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Latent Class Analysis Reveals Distinct Groups Based on Executive Function and Socioemotional Traits, Developmental Conditions, and Stuttering: A Population Study

Sara Ashley Smith[1] · **Ai Leen Choo**[2] · **Matthew E. Foster**[3]

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Abstract
A growing body of research has reported associations between weaker Executive Functions (EF), the set capacities that are needed to manage and allocate one's cognitive resources during cognitively challenging activities and various neurodevelopmental conditions, including stuttering. The majority of this research has been based on variable-centered approaches, which have the potential to obscure within-population heterogeneity. Person-centered analyses are essential to understanding multifactorial disorders where relationships between indicators have been elusive, such as stuttering. The current study addressed gaps in the literature by using latent class analysis (LCA), a person-centered approach, to identify homogenous subgroups within the National Health Interview Survey (2004–2018) publicly available data set. Using this exploratory approach, we examined the hypothesis that there exist distinct classes (or subgroups) of children based on parent reports of EF, Socioemotional (SE) traits, developmental atypicality, and stuttering. Our analyses revealed distinct subgroups with substantially different likelihoods of parent-reported stuttering behaviors and developmental atypicality. For children with both EF and SE difficulties, the likelihood of parental report of stuttering and atypical development was even higher, in fact this likelihood (of stuttering and not-typically developing) was highest among all subgroups. In contrast, children without difficulties were the least likely to be reported with stuttering or not-typically developing. Our findings are consistent with theoretical frameworks for stuttering, which cite EF as a crucial component in the disorder. Additionally, our findings suggest within-population heterogeneity among children with EF difficulties and, specifically, EF and SE heterogeneity among children who stutter.

Keywords Latent profile analysis · Children · Executive function · Emotion regulation · Stuttering

Introduction

Executive Functions (EF) is an umbrella term used to describe a constellation of higher order, top-down capacities that are needed to manage and allocate one's cognitive resources during cognitively challenging activities [1, 2]. These capacities include switching between tasks, focusing attention, ignoring distractions, inhibiting unhelpful impulses, and updating and manipulating information stored in working memory (WM; [3, 4]). A growing body of research has reported associations between weaker EF and various neurodevelopmental conditions, such as stuttering which is characterized by disfluent speech (for a review see [5–7]).

Many studies have used regression analysis to compare EF among individuals with and without developmental disorders and sought to identify clinical thresholds for deficits.

✉ Sara Ashley Smith
sarasmith3@usf.edu

Ai Leen Choo
achoo1@gsu.edu

Matthew E. Foster
mefoster@usf.edu

[1] College of Education, University of South Florida, 4202 East Fowler Ave., EDU 302H, Tampa, FL 33620, USA

[2] Department of Communication Sciences and Disorders, Georgia State University, 30 Pryor St. SW, Atlanta, GA 30303, USA

[3] Rightpath Research and Innovation Center, University of South Florida, 13301 Bruce B. Downs Blvd., MHC 1721, Tampa, FL 33602, USA

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This body of work has generated many hypotheses related to EF as the core deficit or one of multiple contributors in various conditions. Examples for stuttering include, Dual Diathesis-Stressor Model [8], Covert Repair Hypothesis [9], Vicious Circle Hypothesis [10]. The Dual Diathesis-Stressor Model of Stuttering (DD-S) proposes that a combination of predisposing factors and situational stressors, specifically emotion and language, increase stuttering [8]. The Covert Repair Hypothesis points to multiple or excessive attempts to repair speech plans and deficits in phonetic priming and encoding as the cause of stuttering [9]. The Vicious Circle Hypothesis [10] suggests that increased attention on speech errors and ensuing attempts at repairs causes stuttering. However, there are also contradictory findings (for an overview see [6]) and potential for bidirectional relationships, i.e. an atypical child might not have the same opportunities or access to various EF developing activities (for examples see, [2]).

The majority of developmental research on EF has been based on variable-centered approaches [11]. There are limitations intrinsic to making group comparisons using variable-centered approaches (e.g., regression) and potential to over-simplify the complex relationships among indicators of EF, socioemotional (SE) traits, and developmental disabilities. Implicit in this framework are assumptions of homogeneity (i.e., no subgroups) within the population [12]. Variable-centered approaches (c.f. regression) describe how independent and dependent variables are related, based on previously observed relationships. In contrast, person-centered approaches such as latent class analysis focus on identifying unobserved relationships in a population. Individuals within the population are classified into distinct subgroups based on a chosen set of indicators, not arbitrarily based on cut scores or previously established clinical groups and thresholds. Individuals in each group are more similar to one another than they are to individuals in other groups (for review see, [13, 14]).

Person-centered analyses are essential for understanding multifactorial disorders where relationships between indicators have been elusive [11], such as stuttering. The person-centered approach allows researchers to identify particular sets of characteristics that describe subgroups of children and detect complex interactions of multiple factors [11, 12]. Further, person-centered approaches align with holistic theories of human development; factors are meaningful as components of an entire person-environment system [11].

Latent class analysis (LCA) is a type of mixture modeling that involves nominal and/or categorical variables. LCA is advantageous because there are no assumptions about the distributions of the indicators (e.g., normality). LCA has also been applied in several domains [11, 15–19]. In the present study, we use LCA to identify subgroups within the larger population of children in the US based on indicators of EF, SE traits, stuttering, and developmental typicality. Individuals can demonstrate no, mild, moderate, or severe difficulties with EF, SE, or any combination of these, which can be further differentiated by the presence or absence of stuttering and/or developmental typicality. In theory, many classes of EF, SE, stuttering, and developmental typicality/atypicality could emerge.

Executive Functions and Socioemotional Traits

EF underpins self-control, emotional regulation (modulation of internal emotional arousal, positive or negative), fluency, and goal-oriented behavior [2, 20]. EF follows a generally predictable developmental timeline, manifesting in infancy as the ability to direct attention and progressing into the complex capacities found in typical adults (for a review, see [2]). Higher EF in childhood is associated with greater academic achievement (for a review see [21]). This likely due to the supporting role EF plays for many schooling-related factors (sustained attention, problem solving, planning, and critical thinking); EF is associated with language learning (for a review see [22]), literacy [23], mathematics [24].

SE development refers to "the developing capacity of the child from birth through five years of age to form close and secure adult and peer relationships; experience, regulate, and express emotions in socially and culturally appropriate ways" ([25], p.2). EF underpins some factors relevant to SE, such as emotional regulation, inhibition, and goal orientated behavior [2]. Children must use inhibition to halt socially inappropriate responses, selectively attend to relevant information, remember social norms, and utilize EF as a whole to regulate behavior [1, 26, 27]. In typically developing children, EF predicts SE competence [28, 29]. Stronger inhibitory control, i.e. better self-regulation, is correlated with higher social status (more popular) in children [30]. Conversely, EF difficulties are associated with negative behaviors [29, 31–33].

Stuttering

Developmental stuttering is a neurodevelopmental disorder wherein the speaker produces disfluencies in the forward flow of speech at a degree that is considered clinically atypical (i.e. receive a clinical diagnosis of stuttering); disruptions in overt speech (i.e. blocks, prolongations and repetitions) are the hallmark of this disorder [34]. Developmental stuttering (hereinafter referred to as stuttering) is relatively low prevalence (4–8% of children and 1% of the general population; [35, 36]). Approximately 70% of children who stutter experience unassisted recovery within two to three years after onset [37]; reasons for this are unknown [8]. For the remaining 1% of children who continue to stutter after age 6, stuttering

can be a "life-changing disorder" ([8], p. 633). Children who stutter face greater risk for peer victimization and lower academic achievement [38–40]. Individuals who stutter are less likely to graduate high school, have lower rates of employment, lower quality of life [38, 39, 41–48]. Stuttering is not well understood and few successful remediations exist for those who do not experience unassisted recovery [49]. The ability to pinpoint factors that increase risk for developing stuttering, chronicity, and severe symptom manifestation is crucial [8].

Stuttering is a multifactorial disorder that includes speech, language, cognitive, and emotional components; all of which likely impact quantity, quality, and recovery [8]. In general, children who stutter show weaker EF compared to children who do not stutter [6, 50], however, relationships between EF and stuttering are not fully understood. Even among individuals who do not stutter, stronger EF is correlated with greater speech fluency [51, 52]. EF development may impact functional outcomes among children who stutter. The mechanisms underlying unassisted recovery are unclear, improvement in EF is a candidate cause. Children with weaker EF are less likely to recover compared to those with stronger EF [53]. Reductions in stuttering severity following EF training [54] and lower rates of stuttering in children who stutter with stronger EF are also in agreement with this hypothesis [55]. It is noteworthy that stuttering commonly, although not always, co-occurs with other neurodevelopmental disorders in which EF is implicated, including ADHD and ASD [39, 49]. Thus, children who stutter may reveal insights into the relationship between developmental atypicality and EF.

Children who stutter also show higher rates of SE difficulties, psychological distress, and anxiety compared to children who do not stutter (for an overview see [56]). This may be multiply determined and at least in part caused by stuttering. The majority of children who stutter (81%) report psychological distress related to stuttering [40]. Children who stutter also experience lower self-confidence and difficulty in making friends [44, 57]. Further, SE difficulties may also be related EF difficulties, specifically emotional regulation and emotional reactivity, the threshold and frequency with which one experiences intense emotional arousal, distinct from modulating this internal arousal, i.e. emotional regulation [8]. Children who stutter show weaker emotion regulation compared to children who do not stutter, and children who stutter with weaker emotion regulation present more severe stuttering than their counterparts with stronger emotion regulation [58]. Emotion regulation may have consequences for SE [59], as stronger emotion regulation is correlated with better SE competence among children who do not stutter [60].

Developmental Disorders and EF

Children with other speech-language and neurodevelopmental disorders such as ADHD and ASD have varying degrees of clinical EF deficits (for a review see [5, 61–64), although degree of deficit may vary across disorders [65]. Children with developmental delays and disabilities are also at risk for SE difficulties [66]. Comorbidity is commonly reported in neurodevelopmental disorders, and children with comorbid conditions show more profound EF deficits compared to children without comorbidity [64, 67, 68]. For example, children with multiple diagnoses of ADHD with anxiety or conduct disorders show weaker performance on EF tasks which necessitate WM, attention, and inhibitory control, relative to children with ADHD without comorbidity [69]. Findings from the direct measures are consistent with parent reports (Behavior Rating Inventory of EF [BRIEF]; [70]) of lower EF in children with comorbidity compared to children without comorbidity [68].

Current Study

The current study addressed gaps in the literature by using LCA, a person-centered approach, to identify homogenous subgroups within the National Health Interview Survey (NHIS; 2004–2018) publicly available data set. Using this exploratory approach, we examined the hypothesis that there exist distinct classes (or subgroups) of children based on EF, SE, developmental typicality/atypicality, and stuttering. We expected that children with difficulties in EF and SE would also stutter and/or be not-typically developing per parent report. The NHIS data set includes children between the ages of 4- and 17-years, age was controlled for in the final LCA.

Prior to looking at the data, the hypothesis was generated based on previous reports of atypical EF development and socioemotional difficulties in children with neurodevelopmental disorders, including stuttering [6]. Notably, EF is correlated with fluency, children who stutter with stronger EF show less severe stuttering than those with weaker EF [55]. Variables for stuttering, developmental typicality/atypicality, EF, and SE were identified using the NHIS publicly available data set guides and questionnaire documentation available from the Centers for Disease Control NHIS prior to examining any data.

The conspicuous nature of speech disruptions in stuttering has the potential to provide a means to identify EF development in children. Stuttering is easily observed as it manifests as overt speech disruptions. Further, the prognosis of stuttering (chronicity or recovery) could offer insights into EF. Functional speech outcomes could be a viable method to evaluate EF development in children with neurodevelopmental disorders.

Methods

Participants

Data for this study are from the NHIS; 2004–2018. The NHIS is a nationally administered cross-sectional survey, conducted by the Centers for Disease Control and Prevention (CDC) to monitor the health of the U.S., including trends in illness and disabilities [71]. The survey has been administered annually since 1957, providing a nationally representative sample of households in all 50 states and the District of Columbia. For each household, data were collected from a randomly selected sample of adult and children. Information about the child was collected from an adult, typically the parent or guardian. Data were collected face-to-face by trained interviewers who read questions on the survey to interviewees. Some segments of the population were excluded including U.S. citizens not residing in the country, active-duty military personnel, incarcerated inmates, and long-term care facility patients. A total of 180,617 children (females = 81,701, males = 86,492, missing = 12,424) were sampled between 2004 and 2018.

Analysis Sample

Because of the large sample that completed the NHIS, the analysis sample was limited to the children that had complete data across three indicators of EF and three indicators of SE traits, as well as the indicators for stuttering and developmental status ($n = 123{,}809$; described below). The average age of the child participants was 10.79 years ($SD = 4.11$ years, range = 4 to 17 years). This age range aligns with stuttering onset, which begins around 3–4 years old, and is highest among preschool children and decreases with age. 47.70% were male and 44.60% were female (7% of participants did not have information on sex). Of the analysis sample, 25.60% were Hispanic, 66.70% were not-Hispanic, and 7.70% did not provide information on ethnicity. In addition, 66.60% of the analysis sample were White, 14.50% were Black, 5.40% Asian, 1.20% American Indian/Alaskan Native, 4.30% multiple races, 0.30% were of racial backgrounds that were not releasable, and 7.70% were missing. The total number of parents who endorsed that their child stutters was 2119.

Measures

In the following, we describe indicators from the NHIS used in the present study to measure EF and SE competence, stuttering/stammering, and typicality/atypicality. Please see Table 1 for alignment of the following EF and SE competence with items from other measures.

Executive Functioning

Executive functioning (EF) was identified with the following questions: (1) "Well behaved/does what requested, past 6 m", (2) "Good attention/completes chores, homework, past 6 m", and (3) "Difficulties w/emotions/concentration/behavior/getting along". For questions one and two, possible responses were “Unknown”, "Not true", "Somewhat true", and "Certainly true", which were scored as 0, 1, 2, and 3, respectively. For question three, possible responses were “Unknown”, “Severe difficulties”, “Definite difficulties”, “Minor difficulties”, and “No difficulties”, which were scored as 0, 1, 2, 3, and 4, respectively. Responses that did not provide estimates of EF functioning, i.e., "Unknown", were NOT excluded from the analysis.

Social-Emotional Traits

Responses to the following SE traits questions were included in the analysis: (1) "Many worries/often seems worried, past 6 m", (2) "Unhappy/depressed/tearful, past 6 m", and (3) "Gets along better w/adults than children/youth, past 6 m". Each of the previous questions had four possible responses: “Unknown”, “Certainly true”, “Somewhat true”, and “Not true”, which were scored 0, 1, 2, and 3, respectively. Responses that did not provide estimates of SE traits (i.e., "Unknown") was not excluded from the analysis.

Group

Responses to the question about a parent’s child stuttering or stammering during the past 12 months was included. The responses included “Child with no stuttering/stammering”, “Child with stuttering/stammering”, and “Unknown”. The previous responses were scored as 0, 1, and 3 respectively.

Developmental Status

Responses to the question regarding the developmental status of the child were “Typically developing” and “Non-typically developing”. These responses were scored as 0 and 1, respectively.

Table 1 Questions related to executive function and socioemotional competence on the National Health Interview Survey (NHIS) and equivalent questions on the BRIEF, Behavior Assessment Scale for Children (BASC), Child Behavior Checklist (CBCL), and Strengths and Difficulties Questionnaire (SDQ)

NHIS	BRIEF	BASC – EF Domain	CBCL	SDQ
Executive functioning				
Well behaved/does what requested, past 6 m	Gets out of control more than friends; Has outburst for little reason; Acts too wild or "out of control" (on the Teacher form)	Acts out of control; Listens to directions		
Good attention/completes chores, homework, past 6 m	Has short attention span; Has trouble finishing tasks (chores, homework, etc.)	Pays attention; Has short attention span; Is easily distracted		
Difficulties/emotions/ concentration/ behavior/getting along	Has explosive angry outburst; Has trouble concentrating on tasks, schoolwork, etc.; Reacts more strongly to situations than other children, Becomes upset too easily	Has trouble concentrating		
Socioemotional competence				
Many worries/often seems worried, past 6 m			Worries	Many worries, often seems worried
Unhappy/depressed/tearful, past 6 m			Cries a lot; Unhappy, sad, depressed	Often unhappy, down-hearted or tearful
Gets along better w/adults than children/youth, past 6 m			Doesn't get along with other kids; Compared to others of his/her age, how well does your child: Get along with his/her brothers & sisters? Get along with other kids? Behave with his/her parents?	Gets on better with adults than with other children

Data Analytic Strategy

To empirically identify classes of children based on indicators of EF, SE traits, stuttering, and developmental status, a series of mixture models were estimated in Mplus (Version 8.2). Mixture modeling refers to modeling with categorical latent variables that represent subpopulations (or subgroups) where population membership is inferred from the data. Such person-centered approaches are advantageous because they can help us understand how dimensions of development coalesce within clusters of students [72]. In the present study, we used a particular type of mixture model, referred to as a LCA. All LCAs were based on binary and ordered categorical data from the measures described above.

All models used full information maximum likelihood estimation (FIML) with robust standard errors using the expectation–maximization (EM) procedure. All models were estimated with 1000 random starts and 100 iterations to ensure that a global rather than a local solution (or maxima) was identified [73]. By default, the variances and covariances were held to equality across classes. To help approximate the correct number of latent classes, the number of classes estimated was increased incrementally, one class at a time, until model interpretability clearly indicated that model testing should cease [74, 75]. In addition, the overall fit of each model was assessed using the Bayesian information criteria (BIC), change in BIC (ΔBIC), sample size adjusted BIC (SSABIC), entropy, and Vuong-Lo-Mendell-Rubin likelihood difference test (VLMR). Lower values of the BIC and SSABIC indicate better model fit than higher values. Entropy is the average probability that each individual is correctly classified into a specific group, with values closer to 1.00 indicating better classification accuracy [76]. The VLMR tested the current model against the model with one less class. VLMR *p*-values less than 0.05 indicate that the current model is a significant improvement in model fit over the more parsimonious model with one less class. In addition to the previous model fit criteria, theoretical justification, model parsimony and interpretability, successful model convergence, high posterior probabilities (near 1.0), and the number of students within each class (i.e., no less than 1% of the total sample within a class) were considered when selecting the number of classes and determining the optimal solution [74, 75]. After identifying the optimal class solution, age was included as a covariate in that model as recommended in Nylund-Gibson and Masyn [74, 75]. Finally, item response probabilities, which are specific to each class and in this study, provide information on the probability of a parent of a child in that class to endorse the item response, were examined. Item probabilities > 0.70 and < 0.20 indicate high homogeneity or how similar children were to one another with respect to their item responses within a latent class.

Results

Prior to running the series of LCAs, the frequency distributions for the eight variables from the NHIS data set were examined according to participant's sex (see Table 2).[1] The results of each LCA is reported in Table 3. The BIC continued to decline with the addition of each class, indicating the appropriateness of adding classes. Entropy was greater than 0.78 for each class solution, indicating that each student, on average, was correctly classified into a specific class. In addition, the posterior probabilities for the first five solutions correctly estimated the latent group membership. The posterior probabilities dropped substantially for the six- and seven-class solutions and were therefore ruled out as plausible. Despite not supporting the addition of the second class to the one class model, the VLMR supported the addition of a class to the two-, three-, and four-class solutions. The interpretability of each class solution was also considered as were each solution's item-response probabilities.

Given the collective information, the five-class solution was considered the optimal, most theoretically meaningful, and interpretable solution. Before describing the five classes, an additional LCA was run, controlling for the effect of age within the five-class solution. The fit statistics of that model were exactly the same as those reported in Table 3 Model 5. In addition, the same number of participants were in each class when we controlled for participants' age as when we did not. We therefore describe the five classes here, based on the final class counts and proportions for the most likely latent class membership. Table 4 displays the item-response probabilities given class membership. Probabilities greater than 0.50 are bold to facilitate interpretation, indicating that parents had a higher probability of endorsing a category for children in that latent class. Please note that preliminary models indicated that sex did not differentiate the classes identified in the present study. Initially, this was surprising, given prior literature demonstrating differential associations between EF, SE, and sex (see for examples, [77–79]; however, for a recent review finding no conclusive differential relationships between sex and EF in childhood, see [80]).

[1] Preliminary analyses suggested that participant's sex was minimally associated with parent report of stuttering ($r_{Spearman}$ = -0.054). In addition, LCAs with participant sex included as an indicator evidenced convergence issues and fit more poorly than the corresponding LCAs without sex (see Appendix A). Participant's sex was therefore not included in our final LCAs.

Table 2 Frequency distributions for the observed variables from the NHIS data by sex (n = 114,310)

Observed variables and responses	Frequency (Valid %)	
	Male	Female
Well behaved		
Unknown	697 (1.2%)	623 (1.1%
Not true	2075 (3.5%)	1466 (2.7%)
Somewhat true	13,232 (22.4%)	9565 (17.3%)
Certainly true	43,033 (72.9%)	43,619 (78.9%)
Good attention, completes chores, homework		
Unknown	768 (1.3%)	686 (1.2%)
Not true	7894 (13.4%)	4760 (8.6%)
Somewhat true	18,138 (30.7%)	12,964 (23.5%)
Certainly true	32,237 (54.6%)	36,863 (66.7%)
Difficulties with emotions, concentration, behavior, and getting along with others		
Unknown	661 (1.1%)	584 (1.1%)
Sever difficulties	889 (1.5%)	504 (0.9%)
Definite difficulties	2956 (5.0%)	1711 (3.1%)
Minor difficulties	9981 (16.9%)	7219 (13.1%)
No difficulties	44,550 (75.5%)	45,255 (81.9%)
Many worries; often seems worried		
Unknown	748 (1.3%)	663 (1.2%)
Certainly true	3299 (5.6%)	3310 (6.0%)
Somewhat true	10,425 (17.7%)	10,722 (19.4%)
Not true	44,565(75.5%)	40,578 (73.4%)
Unhappy, depressed, and tearful		
Unknown	723 (1.2%)	655 (1.2%)
Certainly true	1637 (2.8%)	1721 (3.1%)
Somewhat true	4860 (8.2%)	5111 (9.2%)
Not true	51,817 (87.8%)	47,786 (86.5%)
Gets along better with adults than children or youth		
Unknown	981 (1.7%)	887 (1.6%)
Certainly true	6509 (11.0%)	6158 (11.1%)
Somewhat true	12,694 (21.5%)	11,716 (21.2%)
Not true	38,853 (65.8%)	36,512 (66.1%)
Group		
Child without stuttering	57,492 (97.4%)	54,641 (98.9%)
Child with stuttering	1517 (2.6%)	602 (1.1%)
Unknown	28 (< 0.01%)	30 (0.10%)
Development status		
Typically developing	40,082 (67.9%)	43,322 (78.4%)
Not typically developing	18,955 (32.1%)	11,951 (21.6%)

However, after taking a closer look at the results, we identified that the correlation between sex and stuttering was only − 0.054. Despite this low correlation, Table 2 was consistent with reports in the literature, that males ($n = 1517$) are more likely to stutter than females ($n = 602$), but sex did not further differentiate the profiles beyond the results presented below.

Children Without Difficulties Subgroup (n = 82,557; 66.68%)

Most of the children could be described as not having EF or SE difficulties. Parents of these children displayed a high probability of endorsing their children as well-behaved (92.70%), showing good attention, and

Table 3 Model fit statistics for latent class solutions

		BIC	BIC change	SSABIC	Entropy	Classification probabilities	VLMR LRT *p*	Smallest profile size
1	Profile solution	1,293,982	NA	1,293,912	NA	NA	NA	123,809
2	Profile solution	1,188,528	105,454	1,188,385	0.853	.913 to .969	0.3333	22,676
3	Profile solution	1,136,054	52,474	1,135,838	0.881	.911 to 1.00	0.00001	1596
4	Profile solution	1,124,534	11,520	1,124,245	0.815	.779 to .999	0.00001	1596
5	**Profile solution**	**1,113,018**	**11,516**	**1,112,656**	**0.791**	**.794 to 1.00**	**0.00001**	**1594**
6	Profile solution	1,109,557	3,461	1,109,122	0.796	.690 to .999	0.00001	1594
7	Profile solution	1,107,207	2,350	1,106,698	0.780	.509 to .999	0.046	2072

Bold indicates the solution

completing chores and homework (81.40%). These parents also endorsed their children as not having difficulties with emotions, concentration, behavior, or getting along with others (98.50%). The probability that the children in this group worried (10.70%), were unhappy (1.60%), and got along with adults better than children or youth was low (27.50%) compared to the other groups. The probability that a child in this group stutters was 0.07% and the probability that children in this group were described as not-typically developing by their parents was lower (16.5%) than parents of children in all other groups.

Children with Executive Functioning Difficulties Subgroup (n = 21,359; 17.25%)

Children with Executive Functioning (EF) difficulties made up the second largest group in the sample. Compared to the Children without Difficulties subgroup, parents of these children had a lower probability of endorsing that their children were well-behaved (46.80%) and had good attention and completed chores and homework (16.60%). Parents of these children were also less likely to endorse that their children did not have difficulties with emotions (58.70%) than the parents of children in the Children without Difficulties subgroup. The probability of parents endorsing that their child did not worry (77.10%) was lower than that of the Children without Difficulties subgroup, but not the other groups. The probability that children in the Children with EF Difficulties were unhappy (6.50%) and getting along better with adults (33.90%) was similar to that of the Children without Difficulties subgroup. The probability of the Children with EF Difficulties subgroup including children who stutter (2.80%) was higher than that of the Children without Difficulties subgroup and the Children with SE Difficulties subgroup. The probability that children in the Children with EF Difficulties group were described as not-typically developing (37.60%) was higher than all other groups with the exception of the group of Children with EF and SE Difficulties.

Children with Socioemotional Difficulties Subgroup (n = 9792; 7.91%)

The Children with SE Difficulties group represented the third largest in the sample. Compared to the Children without Difficulties subgroup, children in this group were less likely to be well behaved (74.10%) and have good attention (62.10%), though their behavior and attention was better than children in the other groups. Children with SE difficulties were more likely than the Children without Difficulties subgroup to evidence difficulties with emotions (45.00%), though probability was similar to that of the Children with EF Difficulties group. Compared to all other groups, the Children with SE Difficulties group had a higher probability worrying (89.40%) and being unhappy (64.00%), whereas their probability of getting along better with adults than children (55.60%) was lower than the Children without Difficulties and Children with EF Difficulties groups, but similar to that of the Children with EF and SE Difficulties group. The probability that children in Children with SE Difficulties group stutter was 1.90% while the probability that they were described as not-typically developing (32.30%) was lower than the group of Children with EF Difficulties (37.60%) and Children with EF and SE Difficulties (81.60%).

Children with Executive Functioning and Socioemotional Difficulties Subgroup (n = 8507; 6.87%)

This class represented the second smallest group of the sample. They were less likely to be well-behaved (24.70%), have good attention (30.60%), and evidence no difficulties with emotions (1.80%) compared to all other groups. Other than the Children with SE Difficulties group, children in the Children with EF and SE Difficulties group had higher probabilities of worrying (67.60%), being unhappy (51.60%) and getting along better with adults than children (56.00%). This

Table 4 Item response probabilities for the five class latent solution

Observed variables	Without difficulties	EF difficulties	SE difficulties	EF & SE difficulties	Unknown traits
Well behaved					
Unknown	0.000	0.000	0.000	0.000	**0.952**
Not true	0.010	0.038	0.021	0.214	0.004
Somewhat true	0.063	0.494	0.237	**0.539**	0.011
Certainly true	**0.927**	0.468	**0.741**	0.247	0.033
Good attention, completes chores, homework					
Unknown	0.001	0.001	0.001	0.001	**0.992**
Not true	0.031	0.182	0.048	**0.694**	0.002
Somewhat true	0.154	**0.651**	0.330	0.245	0.001
Certainly true	**0.814**	0.166	**0.621**	0.061	0.005
Difficulties with emotions, concentration, behavior, and getting along with others					
Unknown	0.000	0.001	0.001	0.002	**0.796**
Severe difficulties	0.000	0.000	0.004	0.164	0.007
Definite difficulties	0.000	0.020	0.044	0.458	0.002
Minor difficulties	0.014	0.392	0.402	0.357	0.010
No difficulties	**0.985**	**0.587**	**0.550**	0.018	0.185
Many worries; often seems worried					
Unknown	0.000	0.001	0.001	0.005	**0.974**
Certainly true	0.009	0.007	0.337	0.302	0.002
Somewhat true	0.098	0.222	**0.557**	0.374	0.004
Not true	0.**985**	**0.771**	0.084	0.319	0.020
Unhappy, depressed, and tearful					
Unknown	0.000	0.000	0.001	0.003	**0.980**
Certainly true	0.006	0.000	0.175	0.138	0.001
Somewhat true	0.010	0.065	0.465	0.378	0.001
Not true	0.**983**	0.**935**	0.359	0.481	0.018
Gets along better with adults than children or youth					
Unknown	0.005	0.003	0.005	0.006	**0.995**
Certainly true	0.083	0.077	0.282	0.275	0.001
Somewhat true	0.192	0.259	0.274	0.285	0.001
Not true	**0.719**	0.**661**	0.439	0.435	0.004
Group					
Child without stuttering	**0.993**	**0.972**	**0.981**	**0.905**	**0.974**
Child with stuttering	0.007	0.028	0.019	0.093	0.013
Unknown	0.000	0.000	0.000	0.001	0.014
Development status					
Typically developing	**0.835**	**0.624**	**0.677**	0.184	**0.773**
Not TD	0.165	0.376	0.323	**0.816**	0.227

Probabilities greater than .50 are bold to facilitate interpretation

CWOD children without difficulties, *EF* executive functioning, *SE* socioemotional

group had the highest probability of stuttering (9.30%) and the highest probability of being described as not-typically developing (81.60%)0.40%).

Children with Unknown Traits Subgroup (n = 1,594; 1.29%)

This class represented the smallest group of the sample. Rather than missing data, the overwhelming majority of parents of children in this group endorsed "unknown" as the answer choice for the three indicators of EF and the

three indicators of SE difficulties. The majority of parents of children in this group reported that their children did not stutter (97.40%), although a small proportion of parents in this group reported that their children stuttered (1.3%). Further, parents of children in this group reported that 22.70% of their children were not-typically developing, which was lower than all other groups with the exception of the Children Without Difficulties (16.50%). Fittingly, it is unknown why parents in this subgroup were likely to select "unknown" for many items.

Discussion

This is the first study to identify distinct subgroups of children based on parent report of EF, SE, presence of stuttering, and developmental atypicality in large population-based data set. Using and LCA, a person-centered approach, we identified five subgroups of children that varied in the presence of parent reported difficulties with EF and SE functioning, presence of stuttering and developmental atypicality. The present results are consistent with prior findings of lower EF and SE among children stutter as compared to children who do not stutter (for a review see [6, 81, 82]), however, the results of the present study are highly generalizable to the population of US children ages 4–17. Our analyses identified five distinct subgroups: Children without Difficulties, Children with EF Difficulties, Children with SE Difficulties, Children with EF and SE Difficulties, and Children with Unknown Traits. Within these subgroups, reports of stuttering were highest among Children with EF and SE Difficulties (9.30%), followed by Children with EF difficulties (2.80%), Children with SE Difficulties (1.90%), and Children without Difficulties (0.07%), respectively. The presence of children who stutter in multiple subgroups reveals within-group EF and SE heterogeneity among children who stutter, something not previously identified. Further, the present results suggest that differences in EF and SE traits may be associated with the risk of stuttering.

While previous research using group comparison methods have demonstrated associations between EF, SE, stuttering, and developmental disabilities (e.g., ADHD; [5–7]), the present study is the first to identify that distinct subgroups based on parent reports of EF and SE traits exist and that these subgroups have substantially different probabilities of stuttering and being described as typically/atypically developing. Our subgroups are not based on cut scores or previously established groups. Instead, children within each subgroup have more in common with each other, with regards to the chosen indicators, than the entire sample or than the children in the other subgroups. The presence of children who stutter in multiple subgroups (Children with EF Difficulties, Children with SE Difficulties, Children with EF and SE Difficulties) indicates that there is potential for overlooked heterogeneity related to EF and SE traits when combining children who stutter into one group based on this clinical grouping and comparing them to children who do not stutter, another group with potential EF and SE heterogeneity. Additionally, the fact that a distinct subgroup of children who stutter did not emerge, nor did a distinct subgroup of children who were not typically developing, further underscores the EF and SE heterogeneity within these groups and the potential for oversimplification of complex variables when using group level comparisons [11].

The children who were described in the current study as "stuttering" may or may not have a clinical diagnosis of developmental stuttering and parent reports could be inaccurate. However, the current study used a person-centered methodology based instead on EF and SE traits in addition to the presence and absence of stuttering and atypicality. The study does not compare children who stutter as a group to children who do not stutter as others have done (e.g., [83]); instead, we present findings of empirically identified subgroups based on EF and SE traits and evidence that the likelihood of parent reported stuttering behaviors (which may encompass developmental stuttering per clinical diagnosis and other types of speech atypicality and/or disfluencies) substantially differs among these EF- and SE-based groups. Similarly, parent report of typical development (or not) may or may not be an accurate reflection of a clinical diagnosis. Our findings are consistent with theoretical frameworks for stuttering, which cite EF as a crucial component in the disorder. However, they do not demonstrate temporal causality. Nonetheless, our findings indicate that distinct subgroups of children do exist and differ in likelihood of parent reported stuttering and developmental typicality.

Subgroups

The largest subgroup was the Children without Difficulties subgroup. This subgroup had the highest probability of being described as typically developing by parents. The probability that a child in this subgroup was described as stuttering was low (less than 1%); however, it should be recognized that there are children who stutter in this subgroup. Although stuttering has been associated with concomitant conditions [49, 84], the disorder may not be the predominant condition in some cases and not all people who stutter have concomitant conditions.

The second largest subgroup (Children with EF Difficulties) consisted of children with some elevated difficulties related to EF; although these traits are not necessarily at a threshold that would be considered clinical. Children in this group were unlikely to be described as having good attention, however, they had low probability of being described as

worrying or being unhappy. Children in this subgroup were more likely than any other subgroup to be described as getting along better with peers than adults. This subgroup had a higher likelihood of stuttering than the Children without Difficulties and Children with SE Difficulties subgroups. The Children with EF Difficulties had a higher likelihood of being described as not typically developing than the Children without Difficulties subgroup. It is unclear why children in this subgroup differ in SE from children in the Children with EF and SE Difficulties subgroup. Children in this subgroup may have less severe EF difficulties or there may be an additional variable that contributes to SE wellbeing.

Compared to other subgroups, children in the Children with SE Difficulties subgroup were characterized as having a high probability of being described as worrying and being unhappy. This group had a lower probability of having a developmental disorder than children in either of the two subgroups characterized by EF difficulties (Children with EF Difficulties, Children with EF and SE Difficulties) and was less likely to be described as having a stutter than the two subgroups characterized by parent-reported EF difficulties. However, children in the Children with SE Difficulties subgroup were more likely to have a reported stutter than children in the Children without Difficulties subgroup. It is not known why children in this group are having SE difficulties; however, it appears that for the most part they are developmentally typical with regards to EF. SE wellbeing is a multifaceted construct and while it is associated with developmental challenges and stuttering [40, 44, 57, 66] there are many contributing factors. Prior research has identified variables that impact SE wellbeing such as health and wellness, socio-economic status, adverse childhood experiences such as stressful events, divorce, and trauma [66]. While not the focus of the current study, a future analysis could explore distinct subgroups of children based on indicators of SE wellbeing.

The smallest subgroup of children with known traits was the Children with EF and SE Difficulties subgroup. Among the subgroups with known traits, children in the Children with EF and SE Difficulties group were least likely to be described as being well-behaved and have good attention. They were more likely to evidence difficulties with emotions and had higher probabilities of worrying, being unhappy, and getting along better with adults than children (comparable to children in the SE Difficulties subgroup). Children in this subgroup had the highest probability of stuttering (9.3%) and the highest probability of being described as having not being developmentally typical (81.6%).

EF, Stuttering, and Comorbidity

In the current study, children in subgroups with lower likelihood of being described as having EF difficulties were also less likely to stutter. Children in subgroups that had lower likelihood of stuttering were also less likely to described as not developmentally typical. Stuttering is likely a multiply determined condition [8]. The presence of stuttering may be useful for identifying children (i.e. via heightened levels of overt speech disruptions) as it is an overt indicator of other potential challenges related to EF and SE difficulties, although the heterogeneity of stuttering could also mean that not all children who stutter have EF and SE difficulties. The majority of children who stutter (regardless of sex) were included in one subgroup, Children with EF and SE Difficulties. The results also suggest that male and female stutterers were statistically equivalent in terms of the other class indicators, which are crude parent reports and not reports from clinicians.

Our analyses cannot identify a direct link between stuttering and EF as we did not use an experimental research design and therefore, cannot infer causation. It is possible that higher reports of stuttering in children with EF difficulties is unrelated to EF development in this group. However, our findings are consistent with studies that report weaker EF in children who stutter, and higher stuttering severity in children who stutter with weaker EF compared to children who stutter with stronger EF (e.g., [54, 83]). Thus, our results are consistent with prior research that indicate and association between EF difficulties and the likelihood of comorbid stuttering.

For some children who stutter, stuttering may be the overt expression of challenges related to EF and relatedly might indicate the child could benefit from further interest to figure out if they could use EF or SE supports. In this way, stuttering has the potential to be a used as a means to identify children who might benefit from further support and consideration for possible EF and/or SE difficulties. This is not to say that all children who stutter have EF and/or SE difficulties (see Children without Difficulties) nor does it mean that all children with EF and/or SE difficulties will also stutter. Children with EF and SE difficulties who do not have overt speech expression indicators likely have expressions of EF and SE challenges; these may more subtle or more difficult to identity or they may be highly apparent (for example, attention difficulties) expressions of these challenges. Further, the degree of this overt expression may reflect the magnitude of deficits/difficulties.

Due to the design of the current study, findings do not reveal if stuttering is a cause, a symptom, or if bidirectional relationships might exist (for example, between stuttering and SE items). Children who stutter have a higher prevalence of other conditions such as learning disabilities and developmental delay, as compared to children who do not stutter [82, 83]. In clinical cohorts, stuttering is reported with concomitant language, speech, and behavioral disorders (e.g., expressive language, receptive language, articulation,

phonology, ADHD; [49, 85]). In a study of 2628 children who stutter, Blood et al. [39] found that 62.8% had comorbid speech-language or non-speech-language disorders. The most commonly reported comorbidities were learning disorders (15.2%), reading disorders (8.2%), attention deficit disorders (ADD, 5.9%) and behavioral disorders (2.4%; [39]); all are also associated with EF difficulties.

Not all children who stutter have additional comorbid conditions, however, and the intervening role of comorbidity and EF is not fully known. It is plausible that, similar to findings among children with other developmental disorders, among children who stutter, those that have other conditions have more EF difficulties than children who stutter and do not have other conditions. That is to say, among children who stutter there may exist subgroups based on EF traits. Our findings indicate that there are distinct subgroups of children and that these children differ in part, due to EF. Among these subgroups, likelihood of stuttering is significantly higher among subgroups with EF difficulties than those without (Children without Difficulties; Children with SE Difficulties SED) and higher among Children with SE Difficulties than Children without Difficulties. This indicates meaningful differences among children who stutter.

SE difficulties among children are also likely multiply determined [66]. Parent reported worrying and unhappiness among children in the EF and SE subgroup may be related at least in part to the presence of developmental disabilities and/or stuttering. Prior studies indicate that children who stutter show higher rates of SE concerns, psychological distress, and anxiety than children without stuttering [19, 83, 86–91]. Similarly, children which developmental delays and developmental disabilities are also "at risk" for SE difficulties [66]. However, many factors contribute to SE wellbeing in childhood, include factors unrelated to developmental conditions [66]. SE differences are multifaceted and warrant further exploration.

Theoretical Models

Frameworks for stuttering, such as the Dual Diathesis-Stressor Model, EXPLAN model, Vicious Circle Hypothesis and Cover Repair Hypothesis, cite EF as a crucial component in the disorder [8–10, 92–94]. The Dual Diathesis-Stressor Model suggests that weaker emotion regulation in response to emotional stressors plays a key role in stuttering onset and chronicity [8]. The premise of the model is that greater vulnerability to stressors, related to temperament and EF (emotion regulation) heightens emotional reactivity, triggering stuttering. The EXPLAN model proposes that asynchronous linguistic planning and motor execution due to slower phonological processing results in disfluencies [9, 95, 96]. The Vicious Circle Hypotheses posits that deficits in attentional control are the cause of stuttering [94]. The key assumptions of the Vicious Circle Hypotheses are that increased monitoring and focus on speech errors, and lower threshold for repairs generate high rates of disfluencies [94]. Similarly, the Covert Repair Hypothesis point to multiple or excessive attempts to repair speech plans [9], weaker inhibitory control [97], as the cause of stuttering.

Results from the present study align with these previous frameworks for stuttering. We found that children with EF difficulties were more likely to be reported by parents as stuttering. Deficits in phonological or attentional processing or inhibitory control are associated with stuttering. Findings from studies comparing children who do and do not stutter provide further support for this relationship. In general, children who stutter show weaker EF compared to those who do not stutter [6]. In addition, children who stutter with weaker EF show more severe stuttering compared to children who stutter with stronger EF [54, 55, 90]. This association between EF and speech disruptions is not limited to those who stutter, children who do not stutter with weaker EF also show higher rates of speech disruptions relative to children who do not stutter with stronger EF [81]. Weaker EF is associated with speech disruptions regardless of a stuttering diagnosis, although this relationship may be more salient in children who stutter.

Parents were not asked about their child's stuttering severity. Thus, it is plausible that children who stutter in the different subgroups may differ in severity. For example, some theoretical frameworks for stuttering would predict that children who stutter in the Children without Difficulties would have milder stuttering than those in the subgroups with EF difficulties. The EXPLAN theory attributes stuttering to a lag in linguistic planning, a process which necessitates WM, that is unable to keep up with motor execution [97]. The Covert Repair Hypothesis proposes that deficits in phonetic priming and encoding, both of which rely on phonological WM and attention as the cause of stuttering. If so, both the EXPLAN and Covert Repair Hypothesis would predict milder stuttering with better WM capacity and attentional control. These predictions are partially supported by the finding that children who stutter with stronger WM and attention show milder stuttering compared to children who stutter with weaker EF [54, 55, 91].

There may also be differences in severity between the children who stutter in Children with EF Difficulties and Children with EF and SE Difficulties subgroups. The Dual Diathesis-Stressor model would predict that the degree of emotion regulation would distinguish children across stuttering severity, whereby those with greater capacity for regulation would present milder stuttering than those who are unable to regulate their emotion. Reports that children who stutter are less able to regulate their emotions compared to children who do not stutter [98] as well as findings that

children with higher emotion regulation present less severe stuttering [8, 58] are consistent with this prediction.

Implications

With regards to relationships between EF and stuttering; it is unknown why over 70% of children who stutter experience unassisted recovery within two to three years after onset [37], yet the remaining children stutter persistently. We posit that EF and EF developmental trajectories are a potential contributing factor. Stuttering is still not well understood; our findings indicate that there exist distinct subgroups of children based on EF and SE traits and stuttering, however, there may also be subgroups of children who stutter related to EF. Data that further provides information regarding children who recover from stuttering could further provide insights into EF developmental trajectories and relationships with speech disorders. At present, few successful remediations exist for children who do not experience unaided recovery [50, 98]; thus, we see a possible opportunity gap. There is potential that we are providing less effective remediation based on this incomplete understanding.

The presence of stuttering may be useful for identifying children (i.e. via heightened levels of overt speech disruptions) as it is an overt indicator of other potential challenges related to EF and SE difficulties. This is not a substitute for direct EF assessment as stuttering and EF/SE difficulties are not completely overlapping; our own findings reveal many children with EF and SE difficulties do not experience stuttering. However, speech disruptions are one easily observable marker of possible EF difficulties, although not the only marker and not present in all cases. This could be helpful in settings where individuals not qualified to administer EF screening (for example, teachers) refer children for further evaluation. Prior studies report higher rates of disfluencies in children who do not stutter with weaker EF as compared to their peers with stronger EF (e.g., [81]), thus children with EF difficulties who do not stutter may have more disfluent speech compared to their peers with stronger EF. There is not a one-to-one correspondence between EF and stuttering, however, disfluencies (particularly when present with other challenges) could help direct attention toward children who may need more formal screening and diagnosis.

Limitations and Suggestions for Future Research

While this study revealed several important findings and implications, there were also limitations that must be considered. First, LCA is an exploratory approach and the interpretations of the results are limited to by the variables included in the model. The current study employed parent reports for all indicators (EF, SE, stuttering, and developmental atypicality). In the case of stuttering for example, a parent report is not comparable to a clinical report. We therefore interpret the parent report as indication of reported speech disruption, although there is the potential that a parent would report "stuttering" when a child has a different speech or language condition (e.g., imprecise articulation), and/or may not meet the clinical criteria for stuttering. However, because the present study used person centered method, findings were not reliant on group membership (i.e., children who stutter, children who do not stutter) to draw conclusions. Our findings revealed that children in subgroups based on EF and SE difficulties as well as indicators of typicality and stuttering are more likely to include children with a reported speech disruption issue, which represents a novel contribution to the literature. We suggest future research examine these constructs using direct measures of EF, including direct measures of subcomponents of EF (for example working memory and set-shifting), and clinical reports of stuttering and developmental atypicality, however, this was beyond the scale of current study. As that may be, our findings demonstrate the existence of subgroups even with parent report.

This exploratory approach confirmed our hypothesis that there exist distinct subgroups of children based on parent reports of EF and SE traits, and that the likelihood of developmental atypically and stuttering would differ between these groups. Additionally, our findings suggest within-population heterogeneity among children with EF difficulties and, specifically, EF and SE heterogeneity among children who stutter. The current study used indirect measures (i.e. parent reports), which allowed this person-centered approach (latent class analysis) to identify relationships and potential heterogeneity that could have been overlooked with variable centered group approaches. The current study does not reveal how EF, SE, development (typical or atypical), and stuttering may change over time. We suggest that large-scale longitudinal studies are needed.

Summary

A growing body of research has reported associations between weaker Executive Functions (EF), the set capacities that are needed to manage and allocate one's cognitive resources during cognitively challenging activities and various neurodevelopmental conditions, including stuttering. The majority of this research has been based on variable-centered approaches, which have the potential to obscure within-population heterogeneity. Person-centered analyses are essential to understanding multifactorial disorders where relationships between indicators have been elusive, such as stuttering. The current study addressed gaps in the literature by using latent class analysis (LCA), a person-centered approach, to identify homogenous subgroups

within the National Health Interview Survey (2004–2018) publicly available data set. Using this exploratory approach, we examined the hypothesis that there exist distinct classes (or subgroups) of children based on parent reports of EF, Socioemotional (SE) traits, developmental atypicality, and stuttering. Our analyses revealed five distinct subgroups with substantially different likelihoods of parent-reported stuttering behaviors and developmental atypicality. The majority of children were not reported to have any EF or SE difficulties. Children with EF and SE difficulties were less likely to be "well-behaved." Children with EF and SE difficulties were more likely to stutter. For children with both EF and SE difficulties, the likelihood of parental report of stuttering and atypical development was even higher, in fact this likelihood (of stuttering and not-typically developing) was highest among all subgroups. In contrast, children without difficulties were the least likely to be reported with stuttering or not-typically developing. Our findings are consistent with theoretical frameworks for stuttering, which cite EF as a crucial component in the disorder. Additionally, our findings suggest within-population heterogeneity among children with EF difficulties, specifically, EF and SE heterogeneity among children who stutter.

Appendix A

See Table 5 and 6.

Table 5 Model fit statistics for latent class solution with participant's sex as an indicator

		BIC	BIC change	SSABIC	Entropy	Classification probabilities	VLMR LRT *p*	Smallest profile size
1	Class solution	1,452,337	NA	1,452,264	NA	NA	NA	123,809
2	Class solution	1,346,093	106,244	1,345,944	0.853	.875 to .979	0.3333	23,014
3	Class solution	1,293,540	52,553	1,293,315	0.882	.851 to 1.00	0.00001	1596
4	Class solution	1,281,165	12,375	1,280,863	0.882	.732 to .999	0.00001	1596
5	Class solution	1,268,988	12,177	1,268,610	0.789	.697 to .999	0.00001	1594
6	Class solution	1,265,612	3376	1,265,157	0.795	.650 to .999	0.7619	1594
7	Class solution	1,263,045	2567	1,262,514	0.773	.675 to .999	0.7640	1594

Table 6 Correlations among latent class indicators, group, and developmental status

		1	2	3	4	5	6	7	8	9	10
1	Well Behaved	–	0.42**	0.41**	0.21**	0.27**	0.13**	−0.14**	−0.07**	0.07**	0.04**
2	Good attention, completes chores, homework		–	.46**	.22**	.22**	.11**	−0.23**	−0.08**	0.12**	0.01*
3	Difficulties with emotions, concentration, behavior, and getting along with others			–	.38**	.39**	.19**	−0.33**	−0.12**	0.08**	−0.04**
4	Many worries; often seems worried				–	0.50**	0.21**	−0.16**	−0.06**	−0.02**	−0.12**
5	Unhappy, depressed, and tearful					–	0.22**	−0.13**	−0.06**	−0.02**	−0.09**
6	Gets along better with adults than children or youth						–	0.09**	−0.04**	.01	−0.07**
7	Group							–	0.10**	−0.12**	.08**
8	Development status								–	−0.05**	−0.04**
9	Sex									–	−0.01
10	Age										–

Spearman rank correlations were estimated because the variables are ordinal

*$p < 0.05$

**$p < 0.01$

Compliance with Ethical Standards

Conflict of interest No potential conflict of interest.

Ethical Approval Secondary data analysis of publicly available data set, the National Health Interview Survey (2004–2018).

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