-19/Infectious Diseases

According to ecological theories of child development, larger societal systems can influence child and parent behaviors, as well as the family system via the implementation of rules and regulations (Bronfenbrenner, 1992). In the midst of the COVID-19 pandemic, the implementation of social distancing and mandatory quarantine measures introduced novel challenges for families with young children, especially those with ADHD. As one of the most common neurodevelopmental disorders, ADHD is characterized by two distinct behavioral dimensions (inattention and impulsivity/hyperactivity), which can lead to costly functional impairments in several life domains. For example, compared with typically developing (TD) children, children with ADHD are at higher risk for long-term academic difficulties, low self-esteem, and poor social functioning (Arnold et al., 2020; Harpin et al., 2016). The only study to date, to the best of our knowledge, to examine the link between ADHD and acquiring COVID-19, found that individuals with COVID-19 and ADHD were at increased risk for hospitalization referrals and reported more severe symptoms of COVID-19, even after accounting for variables known to increase the risk for both disorders (i.e., age, hypertension, obesity, asthma; Merzon et al., 2022). While several studies have documented the negative toll COVID-19 has taken among youth and adults with ADHD in terms of increased sad/depressed mood, limited physical activity, and less enjoyment in activities (Sciberras et al., 2022), limited work has examined the mechanisms by which ADHD may lead to higher rates of COVID-19 infections.

Recent papers suggest that youth/adults with ADHD are less like to wash their hands, use hand sanitizer, maintain social distance, and more likely to engage in rule-breaking behaviors related to COVID-19 restrictions (Conway et al., 2022; Rosenthal et al., 2022). Rosenthal and colleagues (2021) theorize that individuals with ADHD, due to their inattention and hyperactivity/impulsivity, may be more likely to put themselves in high-risk situations as it relates to health safety measures (e.g., not socially distancing). In fact, COVID-19 itself seems to exacerbate ADHD-related symptomatology including difficulties concentrating and increased irritability in young children (Brooks et al., 2020; Wendel et al., 2020). It appears that all of the research to date that has investigated the link between ADHD and COVID-19 has done so via self or parent report and have assumed the link is due to the core symptoms of ADHD contributing to poor health-related behaviors. No study to date has been conducted via an observational design to determine whether ADHD symptomology (or which domains; hyperactivity/impulsivity vs. inattention) relates to health behaviors. Additionally, no study to date has examined other potential mechanisms such as EF that are variable within the ADHD population and may also be an important culprit towards unhealthy behaviors.

ADHD and EF

EF and self-regulation have emerged as defining aspects related to the heterogeneity in ADHD and related impairment (Willcutt et al., 2005). EF is a construct that refers to a set of higher-order cognitive processes that enable secondary abilities such as goal-directed behavior and problem-solving (Kofler et al., 2019; Miyake et al., 2000). Despite the various definitions of EF, most point to components of working memory (WM), set shifting, and inhibitory control (IC; McClelland & Cameron, 2012; Miyake et al., 2000; Willcutt et al., 2005). Theoretical and empirical work suggests that EF impairments strongly influence behavioral symptoms of ADHD (Martel et al., 2008; Raiker et al., 2012), with significant variability in the presence of EF deficits among children with ADHD (Martel, 2013; Silverstein et al., 2020). Most importantly, EF deficits seem to exacerbate adverse functional outcomes in areas like reading (Kofler et al., 2019) and social functioning (Hilton et al., 2017; Kofler et al., 2011). In adulthood, EF is of critical importance in the adoption and maintenance of health promoting behaviors. While higher levels of EF promote positive health behaviors, such as increased exercise and abstaining from substance use (Allan et al., 2016), poor EF is associated with poor eating habits, risky driving, and increased tobacco use (Reimann et al., 2020; Williams & Thayer, 2009). Hall and Fong's Temporal Self-Regulation Theory (Hall and Fong, 2015) proposes that individuals with higher levels of EF are more likely to resist temptation/inhibit responses that are detrimental to their health, with individual differences in EF moderating the strength of association between intentions and health-related behaviors (Hall et al., 2008). What remains unclear is the extent to which ADHD symptomatology and EF predict health-related outcomes such as germ spreading behaviors in young children.

Parenting and ADHD

Behavioral parent training programs are considered the first line of treatment for young children with ADHD due to the strong link between parental involvement, positive parenting skills, and consistent discipline on behavioral outcomes (Kling et al., 2010; Ros et al., 2016; Tynan et al., 2004; Wolraich et al., 2019). Not only do parents of children with ADHD report increased levels of stress compared with parents of TD children (Dabrowska & Pisula, 2010), but they also differ on their parenting styles (Hutchison et al., 2016). Higher rates of negative parenting practices (e.g., less involvement/affection, more inconsistency and hostility) and greater use of permissive parenting style are reported in families of children with ADHD compared with TD (Bhide et al., 2019; Hutchison et al., 2016). More recently, during the COVID-19 pandemic parents report higher levels of stress due to financial strain and increased time at home, which has resulted in increased negative disciplinary practices (Lee & Ward, 2020). Given the bidirectional associations between parenting practices and child behaviors, it is important to understand parenting responses to germ spreading behaviors.

Current Study

The risk of testing positive for COVID-19 and other infectious diseases is higher for individuals with ADHD (Merzon et al., 2021). Studying germ spreading behaviors in young children may offer important insights towards understanding which individual factors contribute to illness transmission among at risk groups. We hypothesized that ADHD diagnostic status would relate to higher rates of germ spreading behaviors (i.e., touching their face with their hands, putting toys in their mouth) during a play situation. We also hypothesized that greater severity levels of ADHD symptomatology (inattention and hyperactivity/impulsivity) as well as greater impairments in EF would relate to an increase in germ spreading behaviors. Finally, in an exploratory fashion, we examined whether parents of children with ADHD differed in their real-time responses to children's germ spreading behaviors compared with parents of TD children. Given prior work suggesting more lax parenting strategies among parents of children with ADHD (Kaiser et al., 2011; Lange et al., 2005), we hypothesized that parents of children with ADHD would respond less frequently, both physically and verbally, to germ spreading behaviors compared with parents of TD children.

Methods

Participants

The study was conducted at a large, urban university in the southeastern United States with a large Hispanic population. Participants for this study included 100 children (M_{age} 4.62; 76% male) who were participating in a larger ongoing longitudinal study, the ADHD Heterogeneity of Executive Function and Emotion Regulation Across Development study (Graziano et al., 2022). All assessments and observations were completed prior to the COVID-19 pandemic, between September 2017 and May 2019. One hundred and ninety-eight participants were initially recruited from local preschools and mental health agencies via brochures, open houses, and online ads. For the ADHD sample, inclusion criteria consisted of: (a) endorsed clinically significant levels of ADHD symptoms (six or more symptoms of either Inattention or Hyperactivity/Impulsivity according to the DSM-5 OR a previous diagnosis of ADHD), (b) indicated that the child is currently displaying clinically significant academic, behavioral, or social impairments as measured by a score of 3 or higher on a seven-point impairment rating scale (Fabiano et al., 2006), and (c) were not taking any psychotropic medication, the parent and child were invited to participate in an assessment to determine study eligibility. For the TD sample, if the parent (a) endorsed less than four ADHD symptoms (across either Inattention or Hyperactivity/Impulsivity according to the DSM-5), (b) less than four Oppositional Defiant Disorder symptoms, (c) indicated no clinically significant impairment (score below 3 on the impairment rating scale), (d) were not taking any psychotropic medication, the parent and child were invited to participate in an assessment to determine study eligibility. Participants were also required to be enrolled in school during the previous year, have an estimated IQ of 70 or higher, have no confirmed history of an Autism Spectrum Disorder, and be able to attend an 8-week summer treatment program prior to the start of the next school year (ADHD group only). Given the current study's focus on germ spreading behaviors in young children, only participants between the ages of 4 and 5 years currently attending preschool or kindergarten from the larger study were included. There were no significant differences in sex, income, or ADHD severity between the current subsample and the larger study sample. Of note, during the intake process none of the participants indicated a previous or current diagnosis of a tic disorder, which would have impacted any observation of repetitive germ spreading behaviors.

During intake, ADHD diagnosis (and comorbid disruptive behavior disorders) was assessed through a combination of parent structured interviews (Computerized-Diagnostic Interview Schedule for Children; Shaffer et al., 2000) and parent and teacher ratings of symptoms and impairment (Disruptive Behavior Disorders Rating Scale, Impairment Rating Scale; Fabiano et al., 2006) as is recommended practice (Pelham et al., 2005). Dual PhD level clinician review was used to determine diagnosis and eligibility. The final sample consisted of 53 children (86.8% male) with a diagnosis of ADHD and 47 TD children (63.8% male). See Table I for additional demographic characteristics.

Study Design and Procedures

The current study was approved by the university's Institutional Review Board. In addition to participating in the diagnostic intake protocol described previously, children completed a series of EF tasks in the laboratory and, as part of the larger study, participated in a magnetic resonance imaging scanning session. Parents and teachers also completed various questionnaires regarding children's emotional, behavioral, and cognitive functioning. Finally, a 5-min child-led observation period designed to assess parent–child interactions (Robinson & Eyberg, 1981) was used to observe germ spreading behaviors and parental monitoring of these behaviors.

Measures

ADHD: Inattention and Hyperactivity/Impulsivity

Parents and teachers completed the Behavior Assessment System for Children (BASC-3; Reynolds et al., 2015). The teacher rating scale contains 105 items and the parent rating scale contains 175 items, both rated on a 4-point Likert scale (*never, sometimes, often*, and *always*). The BASC-3 provides insight for several emotional and behavioral domains such as, aggression, anxiety, attention, and hyperactivity/impulsivity. The attention problems and hyperactivity/impulsivity t-scores were examined in this study as a proxy for symptoms of inattention and hyperactivity/impulsivity (Pelham et al., 2005). Consistent with prior work (Bird et al., 1992; Martel et al., 2009; Piacentini et al., 1992), the t-score among parent and teacher reports was used for both the inattention ($\alpha = .93$–$.98$ and .96–.99, respectively) and the hyperactivity/impulsivity scale ($\alpha = .92$–$.94$ and $= .95$–$.96$, respectively).

Executive Functioning

The Head-Toes-Knees-Shoulders task (HTKS; Ponitz et al., 2009) is a structured observational measure of self-regulation, which integrates multiple EF components (i.e., attentional and cognitive flexibility, WM, and IC). The HTKS is a short "game-like" assessment appropriate for children aged 4–6 years (McClelland & Cameron, 2012). During the HTSK task, children are presented with a set of behavioral rules (i.e., "touch your head" and "touch your toes") and instructed to perform the opposite behavior (i.e., "touch your head means touch your toes" and "touch your toes means touch your head") across 10 test trials. The second test trial pairs two new behavioral rules (i.e., "touch your knees" and "touch your shoulders") and requires the child to remember the rules from the first trial. In the final trial, all four behavioral rules are changed (i.e., "now touch your head means touch your knees") and the child must remember all four commands for the 10 test trials. The child receives scores of 0 for an incorrect response, 1 for self-correction, and 2 for a correct response. Scores range from 0 to 60, with higher scores indicating better EF. The HTKS is a well-established measure, which has demonstrated internal consistency, reliability, and concurrent/predictive validity (Graziano et al., 2015; McClelland et al., 2014; Ponitz et al., 2009).

As part of the National Institutes of Health (NIH) Toolbox Cognition Battery (Zelazo et al., 2013), children completed the Flanker task (Mullane et al., 2009), and the Dimensional Change Card Sort (DCCS; Zelazo, 2006). The Flanker task measures the ability to inhibit visual attention to irrelevant stimuli, while also performing a stimulus conflict task, which taps into the IC construct of overall EF. The task consists of 40 trials, in which a central target (a fish), pointing either right or left, is flanked by identical fish pointing either the same or opposite direction. The child is then instructed to indicate which arrow is pointing in the same direction as the middle fish, while ignoring the surrounding fish. In the second trial, arrows replace the fish and the goal of the task remains the same. Higher raw scores indicate better EF. This task has excellent test–retest reliability and convergent validity among children aged 3–6 years (Mungas et al., 2013; Zelazo et al., 2013). The DCCS (Zelazo, 2006) is an EF measure used to assess cognitive flexibility. During the DCCS task children are required to sort a series of bivalent cards according to the presented dimension (e.g., color and shape). The first trial is based on one dimension, and then the second trial is based on the other. For example, the child may see a yellow ball and a blue truck; then they are told to choose the picture that is the same color as the third target picture in the middle of the screen. If the target picture is a yellow truck, then the child must choose the yellow ball, since the presented dimension is color. The third phase includes both dimensions, which change item by item. Higher scores indicate better EF. The DCCS is a valid measure of cognitive flexibility with children 3–8 years (Zelazo et al., 2013) and has excellent test–retest reliability (Weintraub et al.,

Table I. *Demographics for Sample*

Characteristic	*n*
Child race	
White	93
Black/African American	2
Asian	3
Biracial (White/American Indian/Alaska Native/Asian)	2
Child ethnicity	
Hispanic/Latinx	86
Non-Hispanic/Latinx	14
Parent race	
White	92
Black/African American	2
Asian	5
Biracial	1
Parent ethnicity	
Hispanic/Latinx	81
Non-Hispanic/Latinx	19
Parent primary language	
English	78
Spanish	20
Other	2
Family marital status	
Intact two-parent household	80
Living with a partner	6
Single-parent household-divorced/separated	9
Single-parent household-never married	5
Parental education	
Some high school	1
High school graduate	4
Some college or associate's degree	18
Bachelor's degree	32
Graduate degree	45
Reporter of questionnaires	
Mothers	85
Fathers	15

2013). Age-corrected standard scores were used for both the Flanker and DCCS.

Parents and teachers completed the Behavioral Rating Inventory of Executive Function-Preschool Version (BRIEF-P; Gioia et al., 2002). Both the parent and teacher versions contain 63 items rated on a 3-point Likert scale (never, sometimes, and often), which provide distinct but correlated clinical scales (inhibit, shift, emotional control, WM, and metacognition). For the purposes of the current study, and to reduce the potential symptom overlap between ADHD and EF dimensions (e.g., Inhibit subscale), the Metacognition age and gender-normed t-score was used, which combines the Working Memory and Plan/Organize subscales. Specifically, the highest t-score between parent and teacher reports was used, with higher scores indicating poorer EF (α = .97–.99, respectively). In the overall sample, 40% of children scored in the clinical range across parent/teacher report.

Germ Spreading Behaviors

Germ spreading behaviors were observed within the context of a child-led 5-min observation. During the 5 min, the parent was told to let the child play with whatever toy they wanted (e.g., Legos, Mr. Potato head, or food toys) and to follow along with their child's lead. A coding system was created by the authors to track germ spreading behaviors as measured by how many times a child (a) touched their face/mouth with their hand and/or (b) put a toy in/on their mouth. Although we had an interest in examining common means of respiratory transmission (e.g., coughing and sneezing), they only occurred in <1% of the sample and therefore they were excluded from this study. Parenting behaviors were also tracked by counting verbal and physical prompts towards the child to remove the toy from their mouth or move their hand from their face (e.g., telling the child to remove a toy from the child's mouth, moving the child's hand away from the child's face). A graduate student, masked to the diagnostic status of the children, served as the primary coder with 20% of the videos coded by a second observer who was also masked to the diagnostic status of the children. Interrater reliability was excellent (*r*'s ranged from .94 to .99 across the frequency counts).

Data Analysis Plan

All analyses were conducted using the Statistical Package for Social Sciences, version 20 (SPSS 20). Given that the current study focused on the baseline assessment, there were minimal missing data. Due to equipment difficulties the following minimal data was missing: one complete parent–child interaction video, two partial parent–child interaction videos, and two NIH Toolbox scores. Following statistical guidelines, given the extremely low levels of missing data (<5%), multiple imputations are not necessary (Jakobsen et al., 2017). Therefore, listwise deletion was used. Preliminary data analyses were conducted to examine differences in EF and symptomatology between children with ADHD and TD children (Table II). Given the dependent variables were count variables, several assumptions for ordinary least squares analyses were violated. First, all the outcomes had a right-skewed distribution (kurtosis range 18.09–52.71), violating conditional normality. Second, the variance for each outcome violated the assumption of homoscedasticity, such that the variance increased at different values of the predictors. According to Coxe et al. (2009), negative binomial regression model is optimal for analyses involving count data that is overdispersed. Briefly, the negative binomial model allows the predicted variance to be larger/smaller than the predicted mean, which directly effects standard errors. Given that the current data are overdispersed, meaning that the residual variance is larger than the mean, a negative binomial regression model was estimated. We examined the extent to which diagnostic status (ADHD and TD), ADHD symptomatology (inattention and

Table II. *Results Comparing ADHD and TD on Symptomatology, EF, and Germ Spreading Behaviors*

	ADHD Mean (SD)	TD Mean (SD)	*T*	Cohen's *d*	95% CI [LB, UB]
BASCatten(P/T)[a]	66.94 (7.12)	48.30 (5.68)	14.35***	2.87	16.07, 21.22
BASChyp(P/T)[a]	68.09 (9.89)	48.83 (5.47)	11.84***	2.37	16.04. 22.49
DCCS (O)	92.65 (15.39)	103.80 (11.60)	−3.98***	−0.81	−16.71, −5.58
HTKS (O)	25.40 (15.94)	33.89 (18.75)	−2.43*	−0.49	−15.41, −1.57
Flanker (O)	93.68 (15.52)	105.80 (10.93)	−4.39***	−0.89	−17.60, −6.64
BRIEF(P/T)[a]	78.38 (14.00)	50.55 (8.37)	11.87***	2.38	23.17, 32.48

Note. All effects remained significant after FDR correction was applied. ADHD = attention-deficit/hyperactivity disorder; TD = typically developing; EF = executive functioning; BASCatten = Behaviors Assessment System for Children attention problems subscale; BASChyp = Behaviors Assessment System for Children hyperactivity/impulsivity subscale; DCCS = Dimensional Change Card Sort; HTKS = Head-Toes-Knees-Shoulder task; Flanker = Flanker Task; BRIEF = Brief Rating Inventory of Executive Function metacognition subscale; O = observational measure/assessment; P = parent report measure; T = teacher report measure; 95% CI = 95% confidence interval of the difference; FDR = false discovery rate.

[a]Max score was derived from the highest score between parent and teacher rating.

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

hyperactivity/impulsivity), and child EF uniquely predicted toy to mouth (Models 1a and 2a) and face touching frequency (Models 1b and 2b) before entering significant effects into a final integrative model (Model 3a).

Results

Preliminary Analyses

As expected, there were significant differences between children with ADHD versus TD children as it relates to symptomology and EF variables. As seen in Table II, children with ADHD were reported as having greater attention problems ($d = 2.87$), hyperactivity/impulsivity ($d = 2.37$) as well as worse scores on the DCCS ($d = 0.81$), HTKS ($d = 0.49$), Flanker ($d = 0.89$), and were reported as having more severe EF problems on the BRIEF-metacognition subscale ($d = 2.38$) relative to TD children. Of note, no demographic variables were associated with any of the outcome variables. Due to the number of analyses conducted, the false discovery rate (FDR) correction was utilized to decrease likelihood of Type I error (Benjamini & Hochberg, 1995). All significant effects remained significant.

Negative Binomial Analyses: Diagnostic Status and Germ Spreading Behaviors/Parental Responses

As seen in Table III, negative binomial regression analyses indicated that diagnostic status was a significant predictor of toy to mouth, Wald χ^2 (1) = 26.28, $\beta = 1.94$, $p < .001$, and face touching frequency, Wald χ^2 (1) = 4.54, $\beta = 0.60$, $p = .03$, and was only marginally associated with parental responses ($p = .08$). For children diagnosed with ADHD, there was a 1.94 and 0.60 multiplicative increase in toy to mouth and face touching frequency, respectively.

Negative Binomial Analyses: ADHD Symptomatology, EF, and Toy to Mouth Frequency

Model 1a: Only ADHD Symptomatology

As seen in Table IV, negative binomial regression analyses for Model 1a, Wald's test indicated that only inattention was a significant predictor of toy to mouth frequency, Wald χ^2 (1) = 18.72, $p < .001$, such that higher levels of inattention ($\beta = 0.09$, $p < .001$), but not hyperactivity/impulsivity ($p = .83$), were uniquely associated with higher toy to mouth frequency. For every 1-unit increase in inattention, there was a .09 multiplicative increase in toy to mouth frequency. Therefore, inattention was retained as a predictor in the final model.

Model 2a: Only EF Questionnaires and Observations

In Model 2a, Wald's test revealed that only the DCCS task and BRIEF were significant predictors of toy to mouth frequency, Wald χ^2 (1) = 11.05, $p = .001$ and Wald χ^2 (1) = 8.32, $p < .01$, respectively. Worse performance on the DCCS task ($\beta = -0.04$, $p = .001$) and increased EF problems as rated by the parent and teacher on the BRIEF ($\beta = 0.03$, $p < .01$), were associated with increased toy to mouth frequency. Therefore, only DCCS and BRIEF were retained as predictors in the final model.

Model 3a: Combined

Finally, Model 3a combined all significant main effects of symptomatology and EF measures from Models 1 and 2 (i.e., inattention, DCCS, and BRIEF). As seen in Table IV, the BRIEF was no longer a significant predictor ($\beta = -0.003$, $p = .85$), whereas the DCCS was marginally significant ($\beta = -0.02$, $p = 0.06$). Inattention remained significantly associated with toy to mouth frequency ($\beta = 0.07$, $p < .01$). For every 1 unit increase in attention problems, there was a .07 multiplicative increase in toy to mouth

Table III. *Model for Diagnostic Status Predicting Toy to Mouth, Face Touching and Parental Response Frequency*

	ADHD Mean (SD)[a]	TD Mean (SD)[a]	b	e^{bx}	95 % CI [LB, UB]	Wald's χ^2	Deviance	Likelihood ratio chi-square
Toy to mouth	1.66 (3.07)	0.24 (0.67)	1.94	6.94	3.31, 14.57	26.28***	118.71	31.88***
Face touching	1.47 (3.32)	0.80 (1.69)	0.60	1.83	1.05, 3.19	4.54*	136.78	4.58*
Parental responses[b]	0.37 (1.40)	0.04 (0.30)	1.44	4.22	0.84, 21.11	3.08+	60.51	21.51***

Note. ADHD = attention-deficit/hyperactivity disorder; TD = typically developing; Toy to Mouth = frequency of how many times a child put a toy in their mouth during the 5-min play period; Face Touching = frequency of how many times a child touched their face/mouth with their hands during the 5-min play period; Parental Responses = frequency of how many times a child's parent either verbally or physically prompts the child to remove the toy or their hands from their face/mouth; 95% CI = 95% confidence interval of the difference; LB = lower bound; UP = upper bound; Diagnostic status coded as ADHD = 1 and TD = 0.

[a]Mean and SD across the 5-min observation period.

[b]Face touching and toy to mouth frequencies included in the model as covariates.

*$p < .05$; ***$p < .001$; +$p < .08$.

Table IV. *Model for Predicting Total Toy to Mouth Frequency*

	B	e^{bx}	95% CI [LB, UB]	Wald's χ^2	Deviance	Likelihood ratio chi-square
Model 1a: ADHD symptomatology					114.07	36.52***
BASCatten (P/T)[a]	0.09	1.09	1.05, 1.14	18.72***	—	—
BASChyp (P/T)[a]	−0.003	1.00	0.97, 1.03	0.04	—	—
Model 2a: EF-based measures					111.40	27.53***
HTKS (O)	0.01	1.01	0.99, 1.03	1.79	—	—
Flanker (O)	0.001	1.00	0.98, 1.03	0.01	—	—
DCCS (O)	−0.04	0.96	0.94, 0.99	11.05**	—	—
BRIEF (P/T)[a]	0.03	1.03	1.01, 1.05	8.32**	—	—
Model 3a: combined					105.78	34.48***
BASCatten. (P/T)	0.07	1.07	1.03, 1.13	8.90**	—	—
BRIEF (P/T)[a]	−0.003	1.00	0.97, 1.02	0.04	—	—
DCCS (O)	−0.02	0.98	0.96, 1.00	3.57+	—	—

Note. ADHD = attention-deficit/hyperactivity disorder; EF = executive functioning; BASCatten = Behaviors Assessment System for Children attention problems subscale; BASChyp = Behaviors Assessment System for Children hyperactivity/impulsivity subscale; items HTKS = Head-Toes- Knees-Shoulder task; Flanker = Flanker Task; DCCS = Dimensional Change Card Sort; BRIEF = Brief Rating Inventory of Executive Function metacognition subscale; LB = lower bound; O = observational measure/assessment; P = parent report measure; T = teacher report measure; UP = upper bound.

[a]Max score was derived from the highest score between parent and teacher rating.

**$p < .01$; ***$p < .001$; +$p < .07$.

frequency. It is important to note that no significant interactions emerged between inattention and EF (BRIEF or DCCS) in predicting germ spreading behaviors. Of note, there were no significant interactions between inattention and any EF measure ($p = .11$–$.89$) in the prediction of toy to mouth frequency. While not part of the final model, there was also no significant interaction between parental responses and ADHD symptomology (inattention nor hyperactivity/impulsivity, $p = .15$ and .65, respectively) nor EF ($p = .10$–.97) in the prediction of toy to mouth frequency.

Negative Binomial Analyses: ADHD Symptomatology, EF, and Face Touching Frequency

Model 1b: Only ADHD Symptomatology

As seen in Table V, negative binomial regression analyses for Model 1b, Wald's test indicated that inattention was not a significant predictor of face touching frequency (p = .55), and hyperactivity/impulsivity was only marginally significant (p = .07). Therefore, no predictor variables from model 1b were retained.

Model 2b: Only EF Questionnaires and Observations

In Model 2b, Wald's test revealed that only the BRIEF was a significant predictor of face touching frequency, Wald χ^2 (1) = 8.45, p = .004, such that increased EF problems as rated by the parent and teacher on the BRIEF (β = 0.03, $p < .01$), were associated with increased face touching frequency. While not part of the final model, there was also no significant interaction between parental responses and ADHD symptomology (inattention nor hyperactivity/impulsivity, $p = .67$ and .78, respectively) nor EF ($p = .26$–.88) in the prediction face touching frequency.

Table V. *Model for Predicting Total Face Touching Frequency*

	b	e^{bx}	95% CI [LB, UB]	Wald's χ^2	Deviance	Likelihood ratio chi-square
Model 1 b: ADHD symptomatology					126.81	14.55**
BASCatten (P/T)[a]	0.01	1.01	0.97, 1.05	0.36	—	—
BASChyp (P/T)[a]	0.03	1.03	1.00, 1.07	3.19+	—	—
Model 2 b: EF-based Measures					120.98	17.07**
HTKS (O)	0.01	1.01	0.99, 1.02	0.24	—	—
Flanker (O)	−0.01	0.99	0.97, 1.02	0.50	—	—
DCCS (O)	0.004	1.00	0.98, 1.03	0.14	—	—
BRIEF (P/T)[a]	0.03	1.03	1.00, 1.05	8.45**	—	—

Note. ADHD = attention-deficit/hyperactivity disorder; EF = executive functioning; BASCatten = Behaviors Assessment System for Children attention problems subscale; BASChyp = Behaviors Assessment System for Children hyperactivity/impulsivity subscale; items HTKS = Head-Toes- Knees-Shoulder task; Flanker = Flanker Task; DCCS = Dimensional Change Card Sort; BRIEF = Brief Rating Inventory of Executive Function metacognition subscale; LB = lower bound; O = observational measure/assessment; P = parent report measure; T = teacher report measure; UP = upper bound.

[a]Max score was derived from the highest score between parent and teacher rating.

$^{**}p < .01$; $^{+}p < .08$.

Discussion

To our knowledge, this is the first study to examine germ spreading behaviors in young children with and without ADHD, and the ways in which their parents respond to these behaviors. Our results indicate that during a play situation, ADHD diagnostic status is significantly associated with higher rates of germ spreading behaviors, such that children with ADHD put toys in their mouth and touch their face with their hands at higher rates compared with TD children. Additionally, increased attention problems, worse cognitive flexibility performance, and parent/teacher report of poor metacognition, predicted higher rates of toy to mouth frequency. Poor metacognition also predicted higher rates of face touching frequency. Lastly, diagnostic status was not significantly associated with parental responses nor did parental responses moderate the link between ADHD symptomology/EF and germ spreading behaviors. In the age of COVID-19, where the prevention of illness transmission is becoming increasingly important, the implications and relevance of these findings are discussed in detail below.

Beyond the spread of COVID-19, it is particularly important to understand the risk factors associated with illness transmission in young children. Specifically in the preschool setting, children are at higher risk for common infectious diseases (i.e., diarrheal illness, upper respiratory infection) compared with children who are cared for in the home (Teherani et al., 2020). Children's infectious diseases are also costly to parents due to lost earnings from staying home from work or alternative child care (Nørgaard, et al., 2021). The current results suggest that children with ADHD may be more likely to spread germs via putting toys in their mouth and touching their face with their hands compared with their TD peers. One important component of personal hygiene interventions for young children is handwashing (Jess & Dozier, 2020), given that hands are the most common mode of transmission of bacteria/virus' (Rabie & Curtis, 2006). Multiple antecedent strategies have been proven useful in increasing handwashing quality and frequency in young children, such as vocal and visual prompts (Deochand et al., 2019; Jess et al., 2019; Rosen et al., 2011). In addition to handwashing efforts, further preventative measures by clinicians, practitioners, and teachers that work with children with ADHD should emphasize sanitizing toys more often when working with this population in order to reduce illness transmission in children. Additionally, interventions that target improving personal hygiene for young children with ADHD may emphasize teaching children not to put toys in their mouth, as well as instructing their parents to clean toys at a higher frequency.

Partially consistent with our second hypothesis on ADHD symptomology, only inattention was significantly associated with germ spreading behaviors. The link between higher levels of inattention and germ spreading behaviors may be due to such children having higher levels of distractibility when being taught by adults social norms regarding hygiene (e.g., not putting toys in your mouth). In terms of the null findings related to hyperactivity/impulsivity, the BASC-3 may reflect a broader measure of gross motor skills (i.e., child is in constant motion, interrupts parents while they are talking, overly active), whereas germ spreading behaviors may be more sensitive to more fine motor behaviors (i.e., fidgeting with toys, touching face). The BASC-3 also does not differentiate which items are associated with neither hyperactivity nor impulsivity, which is a common issue when examining these domains via questionnaires (Martel et al., 2010; Toplak et al., 2009). It may be important for future work to determine with more precise measures (i.e., actigraph, Go/No-Go task) whether symptoms related to impulsivity (i.e., acts without thinking, poor self-control), are more strongly associated with germ spreading behaviors compared with symptoms of hyperactivity (i.e., unable to slow down, in constant motion).

As it relates to EF, two out of the four measures significantly predicted germ spreading behaviors, such that worse cognitive flexibility (DCCS) was associated with increased toy to mouth frequency and parent/teacher report of poor metacognition was associated with both increased toy to mouth and face touching frequency. Previous work supports a two-factor model of EF across preschool-aged children, where cognitive flexibility was differentiated from IC, but not WM (Scionti & Marzocchi, 2021). The findings from our performance-based tasks suggest that impairment only in cognitive flexibility (but not IC) is associated with germ spreading behaviors, in terms of putting toys in one's mouth. This finding is noteworthy given that cognitive flexibility only starts to emerge during the preschool years and improves significantly during early and middle childhood (Buttelmann & Karbach, 2017). As it relates to our ecologically valid measure of EF (i.e., parent/teacher report) the BRIEF metacognition scale, which taps into WM, significantly predicted both toy to mouth and face touching frequency. Overall, these findings highlight that children with poor EF may require multiple prompts/reminders and more careful monitoring, which targets both WM and cognitive flexibility, when engaging in preventative hygienic efforts.

Lastly, contrary to our third hypothesis, parents of children with ADHD did not respond significantly more than parents of TD children in response to germ spreading behaviors, even though children with ADHD put toys in their mouth significantly more than TD children. Parents of children with ADHD may be more focused on their child's behavioral difficulties associated with ADHD (i.e., sitting still, playing quietly) than on germ spreading behaviors. Considering the more lax parenting strategies among parents of children with ADHD (Kaiser et al., 2011; Lange et al., 2005), parents may be "picking their battles" and only responding to extreme behavioral difficulties. There was also no interaction between parental responses and ADHD symptomology or EF as it relates to predicting toy to mouth frequency. As can be seen in the lower half in Table II, the lack of an interaction may have been a function of the very low base rates of parental responses for both children with ADHD and TD children. Given that the parent–child interactions took place before the COVID-19 outbreak, germ spreading may not have been a main focus for parents of children with ADHD. It would be important to longitudinally track such parent–child interactions to determine changes in parenting responses to germ spreading behaviors.

In terms of limitations, we acknowledge that we did not covary for internalizing disorders. Several studies have examined EF deficits in children with ADHD in combination with comorbid disorders; however, results are inconsistent and limited in number. For example, children diagnosed with ADHD that also reported clinical levels of anxiety showed better behavioral inhibition (Bloemsma et al., 2013). However, in a study examining WM, children with ADHD and comorbid anxiety displayed similar impairment to children with only ADHD, compared with TD children and anxiety only group (Manassis et al., 2007). A second limitation of the current study is that the types of toys were not taken into account in regards to their influence on germ spreading behaviors. To our knowledge, there is no research on whether or not the type of toy a child plays with influences their behaviors in regards to germ spreading. It may be that food toys (i.e., pretend food, plates, and cups) encourage children to put the toys in/near their mouth, thereby facilitating germ spreading behaviors more than legos or potato heads, which were utilized in the current study. If in fact this is true, interventions may implement guidelines that specify increased rates of cleaning for food toys specifically. Another limitation was the very low frequency of respiratory means of transmission (e.g., coughing and sneezing), which ultimately resulted in its exclusion. Future work should examine such means of transmission and preventative measures, such as mask wearing, within an ADHD population. In regards to generalizability, another limitation is that participants were medication naïve which may impact the rate at which they put toys in their mouth or touched their face with their hands. While no study to date addresses the effects of psychotropic medications on the frequency of such behaviors in young children, future work should examine whether psychotropic medications mitigate the link between ADHD and germ spreading behaviors, considering that about 18% of children between the ages of 2–5 diagnosed with ADHD take medication (CDC, 2022). Finally, the parent–child interactions occurred before the COVID-19 pandemic when parents may not have been attuned to germ spreading behaviors compared with after prevention efforts were implemented. Future work should examine whether parent–child interactions differ pre to postpandemic.

Despite the limitations, the current study provides some implications for early interventions for children with ADHD and health-related prevention efforts. Even though children with ADHD engage in germ spreading behaviors more than their TD peers, their parents do not respond significantly more than parents of TD children. Treatments targeting behavioral difficulties associated with ADHD may focus on decreasing germ spreading behaviors by teaching parents more positive interventions, such as providing labeled praises for keeping toys out of the child's mouth, in addition to modeling appropriate play. While our sample is predominately Hispanic, there is no research to date that would suggest that Hispanic children would engage in more germ spreading behaviors than other children.

Although Hispanics are at higher risk for contracting COVID-19 and other diseases (Cheng et al., 2019; El Chaar et al., 2020), these associations may be due to other health disparities such as low socioeconomic status and lack of resources (Macias Gil et al., 2020). In terms of cultural considerations on parenting, some researchers have described Hispanic parents as warm, egalitarian, and family oriented, and others as punitive and authoritarian (Cardona et al., 2000). More recent work suggests that parenting styles and behaviors are more closely linked to a family's degree of acculturation and enculturation within the dominant culture (Gonzalez & Méndez-Pounds, 2018), suggesting considerable variability in parenting styles/behaviors within the Hispanic culture. While the current results may not generalize to other populations, we consider our diverse sample strength in identifying specific parenting behaviors within the largest growing minority group in the U.S. Census Bureau (2020). Given the current emphasis on decreasing illness transmission, professionals working with young children (i.e., teachers, pediatricians, and therapists) may consider sanitizing toys more frequently, specifically food-related toys that may encourage children to put toys in their mouth. An additional important implication in understanding the mechanisms of germ spreading behaviors in children with ADHD and parental responses, which may offer important insights towards understanding which factors contribute to illness transmission in young children, such as inattention problems and poor EF.

In summary, this study focused on a novel and unexplored research question by examining germ spreading behaviors in young children with and without ADHD. Strengths include the direct observations of germ spreading behaviors in young children during a play-situation, including multiple indicators of EF, and a well characterized sample of children with and without ADHD. Our results provide preliminary evidence that children with ADHD engage in higher rates of germ spreading behaviors relative to TD children. There were no differences between parents of children with and without ADHD in terms of parental responses. Further examination suggests that poor attention and worse EF both independently predict higher rates of germ spreading behaviors. As health-related prevention efforts become increasingly important, future work should examine the effects of parental responses to germ spreading behaviors in young children (e.g., whether TD children comply with their parent's verbal and/or physical prompt more than children with ADHD) and whether the type of toy a child plays with influences germ spreading behaviors.

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