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Interactive Effects of Temperament and Family-Related Environmental Confusion on Spoken Language in Children Who Are Deaf and Hard of Hearing

Kristina Bowdrie,[a] Rachael Frush Holt,[a,b] and Derek M. Houston[a,b]

[a] Department of Speech and Hearing Science, The Ohio State University, Columbus [b] Department of Otolaryngology–Head and Neck Surgery, Wexner Medical Center, The Ohio State University, Columbus

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ABSTRACT

Purpose: The aim of this study was to examine the influence of caregivers' reports of family-related environmental confusion—which refers to the level of overstimulation in the family home environment due to auditory and nonauditory (i.e., visual and cognitive) noise—on the relation between child temperament and spoken language outcomes in children who are deaf and hard of hearing (DHH) in comparison to age-matched children with typical hearing (TH).

Method: Two groups of families with children between 3 and 7 years of age (TH = 59, DHH = 58) were sequentially recruited from a larger longitudinal study on developmental outcomes in children who are DHH. Caregivers (all TH) completed questionnaires measuring three dimensions of child temperament (i.e., effortful control, negative affectivity, and surgency–extraversion) and family-related environmental confusion. A norm-referenced language measure was administered to children. Testing took place within the families' homes.

Results: For children who are DHH, effortful control was positively related to spoken language outcomes, but only when levels of family-related environmental confusion were low to moderate. Family-related environmental confusion did not interact with temperament to influence spoken language in children with TH.

Conclusions: Homes with low-to-moderate levels of environmental confusion provide an environment that supports DHH children with better effortful control to harness their self-regulatory skills to achieve better spoken language comprehension than those with lower levels of effortful control. These findings suggest that efforts to minimize chaos and auditory noise in the home create an environment in which DHH children can utilize their self-regulatory skills to achieve optimal spoken language outcomes.

Children who are deaf and hard of hearing (DHH) are at risk for delays in spoken language development, even with the use of sensory aids (e.g., Holt et al., 2012; Niparko et al., 2010; Stiles et al., 2012). Understanding variability in DHH children's language outcomes requires a holistic approach that accounts for both child contributions and the context of their development (i.e., the family home environment). Child characteristics, such as temperament, highlight how children can serve as active participants in their language development (Conture et al., 2013; Slomkowski et al., 1992). For example, children with greater regulatory abilities and lower reactivity to stimuli are thought to possess skills supportive of optimal language development (Bloom, 1993; Dixon & Smith, 2000; Slomkowski et al., 1992). However, the influence of the child's physical home environment on the relation between temperament and language remains unexplored despite

Correspondence to Kristina Bowdrie: bowdrie.1@osu.edu. ***Disclosure:*** *The authors have declared that no competing financial or nonfinancial interests existed at the time of publication.*

well-known transactional effects (i.e., bidirectional influences between individuals and their environment; Sameroff, 2010) in child development. Consistent with a transactional model, child temperament has been shown to influence language outcomes through its interactions with the child's environment (Karrass & Braungart-Rieker, 2003; Laake & Bridgett, 2018; Spinelli et al., 2018).

Family-related environmental confusion refers to the level of chaos that exists within the physical home environment. The presence of auditory noise as well as visual and cognitive overstimulation in the home that serve as additional sources of "nonauditory noise" (i.e., crowding, clutter, foot traffic in and out of the home, and temporal and structural irregularity) collectively contribute to family-related environmental confusion (Corapci & Wachs, 2002; Matheny et al., 1995). High levels of family-related environmental confusion can adversely affect the ability for DHH children to leverage optimal temperament traits that positively influence spoken language development. Children who are DHH, even with hearing aids (HAs) and/or cochlear implants (CIs), may experience reduced auditory access (Marsella et al., 2017; Walker et al., 2019) and neurocognitive deficits (Beer et al., 2014; Kronenberger et al., 2014). These deficits may contribute to extra sensitivity to overstimulation in their environment compared to children without sensory and neurocognitive challenges. The purpose of this study was to examine the association between child temperament, family-related environmental confusion, and spoken language in children who are DHH compared to age-matched children with typical hearing (TH) as controls.

Temperament and Spoken Language Development

Temperament refers to biologically based tendencies that contribute to individual differences in various domains including emotion, behavior, and attention (Rothbart & Bates, 2006; Shiner et al., 2012). One of the leading established temperament frameworks in school-age children classifies traits into three global dimensions: effortful control, surgency–extraversion, and negative affectivity (Rothbart et al., 2001). Effortful control is the ability to willfully engage in response inhibition for attentional, emotional, and behavioral regulation (Rothbart et al., 2001; Rothbart & Rueda, 2005). Surgency–extraversion and negative affectivity comprise reactive tendencies and are characterized by positive emotionality and negative emotionality, respectively (Rothbart et al., 2001). Early work on temperament in infants who are typically developing has theorized that language development is supported by high regulatory abilities and neutral reactivity (Bloom, 1993). For example, high levels of effortful control in children allow for optimal regulation of the cognitive resources available for encoding, storing, and retrieving linguistic information compared to children with suboptimal levels of effortful control. Furthermore, children high in surgency–extraversion/negative affectivity expend greater cognitive resources due to alternating between neutral and high positive/negative emotional states. Alternating between emotional states requires tapping into attentional resources, which imposes limits on the child's ability to attend to important linguistic input from their environment when learning language (Bloom, 1993).

A potential mechanism underlying the relation between regulatory temperament dimensions, such as effortful control, and language in typically developing children is how the child is perceived by caregivers during interactions. Good attentional control can encourage caregivers to engage with children for longer periods of time while utilizing linguistic cues to maintain the child's attention (Dixon & Smith, 2000). In other words, a child's temperament can also encourage responsiveness from caregivers, paving the way for more meaningful interactions and opportunities for exposure to linguistic input (Conture et al., 2013). Positive emotionality is also a trait that can lead to increased opportunities for social interactions, as children with high positive emotionality can be perceived as more sociable by their caregivers and peers compared to children high in negative emotionality (Salley et al., 2013; Slomkowski et al., 1992). However, evidence that positive language outcomes can be associated with traits indicative of high regulatory abilities and positive emotionality (i.e., Slomkowski et al., 1992) contrasts with findings that high regulatory abilities and "neutral" emotional states contribute to better language outcomes in children who are typically developing (i.e., Bloom, 1993). One explanation that can account for these contrasting findings views reactive and regulatory dimensions of temperament on a continuum (Gouge, 2011). That is, certain combinations of reactivity and regulation create an optimal dynamic for language acquisition. For example, a child possessing certain traits aligning with surgency–extraversion and effortful control can appear as sociable and attentive—a dynamic that promotes language development (Gouge, 2011). The child's display of positive emotionality elicits language-learning opportunities from caregivers, while their regulatory abilities enable the child to maintain attentional resources needed to engage in the interaction despite possibly exhibiting relatively high levels of emotionality. Indeed, Dixon and Smith (2000) found that both increased attentional skills at 7–10 months of age and positive emotionality at 10–13 months of age were related to advanced language production at 20 months of age.

The influence of temperament on language in children who are typically developing has emphasized the effects of interactions between child temperament and family factors on children's language development. For example, Laake and Bridgett (2018) reported that infants displaying greater positive affect showed better expressive language skills in later infancy when their mothers displayed higher levels of responsiveness to the child. Maternal responsiveness also moderated the relation between infants' distress to novelty (an infant temperamental trait associated with negative affectivity) at 12 months and language at 16 months, with lower distress to novelty being associated with better language when mothers were more responsive (Karrass & Braungart-Rieker, 2003). Additionally, the quality of maternal input (quantified as syntactic complexity and lexical diversity) at 6 and 9 months of age moderated the relation between infant attention and language production at 18 and 24 months of age (Spinelli et al., 2018). Collectively, these studies demonstrate the importance of applying a transactional approach. Transactional perspectives consider the dynamic processes (e.g., positive and/or negative bidirectional influences) that occur between people, including dyadic interactions between children and their caregiver(s) (Sameroff, 2010). By using a transactional approach to examine language acquisition, child-related characteristics can be explored alongside other features of the child's environment to understand relations between temperament and language development.

The relation between temperament and spoken language development in children who are DHH has been explored only partially and indirectly. For example, the influence of attention and inhibitory control—which overlap conceptually with effortful control—on spoken language development has been investigated in children who are DHH with HAs and/or CIs, ages 3 years and older (e.g., Blank et al., 2020; Figueras et al., 2008; Kronenberger et al., 2014). However, the association between Rothbart et al.'s (2001) three broad temperament dimensions (effortful control, negative affectivity, and surgency–extraversion) and spoken language has not been examined in children who are DHH. Investigating the relation between child temperament and spoken language, especially within an environmental context as important as the family, could contribute significantly to the understanding of spoken language development in children who are DHH. One potential aspect of the environment most proximal to children during development—the family (Bronfenbrenner, 1977)—that likely interacts with child temperament is how structured or chaotic the home environment is.

Family-Related Environmental Confusion and Spoken Language

Environmental confusion is an umbrella term encompassing structural and chaotic dynamics in the home. We refer to environmental confusion as "family-related" environmental confusion to emphasize that these dynamics take place within the context of the family home environment. Environmental confusion represents the level of overstimulation within the home environment in the form of auditory noise (e.g., background noise) and overstimulation in the form of "nonauditory noise" (e.g., lack of routineness, clutter, and crowding; Corapci & Wachs, 2002; Matheny et al., 1995). Specific dimensions of family-related environmental confusion such as level of disorganization, unpredictability, and instability have also been studied (Berry et al., 2016; Marsh et al., 2020; Vernon-Feagans et al., 2012). Families with high levels of environmental confusion may have households that are noisy due to the television always running in the background (auditory noise). Other household characteristics may reflect visual and cognitive "noise" or overstimulation that is nonauditory in nature. For example, high levels of environmental confusion also lack structure and routine in daily activities (unpredictability and instability), have high levels of foot traffic in and out of the home (unpredictable chaos that can be both auditory- and nonauditory-based), and persistent difficulty locating household items (physical disorganization).

Whereas family-related environmental confusion has been linked to sociodemographic factors such as socioeconomic status, factors comprising family-related environmental confusion are distinct and can be observed in homes across different socioeconomic profiles (Deater-Deckard et al., 2009; Matheny et al., 1995). However, some family demographics have been associated with higher levels of family-related environmental confusion, such as a large household size and having a greater number of children in the home that are of school age (Kracht et al., 2021). Family-related environmental confusion as a whole captures aspects of the child's physical microenvironment, the setting in which transactional interactions between the caregiver(s) and the child take place (Bronfenbrenner & Crouter, 1983; Matheny et al., 1995; Wachs, 1989). Consequently, family-related environmental confusion can influence the relation between temperament and language because this feature of the child's physical environment can affect opportunities children have for engaging with caregivers. For example, frequent and loud noise and irregular schedules can limit opportunities that children have to interact with their caregiver(s) and even affect the quality of their interactions (Coldwell et al., 2006; Evans & Wachs, 2010).

Similar to temperament, family-related environmental confusion is thought to affect child language development both directly and indirectly. In their systematic review, Marsh et al. (2020) reported that high levels of environmental confusion were associated with poorer language outcomes (i.e., nonverbal abilities, phonological awareness, and receptive and expressive language) in children who are typically developing from infancy through 6 years of age. Environmental confusion is also thought to affect child language indirectly through its effects on caregivers. High environmental confusion has been linked to less responsive caregivers who provide less linguistic input and fewer opportunities for the child to explore their environment (Coldwell et al., 2006; Evans & Wachs, 2010), greater depressive symptoms in caregivers (Hur et al., 2015), negative parenting (Geeraerts et al., 2021), poor caregiver executive functioning (Deater-Deckard et al., 2012), and caregiver stress (Kracht et al., 2021), all of which can strain caregiver–child relationships and language-learning opportunities. Caregivers are also likely to adopt coping mechanisms that can cause them to withdraw from overstimulation within their home environment (Regoeczi, 2008) and ultimately reduce language-learning opportunities for their children.

The negative effects of environmental confusion on language in children who are DHH could be greater than what has been observed in children with TH based on previous work investigating one component of environmental confusion—auditory noise. Although the presence of noise can negatively influence speech understanding for children in general (e.g., Lecheile et al., 2020), this specific feature of environmental confusion puts children who are DHH with HAs and CIs at an even greater disadvantage due to their already reduced access to temporal and spectral cues from auditory signals of interest (Marsella et al., 2017; Walker et al., 2019). Sensory aids have been shown to provide some benefit for listening in noise in pediatric bilateral HA users (Ching et al., 2011) and bilateral and bimodal CI users as young as 3 years of age (Choi et al., 2017; Davidson et al., 2015; Gifford, 2020). However, outcomes related to listening in noise can vary in children who are DHH due to factors related to the signal-to-noise ratio (SNR; Yang et al., 2012), the child's language abilities (Torkildsen et al., 2019), and whether the noise fluctuates (Goldsworthy & Markle, 2019). Children must begin to tap into preexisting cognitive and linguistic skills to piece together content from degraded signals when in adverse listening environments (Nittrouer & Boothroyd, 1990; Rudner et al., 2018). Furthermore, other environmental features associated with high levels of environmental confusion such as disorganization, instability, and lack of routines can add additional cognitive demands on children, especially for children who are DHH—a population at risk for deficits in executive functioning (Beer et al., 2014; Kronenberger et al., 2014; Stiles et al., 2012). Thus, high levels of family-related environmental confusion pose additional risks to children who are DHH above and beyond that of just auditory noise. Homes with high levels of family-related environmental confusion also include chaotic and unpredictable environments that contain non–auditory-based noise and distractions that can interfere with language-learning and the dyadic relationships that support that learning.

This study is the first to examine family-related environmental confusion in school-age children who are DHH with HAs and CIs. Moreover, we examine whether family-related environmental confusion interacts with the relation between temperament and spoken language comprehension in children who are DHH and children who are TH. High regulatory skills and positive reactivity are associated with better language outcomes, especially in infants who are typically developing. Given the wide variability in spoken language and executive function outcomes and the high rate of delayed spoken language and executive function problems in children who are DHH, temperament is likely to contribute to variability in language for longer periods of development in children who are DHH than children with TH. Examining child temperament in preschool- and school-age children might reveal important contributions of temperament to spoken language development in children who are DHH. Additionally, this research could highlight the importance of non–hearing-related child characteristics that interact with the environment to influence language development in children who are DHH. Temperament reflects attributes that are innate and relatively static across development, whereas aspects of the environment, such as environmental confusion, tend to be more modifiable. A model examining how the environment can affect the relation between a stable child characteristic (i.e., temperament) and language outcomes can highlight important attributes of the family to target for intervention, especially in children who are DHH. We hypothesized that children who are DHH will be able to leverage optimal temperament traits to achieve better language outcomes when the physical environment has minimal confusion and chaos. Children with TH with their age-appropriate language comprehension skills should be less sensitive to the effects of temperament and qualities of the physical home environment.

Method

Participants

Families were recruited as part of a longitudinal study investigating developmental outcomes in children who are DHH between the ages of 3 and 8 years old compared to a control sample of children with TH within the same age range. In order to maintain experimental control, families with children older than 7 years of age were excluded as the Temperament in Middle Childhood Questionnaire (Simonds & Rothbart, 2004) was completed by these families as opposed to the Children's Behavior Questionnaire (Rothbart et al., 2001) that was developed for children from 3 to 7 years of age. The resulting TH group consisted of 59 children (M_{age} = 5.53 years, SD = 1.48;

25 girls) who passed a behavioral hearing screening (≤ 20 dB HL bilaterally at audiometric frequencies from 250 to 4000 Hz; re: ANSI, 2004, 2010) and their primary caregiver (56 mothers and three fathers). The DHH group consisted of 58 children with mild-through-profound sensorineural hearing loss bilaterally (M_{age} = 5.78 years, *SD* = 1.31; 29 girls) and their primary caregiver (53 mothers, three fathers, and two grandmothers). Twenty-six of the children who are DHH were fitted with bilateral HAs and 32 had CIs (30 bilaterally; two used a CI in one ear and a HA in the other). Children from each sample were predominately White, reflecting the demographics (U.S. Census Bureau, 2019a, 2019b) of the two states from which the participants were recruited—Ohio and Indiana (TH: White = 43, Black or African American = 7, bi- or multiracial = 9; DHH: White = 45, Black or African American = 8, bi- or multiracial = 2, Asian American = 3). Inclusion criteria for all children included scoring within 2 *SD*s of the mean on a nonverbal IQ test (Differential Ability Scales–Second Edition; Elliot, 2007), no reported neurodevelopmental difficulties (apart from those known to be related to hearing loss, such as language delays), use of spoken English at home and a goal for the child to learn spoken language, and caregiver self-report of TH.

Table 1 displays child and family demographics and descriptive statistics for both participant groups. Children with TH and children who are DHH did not significantly differ in age, gender, or annual household income. Within the DHH group, HA and CI users did not differ in age, gender, amount of early intervention, duration of device use (HA: *n* = 26, CI: *n* = 31), or aided better ear pure-tone average (PTA; HA: *n* = 8, CI: *n* = 27; audiometric information was available for only a subset of children who are DHH despite multiple attempts to obtain this information from children's audiologists). As expected, the only significant demographic difference observed between HA and CI users was the unaided better ear PTA (HA:

Table 1. Demographics for families included in the study.

Variable	TH (*n* = 59)	DHH (*n* = 58)	Statistical results	DHH HA (*n* = 26)	DHH CI (*n* = 32)	Statistical results
Child age (years)						
M	5.53	5.78	*t*(115) = −0.98, *p* = .331	5.50	6.01	*t*(56) = −1.47, *p* = .148
SD	1.48	1.31		1.29	1.31	
Child gender (*n*)						
Female	25	29	χ^2(1) = 0.69, *p* = .408	14	15	χ^2(1) = 0.28, *p* = .597
Male	34	29		12	17	
Duration of device use[a] (years)						
M	—	4.41	—	4.63	4.22	*t*(55) = 0.95, *p* = .348
SD	—	1.64		1.74	1.55	
Aided better ear PTA[b] (dB HL)						
M	—	24.71	—	22.97	25.23	*t*(33) = −0.71, *p* = .483
SD	—	7.86		15.48	3.88	
Unaided better ear PTA[c] (dB HL)						
M	—	52.45	—	47.88*	75.31*	*t*(22) = −3.69, ***p* = .001**
SD	—	16.89		14.31	7.32	
Amount of early intervention received[d] (hr/month)						
M	—	7.00	—	5.21	8.49	*t*(56) = −1.63, *p* = .108
SD	—	7.66		8.54	6.63	
Annual household income bracket[e]						
M	$65k–79.9k	$50k–64.9k	*t*(115) = 1.95, *p* = .054	$65k–79.9k	$50k–64.9k	*t*(56) = 0.73, *p* = .466
Caregiver education[f]						
M	Bachelor's degree*	Partial 4-year college*	*t*(115) = 2.66, ***p* = .009**	Partial 4-year college	Partial 4-year college	*t*(56) = −0.11, *p* = .915

Note. Bold font indicates significant at $p < .05$. TH = typical hearing; DHH = deaf and hard of hearing; HA = hearing aid; CI = cochlear implant; PTA = pure-tone average at 500, 1000, 2000, and 4000 Hz.

[a]Duration of device use calculated from time when children with HAs and CIs were fitted with HAs and CIs, respectively (DHH: *n* = 57; HA: *n* = 26; CI: *n* = 31). [b]From a subset of participants for whom these data were available (DHH: *n* = 35; HA: *n* = 8; CI: *n* = 27). [c]From a subset of participants for whom these data were available (DHH: *n* = 24; HA: *n* = 20; CI: *n* = 4). [d]Caregiver report of the average number of hours per month that the child spent in early intervention services from birth to 3 years of age. [e]Reported gross household income from previous year scored on a 10-point interval: 1 = under $5,000, 2 = $5,500–$9,999, 3 = $10,000–$14,999, 4 = $15,000–$24,999, 5 = $25,000–$34,999, 6 = $35,000–$49,999, 7 = $50,000–$64,999, 8 = $65,000–$79,999, 9 = $80,000–$94,999, 10 = $95,000 and over. [f]Education was scored on a 10-point ordinal scale: 1 = elementary school, 2 = junior high/middle school (9th grade), 3 = partial high school, 4 = general education diploma (high school equivalence), 5 = high school, 6 = technical/vocational school, 7 = partial 4-year college, 8 = bachelor's degree, 9 = master's degree, 10 = doctoral degree.

*$p < .05$.

n = 20, CI: n = 4). Parents of children with TH had a significantly higher educational level (bachelor's degree vs. associate's degree/partial 4-year college) compared to parents of children who are DHH. The difficulty of balancing parental education (and income) levels between hearing groups through recruitment is compounded by the underlying demographic distributions: The prevalence of children who are DHH increases with decreasing household income, a common proxy for parental education because the two are highly correlated with each other (Liberatos et al., 1988; National Center for Health Statistics (U.S.) & National Center for Health Services Research, 1994; Neuhauser, 2018). Within the DHH group, there were no significant differences in education level or income for parents of children with HAs compared to parents of children with CIs.

Materials

Child Receptive Spoken Language

Children's complex language comprehension skills were assessed using the Concepts and Following Directions subscale of the Clinical Evaluation of Language Fundamentals Preschool–Second Edition (CELF Preschool-2; Semel et al., 2004) for children younger than 6 years of age or the Following Directions subscale of the CELF-5 (Clinical Evaluation of Language Fundamentals–Fifth Edition; Semel et al., 2013) for those 6 years and older. Scaled scores were calculated and used in all analyses.

Child Temperament

The Children's Behavior Questionnaire–Short Form (CBQ-SF; Putnam & Rothbart, 2006) was used to evaluate child temperament. The CBQ-SF is a 94-item caregiver questionnaire that assesses three primary dimensions of temperament in children 3–7 years of age: effortful control, negative affectivity, and surgency–extraversion. Primary caregivers are asked to rate observable behaviors from their child across a range of situations occurring over the last 6 months using a Likert scale, ranging from 1 (*extremely untrue of their child*) to 7 (*extremely true of their child*). The items are arranged into 15 subscales representing a range of temperament characteristics that load onto the three temperament dimensions: (a) Effortful control, reflecting the child's ability to regulate emotional, behavioral, and cognitive responses, is composed of four subscales (Attentional Focusing, Inhibitory Control, Low Intensity Pleasure, and Perceptual Sensitivity); (b) Surgency–extraversion captures the tendency for the child to display high levels of positive emotions and activity and is composed of four subscales (Activity Level, High-Intensity Pleasure, Impulsivity, and Reversed Shyness); and (c) Negative affectivity is composed of five subscales (Anger/Frustration, Discomfort, Fear, Sadness, and Reversed Falling Reactivity/Soothability) and refers to the tendency for the child to display high levels of negative emotions. The remaining two subscales (Approach/Positive Anticipation and Smiling/Laughter) did not load into any of the three dimensions (Putnam & Rothbart, 2006; Rothbart et al., 2001) and were not included in any analyses. Subscales on the CBQ-SF revealed variable internal consistency (α = .62–.88) though alphas for 12 of the 15 subscales were above .70, whereas only one subscale revealed an alpha lower than .65 (note that some scales revealed a lower internal consistency among predominately Black/African American and low-income samples; Putnam & Rothbart, 2006). Subscale scores that contribute to each dimension were averaged and used for analyses (consistent with Rothbart et al., 2003). Higher scores for each respective dimension reflect high levels of that specific temperament trait.

Family-Related Environmental Confusion

Level of environmental confusion was measured using the Confusion, Hubbub, and Order Scale (CHAOS; Matheny et al., 1995). The CHAOS is a caregiver report questionnaire composed of 15 questions for use in families with children 3 years and older. Primary caregivers respond to a series of situations (e.g., "There is very little commotion in our home," "We can usually find things when we need them," "We almost always seem to be rushed," "At home we can talk to each other without being interrupted," and "You can't hear yourself think in our home") on a Likert scale from 1 (*very much like our home*) to 4 (*not at all like our home*). Items all relate to the level of organization and noise present in the home. The CHAOS has satisfactory internal consistency (α = .79), even for families of infants and toddlers (Matheny et al., 1995). Scores range from 15 to 60, with higher scores reflecting a higher level of environmental confusion.

Procedure

Parents were mailed a packet of questionnaires (including the CBQ-SF and CHAOS) to complete prior to a scheduled home visit. All questionnaires were completed by the primary caregiver and reviewed and collected during a 1.5- to 2.5-hr home visit. Two trained clinical researchers performed behavioral testing during the home visit. One of the researchers administered child assessments in one area of the home, including the CELF-5/CELF Preschool-2; the other researcher worked with the caregiver. All data collection was obtained in accordance with procedures of the local institutional review board, and consent, caregiver permission, and assent when appropriate were obtained prior to study participation.

Data Analyses

Correlations, *t* tests, and chi-square tests were performed in SPSS Version 27.0 (IBM Corporation, 2020). Moderation analyses were subsequently performed to determine if the relation between caregiver-reported child temperament (effortful control, surgency–extraversion, and negative affectivity) and child spoken language (CELF-5/CELF Preschool-2) depends on the level of environmental confusion within a child's home. Moderation analyses were performed using PROCESS, an SPSS macroinstruction that uses ordinary least squares regression for mediation, moderation, and conditional path analyses (Hayes, 2017). PROCESS was used to output regression models containing the predictor variable (temperament) in addition to an interaction term, which reflected the interaction between the predictor variable and the moderator variable (environmental confusion). A significant interaction term ($p < .05$) means that the effect of the predictor variable on the dependent variable is contingent on the moderator variable. PROCESS further computed the level(s) of the moderator that contributed to the significant interaction between the predictor variable and moderator. Because we employed a continuous moderator variable, PROCESS uses a "pick-a-point" approach, in which the effect of environmental confusion on the relation between child temperament and spoken language was examined at the 16th (low), 50th (moderate), and 84th (high) percentile scores of environmental confusion obtained on the CHAOS within each sample under study (i.e., DHH and TH). PROCESS was also used to implement the Johnson–Neyman approach to probe the relationship between the independent and dependent variables by revealing the exact value of the moderator at which the interaction term was significant (Hayes, 2017). Children with HAs and CIs were combined into one group to increase statistical power for correlation and moderation analyses because they were comparable on demographic factors and most study variables.

Results

Descriptive Analyses

Child Language

The top portion of Table 2 displays descriptive statistics for the receptive language measure. One child who is DHH (a HA user) was unable to complete the CELF Preschool-2 and thus did not contribute a score to the analyses for this measure. Within the DHH group, children with HAs tended to score higher on the language measures than children with CIs, but the difference was not statistically significant. As expected, children with TH

Table 2. Descriptive statistics for each participant group.

Variable	TH (*n* = 59)	DHH (*n* = 58)	Statistical results	DHH HA (*n* = 26)	DHH CI (*n* = 32)	Statistical results
Child language: CELF-5/CELF Preschool-2[a]						
M	10.75	7.53	$t(114) = 5.67$, $\mathbf{p < .001}$	7.88	7.25	$t(55) = 0.66$, $p = .511$
SD	2.50	3.55		3.38	3.70	
Range	5.00–16.00	1.00–14.00		2.00–14.00	1.00–14.00	
Child temperament: CBQ-SF: effortful control						
M	5.36	5.10	$t(115) = 2.32$, $\mathbf{p = .022}$	5.24	4.99	$t(56) = 1.46$, $p = .149$
SD	0.55	0.65		0.68	0.62	
Range	3.75–6.43	3.69–6.27		3.71–6.27	3.69–5.95	
Child temperament: CBQ-SF: negative affectivity						
M	4.05	3.81	$t(115) = 1.87$, $p = .064$	3.75	3.83	$t(56) = -0.59$, $p = .557$
SD	0.68	0.72		0.78	0.67	
Range	2.53–5.56	2.28–5.17		2.28–5.17	2.43–4.94	
Child temperament: CBQ-SF: surgency–extraversion						
M	4.50	4.77	$t(115) = -1.63$, $p = .105$	4.37	5.11	$t(56) = -3.38$, $\mathbf{p = .001}$
SD	0.90	0.90		0.86	0.80	
Range	2.53–6.63	2.53–6.34		2.53–5.76	2.92–6.34	
Family-related environmental confusion: CHAOS						
M	29.73	27.66	$t(115) = 1.52$, $p = .131$	27.46	27.81	$t(56) = -0.18$, $p = .860$
SD	7.27	7.46		8.21	6.92	
Range	17.00–44.00	17.00–44.00		17.00–44.00	18.00–44.00	

Note. Bold font indicates significant at $p < .05$. TH = typical hearing; DHH = deaf and hard of hearing; HA = hearing aid; CI = cochlear implant; CELF-5 = Clinical Evaluation of Language Fundamentals–Fifth Edition; CELF Preschool-2 = Clinical Evaluation of Language Fundamentals Preschool–Second Edition; CBQ-SF = Children's Behavior Questionnaire–Short Form; CHAOS = Confusion, Hubbub, and Order Scale.
[a]TH: $n = 59$; DHH: $n = 57$; HA: $n = 25$; CI: $n = 32$.

had better receptive language than children who are DHH (see statistical results in Table 2).

Child Temperament

The middle portion of Table 2 displays the descriptive statistics for the three dimensions of temperament. Caregivers of children with TH reported higher levels of effortful control in their children than the caregivers of children who are DHH. There also was a trend for caregivers of children with TH to report higher levels of negative affectivity in their children than caregivers of children who are DHH (see statistical results in Table 2). Within the DHH group, the only dimension on which CI and HA users differed was surgency–extraversion, with caregivers of children with CIs reporting higher levels than caregivers of children with HAs (see Table 2). There is no guidance for interpreting cutoff values for "high" versus "low" scores on the CBQ-SF; however, mean scores for both groups on each dimension were comparable to other studies utilizing the CBQ-SF in samples of typically developing school-age children (Atzaba-Poria et al., 2014; Deater-Deckard et al., 2009; Lane et al., 2015).

Family-Related Environmental Confusion

The bottom of Table 2 displays the descriptive statistics for the CHAOS. There was no evidence of significant differences in levels of environmental confusion based on hearing or device status. The range of reported levels of environmental confusion for both families of children with TH and children who are DHH was 17–44. Similar to the CBQ-SF, the CHAOS does not provide cutoff values for "low" or "high" levels of environmental confusion. Means and ranges reported for our TH and DHH samples, however, are comparable to other studies employing a similar administration of the CHAOS scale in representative samples of typically developing school-age children (Colalillo, 2018; Emond et al., 2018).

Associations Among Child Temperament, Family-Related Environmental Confusion, and Child Language

Correlation and subsequent moderation analyses controlled for caregivers' highest level of education because of its known association with household income, as well as the prevalence of hearing loss increasing in households with lower incomes and levels of parental education (LeClair & Saunders, 2019; Neuhauser, 2018). Table 3 displays partial Pearson correlations between child receptive language and each study variable for both participant groups separately. There were no associations between child receptive language (CELF-5/CELF Preschool-2) and any dimension of child temperament or family-related environmental confusion for children with TH. However, family-related environmental confusion was related to all three dimensions of child temperament in children with TH: Children who were high in surgency–extraversion and negative affectivity had families reporting higher levels of environmental confusion, whereas those high in effortful control had families reporting lower levels of environmental confusion.

For children who are DHH, receptive language was positively related to their effortful control (see bottom half of Table 3). None of the other temperament dimensions or family-related environmental confusion were associated with receptive language in children who are DHH. Similar to children with TH, effortful control in children who are DHH was negatively associated with environmental

Table 3. Partial Pearson correlations[a] between child language, child temperament, and family-related environmental confusion for each participant group.

Variable	1	2	3	4	5
TH group					
1. CELF-5/CELF Preschool-2	—	—	—	—	—
2. CHAOS	.171	—	—	—	—
3. CBQ-SF: effortful control	–.012	**–.277**	—	—	—
4. CBQ-SF: negative affectivity	.063	**.337**	–.059	—	—
5. CBQ-SF: surgency–extraversion	–.036	**.279**	–.237	.039	—
DHH group					
1. CELF-5/CELF Preschool-2	—	—	—	—	—
2. CHAOS	–.060	—	—	—	—
3. CBQ-SF: effortful control	**.354**	**–.270**	—	—	—
4. CBQ-SF: negative affectivity	–.145	**.472**	**–.282**	—	—
5. CBQ-SF: surgency–extraversion	–.153	–.102	**–.339**	–.108	—

Note. Bold font indicates significant at $p < .05$. TH = typical hearing; CELF-5 = Clinical Evaluation of Language Fundamentals–Fifth Edition; CELF Preschool-2 = Clinical Evaluation of Language Fundamentals Preschool–Second Edition; CHAOS = Confusion, Hubbub, and Order Scale; CBQ-SF = Children's Behavior Questionnaire–Short Form; DHH = deaf and hard of hearing.

[a]Control variable: caregiver's highest level of education; TH: $df = 56$; DHH: $df = 54$.

confusion, whereas negative affectivity positively correlated with family-related environmental confusion; surgency–extraversion was not related to environmental confusion in children who are DHH. Finally, in the DHH group only, children who had higher levels of effortful control had lower levels of negative affectivity and surgency–extraversion.

Contributions of Child Temperament and Family-Related Environmental Confusion to Child Language

Three multiple linear regression analyses (one for each of the three temperament dimensions) were performed prior to moderation analyses in each participant group to examine the contributions of child temperament and environmental confusion to child receptive language, controlling for caregiver education level. Table 4 displays results of each analysis for the TH group (top half) and the DHH group (bottom half). None of the regression models were significant for the TH group. For the DHH group, only the regression model predicting child receptive language from effortful control and environmental confusion was significant. Effortful control and environmental confusion individually contributed to variability in child receptive language above and beyond caregiver education level. Moreover, the interaction between effortful control and environmental confusion significantly contributed to child receptive language variability. The full models containing negative affectivity and surgency–extraversion were not significant, although negative affectivity was a significant predictor of poorer child receptive language in its model.

Table 4. Results of linear regression analyses sorted by each of the three dimensions of temperament for each participant group.

Group	Predictor variable	β	*SE*	*t*	*p*
TH group					
Effortful control	(Constant)	16.09	14.78	1.09	.401
	Caregiver education (covariate)	0.47	0.30	1.60	.116
	Effortful control	−2.09	2.80	−0.75	.459
	Environmental confusion	−0.35	0.50	−0.70	−.488
	Effortful Control × Environmental Confusion	0.08	0.09	0.83	.410
	Model summary: $F(4, 54) = 1.03$, $R^2 = .07$, $p = .401$				
Surgency–extraversion	(Constant)	−0.39	8.11	−0.05	.962
	Caregiver education (covariate)	0.52	0.30	1.74	.088
	Surgency–extraversion	1.09	1.55	0.70	.487
	Environmental confusion	0.27	0.23	1.17	.249
	Surgency–Extraversion × Environmental Confusion	−0.04	0.05	−0.89	.379
	Model summary: $F(4, 54) = 1.15$, $R^2 = .08$, $p = .344$				
Negative affectivity	(Constant)	5.46	9.78	0.56	.579
	Caregiver education (covariate)	0.44	0.32	1.39	.171
	Negative affectivity	−0.01	2.16	−0.00	.997
	Environmental confusion	0.06	0.30	0.19	.854
	Negative Affectivity × Environmental Confusion	0.00	0.07	0.01	.989
	Model summary: $F(4, 54) = 0.83$, $R^2 = .06$, $p = .515$				
DHH group					
Effortful control	(Constant)	−55.20	12.83	−4.30	**< .001**
	Caregiver education (covariate)	0.70	0.30	2.34	**.023**
	Effortful control	11.13	2.39	4.66	**< .001**
	Environmental confusion	1.66	0.42	3.99	**.001**
	Effortful Control × Environmental Confusion	−0.32	0.08	−3.98	**.001**
	Model summary: $F(4, 52) = 7.35$, $R^2 = .36$, $\mathbf{p < .001}$				
Surgency–extraversion	(Constant)	23.27	11.59	2.00	**.049**
	Caregiver education (covariate)	0.56	0.35	1.59	.118
	Surgency–extraversion	−3.95	2.27	−1.74	.088
	Environmental confusion	−0.55	0.35	−1.58	.121
	Surgency–Extraversion × Environmental Confusion	0.11	0.07	1.50	.139
	Model summary: $F(4, 52) = 1.64$, $R^2 = .11$, $p = .178$				
Negative affectivity	(Constant)	23.54	9.89	2.38	**.021**
	Caregiver education (covariate)	0.54	0.37	1.47	.148
	Negative affectivity	−5.07	2.43	−2.09	**.041**
	Environmental confusion	−0.67	0.37	−1.82	.074
	Negative Affectivity × Environmental Confusion	0.17	0.09	1.87	.067
	Model summary: $F(4, 52) = 1.85$, $R^2 = .12$, $p = .133$				

Note. Receptive language (CELF-5/CELF Preschool-2) was the outcome variable, and caregiver education was a covariate. Bold font indicates significant at $p < .05$. *SE* = standard error; TH = typical hearing; DHH = deaf and hard of hearing; CELF-5 = Clinical Evaluation of Language Fundamentals–Fifth Edition; CELF Preschool-2 = Clinical Evaluation of Language Fundamentals Preschool–Second Edition.

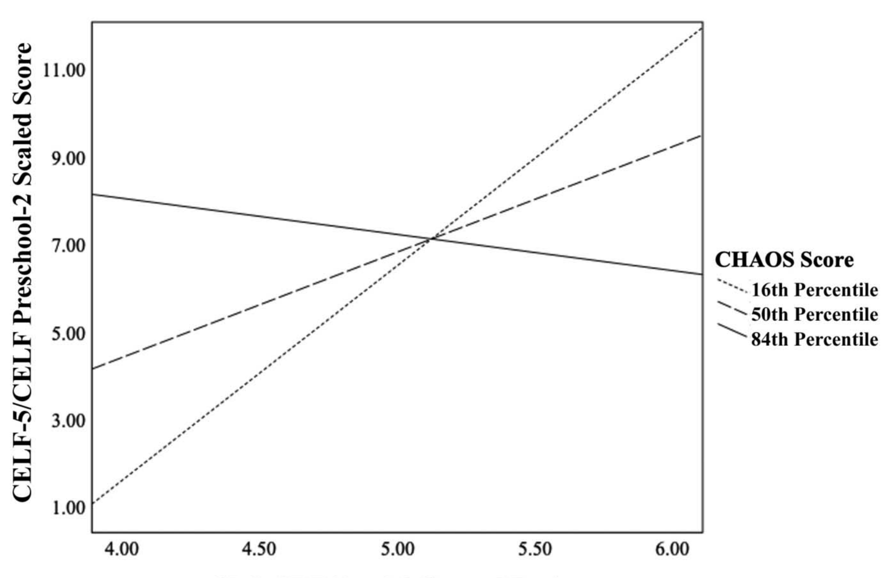
The Effect of Family-Related Confusion on the Relation Between Child Temperament and Child Language

The significant interaction observed between effortful control and environmental confusion in predicting child receptive language was probed with a moderation analysis in PROCESS (Hayes, 2017). The analysis confirmed that family-related environmental confusion significantly moderated the relation between effortful control and receptive language for children who are DHH, $F(1, 52) = 15.82$, $p < .001$, $\Delta R^2 = .19$. The conditional associations between effortful control and receptive language at different levels of environmental confusion revealed that children's effortful control was positively associated with their receptive language only in families scoring in the bottom 16th percentile of the sample ($b = 4.90$, $p < .001$) and the bottom 50th percentile of the sample ($b = 2.41$, $p < .001$) on the CHAOS. At the highest level of environmental confusion (bottom 84th percentile), children's effortful control and receptive language were not related to one another ($b = -0.82$, $p = .385$). Figure 1 displays the conditional effect of family-related environmental confusion on the relation between effortful control and receptive language in children who are DHH. The Johnson–Neyman approach was used to determine the CHAOS scores at which family-related environmental confusion moderated the association between effortful control and receptive language. Moderation occurred at CHAOS scores of 29.15 or below ($b = 1.71$, $p = .010$). Sixty-eight percent of families of children who are DHH ($n = 39$) scored at or below 29.15 on the CHAOS, whereas 32% scored above this value ($n = 18$). The Johnson–Neyman analysis also revealed a significant negative interaction between effortful control and environmental confusion for families scoring 44.00 or higher on the CHAOS ($b = -3.09$, $p = .034$); however, only two families of children who are DHH had scores this high.

Discussion

This study examined the associations among child temperament, family-related environmental confusion, and child language in children who are DHH and TH, including how family-related environmental confusion in the home influences the relation between children's temperament and their receptive language skills. Well-accepted transactional perspectives on child development support that the interaction between temperament and the family environment together influences child language development (Conture et al., 2013; Karrass & Braungart-Rieker, 2003; Laake & Bridgett, 2018; Spinelli et al., 2018). Therefore, it was expected that family-related environmental confusion would affect the relation between child temperament (i.e., effortful control, negative affectivity, and surgency–extraversion) and receptive language in children at risk for optimal language development: DHH children.

Figure 1. Moderating effect of family-related environmental confusion (CHAOS) on the relation between Effortful Control (CBQ-SF) and Receptive Language standard score (CELF-5/CELF Preschool-2) in children who are deaf and hard of hearing. CHAOS = Confusion, Hubbub, and Order Scale; CBQ-SF = Children's Behavior Questionnaire–Short Form; CELF-5 = Clinical Evaluation of Language Fundamentals–Fifth Edition; CELF Preschool-2 = Clinical Evaluation of Language Fundamentals Preschool–Second Edition.



Children with TH had significantly higher effortful control and greater spoken receptive language scores than children who are DHH, consistent with literature reporting that DHH children lag behind children who are TH in language (Holt et al., 2012; Niparko et al., 2010) and regulatory skills (Beer et al., 2014; Kronenberger et al., 2014). In addition, there was a trend for caregivers of children with TH to report higher negative affectivity in their children compared to caregivers with children who are DHH. This finding might reflect different expectations caregivers carry for children with TH compared to children who are DHH (Anmyr et al., 2012; Stevenson et al., 2015). For example, caregivers of children who are DHH may not view displays of negative affectivity as a behavioral issue as DHH children are still developing language skills that aid in emotion regulation, thus resulting in lower ratings of negative affectivity compared to children with TH. In addition, children with CIs scored higher in surgency–extraversion than children with HAs. This finding may reflect a difficulty in regulating extreme emotion and activity for children with more profound degrees of hearing loss.

Children With TH

Temperament and receptive language were not correlated with each other in children with TH. Additionally, there was no correlation between environmental confusion and child language. These null findings likely reflect the decreasing influence of temperament and family-related environmental confusion on language in groups where appropriate language development has been achieved, especially as they enter early childhood. Previous research reporting positive associations between easier child temperament traits for caregivers (i.e., traits associated with high effortful control, low surgency, and low negative affectivity in school-age children) and language outcomes has focused predominately on language development during the infancy period (Dixon & Smith, 2000; Salley et al., 2013). Infancy is a period thought to be marked by the dominance of emotional reactivity, whereas during early and middle childhood, children experience further development of regions within the prefrontal cortex that further enables more conscious regulatory abilities (Gartstein et al., 2016; Posner et al., 2012; Putnam et al., 2006). To be sure, these structures are not mature until early adulthood, but they are more developed in early childhood than in infancy. Thus, temperament can be viewed as a set of stable tendencies that can be altered to some extent by the influence of emerging executive functions and life experiences, which in turn could affect relations between temperament and language in older, school-age children. Language development in our older sample with TH is likely more resilient to temperament and family-related environmental confusion due to other prevalent factors influencing language (and possibly other developmental areas) at their age, such as cognitive processes, linguistic experience, and social experiences that occur outside the home environment (Johnston, 2010).

There was a significant correlation observed between each of the three dimensions of temperament and family-related environmental confusion in children with TH. It appears that children with temperaments that are easier on caregivers (high effortful control, low negative affectivity, and surgency–extraversion) are associated with homes characterized by lower levels of environmental confusion. In comparison, more reactive temperaments (low effortful control, high negative affectivity, and surgency–extraversion) were associated with greater levels of environmental confusion in the home. Early research on temperament has suggested that aspects of the family environment can (to some extent) counteract or exacerbate children's expression of temperament (Thomas & Chess, 1977). An environment with high levels of noise, distractions, traffic, and so forth may "bring out" reactive traits in children. It is also likely that children with more reactive temperaments might promote more chaotic home environments. Because of their lower levels of self-regulation, children with more reactive temperaments tend to react strongly to stimuli and situations, thereby creating a source of unpredictability that challenges structures and routines in the home. The significant correlations observed also support that child temperament and the child's family environment are associated with one another in children with TH, emphasizing the need to examine developmental outcomes using transactional perspectives accounting for both the child and their environment. However, the lack of correlation between child temperament, environmental confusion, and language in this group might suggest that temperament and certain aspects of the environment have greater influence on developmental domains outside of language. For example, in a group of children who are TH who were also school age (i.e., 3–7 years old), environmental confusion influenced the relationship between temperament and socioemotional and behavioral outcomes: Children with low effortful control were less likely to experience behavior and maladjustment problems when environmental confusion is low versus when it is high (Chen et al., 2014).

Family-related environmental confusion did not influence temperament and language in children with TH. In contrast, literature also employing a transactional approach to understanding child temperament and language tend to report positive relations with temperament and language when using measures such as caregiver responsiveness and caregiver input (Karrass & Braungart-Rieker, 2003; Laake & Bridgett, 2018; Spinelli et al., 2018). However, this study differed from the previous literature as we focused on the school-age period as opposed to infancy and we adopted a family-level measure as opposed to a caregiver-level measure. As previously discussed, language in older children with TH appears to be less influenced by child temperament and aspects of the family environment associated with environmental confusion.

Children Who Are DHH

For children who are DHH, temperament, specifically effortful control, was positively related to receptive language. We also found that effortful control was negatively related to negative affectivity and surgency–extraversion in the DHH group, consistent with findings that children with greater regulatory skills (i.e., high effortful control) can better control their emotions and reactivity to stimuli—an important skill for language development (Bloom, 1993; Dixon & Smith, 2000). High effortful control and low negative affectivity in DHH children were associated with low levels of family-related environmental confusion in the home, similar to the results observed in our sample of children with TH. Associations between child temperament and family-related environmental confusion in our sample of children who are DHH support links between temperament and the environment that likely also influence other domains such as social and behavioral outcomes.

DHH children with high effortful control achieved better language outcomes than children with low effortful control only in families that reported lower-to-moderate levels of environmental confusion in the home—that is, environments characterized by lower levels of confusion, agitation, disorganization in time and space, noise, crowding, and traffic. In family environments with higher levels of environmental confusion, children's level of effortful control was unrelated to their spoken receptive language. There was evidence that at the highest levels of environmental confusion in this sample, higher levels of effortful control were related to poorer receptive language, but this is based on only two families and thus should be interpreted with caution. Finally, the level of family-related environmental confusion did not influence how surgency–extraversion or negative affectivity contributed to spoken language in children who are DHH.

Families with lower levels of chaos and disorganization provide a home environment that allows children who have better self-regulatory abilities to harness their attentional resources to achieve better language. Good self-regulation skills may help children who are DHH partially compensate for their reduced auditory access by helping children maintain focused attention during play and social activities, freeing up resources to attend to the spoken language models in their environment to develop better receptive language. However, this appears to only support better language development when the family environment is not too chaotic. Reduced auditory access can put children who are DHH at risk for missing linguistically relevant cues from their environment. Good effortful control can help children who are DHH overcome this challenge by, for example, enabling them to maintain joint attention with caregivers during language learning opportunities (Chen et al., 2019). Joint attention has been linked to better cognitive, social, and language outcomes in children undergoing typical language development (Salley & Dixon, 2007) and children who are DHH (Chen et al., 2020); the ability to shift and sustain attention—which ties into effortful control abilities—is important to ensuring that children can focus and learn from the linguistic input provided by their caregiver(s) during social interactions (Spinelli et al., 2018). However, it appears that children who are DHH are only able to harness their effortful control skills when their environment is not overly stimulating. An environment with only low-to-moderate "noise" and chaos can ensure that children who are DHH can use their effortful control abilities to focus on important stimuli from their environment, such as linguistic cues rather than distractions that may be present in households with higher levels of environmental confusion.

For DHH children raised in more highly chaotic and unorganized family environments, effortful control no longer related to receptive spoken language. Perhaps higher levels of environmental confusion lead to more complex relations between child effortful control and child language. For example, high levels of environmental confusion can indirectly negatively affect child language development through requiring children to develop coping mechanisms so that they can "filter" stimuli within their environment (Coldwell et al., 2006; Evans et al., 1991). A child raised in an environment with high levels of environmental confusion may physically withdraw from the environment by seeking other less stimulating areas within the home (Matheny et al., 1995). Although these coping mechanisms might help children control overstimulation in their environment, they can also prompt them to miss out on aspects of their environment that could be linguistically relevant and otherwise contribute to their overall language development. Recall that for the two families that reported high chaotic environments within our sample, there was evidence of a negative relation between effortful control and language: High effortful control was associated with poorer receptive language. DHH children with good effortful control skills might direct their focus to less stimulating areas within the home as a coping mechanism, thereby missing opportunities for language learning. Future research should investigate the possibility that children who are DHH may begin overregulating in environments with overstimulation (Coldwell et al., 2006; Evans et al., 1991)—as seen in children undergoing typical development—in samples that have families reporting greater levels of environmental confusion in the home.

It is important to consider that environmental confusion might influence child temperament and spoken language through the transactional effects that environmental confusion has on caregiver–child interactions. As discussed in the introduction, high levels of environmental confusion can strain dyadic interactions between children and their caregiver(s). Homes with recurring background noise, unpredictability in schedules, and a lack of routines can interfere with the opportunities that children have to interact with their caregiver and vice versa (Coldwell et al., 2006; Evans & Wachs, 2010; Wang et al., 2022). Environmental confusion can also affect caregiver–child processes through other means. For example, high levels of environmental confusion have been shown to result in heightened levels of physiological stress in caregivers (Bodrij et al., 2021), and even moderate levels of caregiver-reported stress have been shown to affect language in children who are DHH (Blank et al., 2020). Future work should consider how caregiver–child interactions are affected by varying levels of environmental confusion and the impact this has on language development.

The null findings surrounding influences of family-related environmental confusion, negative affectivity, and surgency–extraversion on spoken language in children who are DHH could reflect that temperament dimensions centered around emotionality may show stronger associations to other social and behavioral outcomes in older children rather than to language. This is something that could be explored in future research.

Clinical Implications

For children who are DHH, understanding the role of temperament in child language and its interaction with the child's environment can help families and professionals optimize children's language-learning environments. Whereas temperament is largely stable and not malleable, home environments can be modified with family therapy (Holstrum et al., 2008; Moeller & Tomblin, 2015). Understanding the negative impact of both auditory noise and dynamics of the home environment that can serve as a source of nonauditory noise (i.e., high activity levels, lack of routines, disorganization, etc.) can help families target specific features of the home environment that, if modified, could optimize the environment for language-learning, especially for children who are DHH. For example, audiologists can potentially help address overstimulation caused by auditory noise through providing DHH children with assistive listening devices that can increase SNR when necessary (Benítez-Barrera et al., 2020) and counseling caregivers on reducing background noise. Intervention should also consider collaborating with other professionals to address visual and cognitive overstimulation caused by nonauditory noise such as disorganization, lack of routines, and so forth. Helping families develop consistent structure and routines inside the home through goal setting, education, and motivational interviewing has been shown to reduce environmental confusion (Andeweg, 2021).

Lower levels of environmental confusion enable children who are DHH to effectively harness their effortful control abilities to positively influence language. In our sample, over half of the families of children who are DHH reported low-to-moderate levels of environmental confusion (i.e., a 29.15 or less on the CHAOS). Although means and ranges of environmental confusion were comparable between families of children who are DHH and families of children with TH, children with TH across the different temperament dimensions did not appear to be affected by the level environmental confusion in the home. These results would suggest that temperament (specifically good regulatory skills) positively influences spoken language for school-age children with hearing loss, as long as the environment offers minimal distractions. These findings support working with families of children who are DHH to ensure that families are maximizing their child's effortful control abilities and minimizing levels of environmental confusion in the home.

Limitations

One potential limitation to this study is the use of broad measures to quantify temperament and environmental confusion. For example, there are 15 individual temperament traits that contribute to the three dimensions of temperament (i.e., effortful control, negative affectivity, and surgency–extraversion), and the overall score on the CHAOS represents individual questions centered around organization, noise, and routineness. Perhaps focusing on specific components within these measures could reveal relationships not observed in this study. However, we used these three temperament dimensions and overall CHAOS score as intended by the authors to obtain more robust results between child temperament and family-related environmental confusion in our samples. Furthermore, using broad dimensions to quantify temperament and environmental confusion helps to provide a more holistic picture for understanding dynamics within the home environment, especially for the first investigation into these dimensions in children who are DHH. Another limitation is the lack of standardization/norms available for the scales used in this study to measure temperament and environmental confusion. However, as reported above, scores obtained in our sample were comparable to those in other studies reporting similar administration and use of these measures. Lastly, considering that some theories of temperament argue that a portion of temperament is inherited genetically (i.e., Buss & Plomin, 1975; Saudino & Wang, 2012), these associations between temperament and the family environment as measured by levels of environmental confusion could reflect that children with easy temperaments raised in more organized and structured households have parents who also have easy temperament or personality traits. Perhaps certain adult temperament traits positively influence the surrounding environment, and in turn, adults raise children with similar temperaments within the same environments.

Future Directions

We hypothesized that children who are DHH would exhibit poorer spoken language outcomes in environments high in auditory and nonauditory noise due to reduced auditory access (Walker et al., 2019) and neurocognitive deficits (Kronenberger et al., 2014) that persist even with sensory aids. Although this study provided a groundwork for examining interactive effects of child temperament and environmental confusion on spoken language in children who are DHH, we did not account for additional variables that could impact these relationships. For example, children who are DHH with a greater ability to listen in noise might be able to overcome the auditory overstimulation in homes high in environmental confusion and take more advantage of indirect language learning opportunities. Other factors such as IQ, support from peers and teachers, and intervention history might also contribute to resiliency for DHH children in homes high in environmental confusion. Furthermore, by grouping children who use HAs and those who use CIs into one group to increase power for statistical analyses (in addition to the limited audiological data available), we were unable to assess differences between DHH children with varying degrees of hearing loss and device type/configurations. Future work could examine the influences of these factors on the relation between child temperament, environmental confusion, and child spoken language outcomes.

Finally, our sample included school-age children from 3 to 7 years old. We were able to increase statistical power in our TH and DHH samples by including preschoolers and children in elementary school. However, there could be different dynamics within the home for these different age groups that influence environmental confusion and caregiver–child interactions. Future work should examine the effect age has on mechanisms influencing temperament and language in DHH children, especially in homes with varying degrees of environmental confusion. In addition, future research could benefit from attempts to address the limitations of this study by examining specific subcomponents of temperament and environment confusion, adopting other outcome measures beyond a single measure of receptive language to capture the complexities of language, and/or considering the role of adult temperament in influencing the family environment.

Conclusions

Minimizing chaos and auditory noise in the home allows children who are DHH to harness their effortful control to achieve better spoken language outcomes. The effects of reactive temperament factors such as negative affectivity and surgency–extraversion on receptive language seem to become less important during school age for both children who are DHH and children with TH. Intervention for this clinical population should continue placing focus on helping families optimize the language-learning environment, in addition to promoting children's self-regulatory skills.

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