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TEMPERAMENT, SELF-REGULATION, AND EXECUTIVE FUNCTIONING IN CHILDHOOD STUTTERING

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INTRODUCTION

The purpose of this manuscript is to provide an overview of my presentation given to the March 2022 'Puheen ja kielen tutkimuksen päivät' conference (Helsinki, Finland). Temperament plays an important role in the experience and expression of emotions, such as emotional reactivity and emotional (self-) regulation and is associated with certain executive functioning components. This manuscript describes the empirical studies from my research lab that have focused on the association between temperament, self-regulation, and executive functioning in childhood stuttering. Findings from our initial temperament questionnaire-based work as well as later studies, primarily using behavioral (computer) paradigms focusing on different aspects of self-regulation and executive functioning, will be discussed.

TEMPERAMENT, SELF-REGULATION, AND EXECUTIVE FUNCTIONING

At present, most theorists agree that temperament refers to biologically based individual differences that are relatively stable over time, and appear early in devel-

opment (Goldsmith et al., 1987). Recent models further acknowledge that temperament develops over time (Plomin & Dunn, 1986, Rothbart, 1989), incorporates motivational and self-regulatory systems (Posner & Rothbart, 1998), and is influenced by environmental interactions (Halverson & Deal, 2001; Saudino, 2005).

Rothbart's temperament model, which defines ***temperament*** as constitutionally based individual differences in reactivity and self-regulation, has gained much popularity among child-oriented researchers (Rothbart et al., 2001). Reactivity refers to the arousability of physiological and sensory response systems (e.g., getting frustrated about something), and self-regulation refers to processes that can modulate (facilitate or inhibit) one's reactivity (e.g., shifting one's attentional focus away from the frustrating stimulus). Constitutional refers to the biological basis of temperament (i.e., it is something you are born with), which is influenced over time by genetics, maturation, and experience. In other words, the temperament structure changes over time, from a predominantly reactivity-driven concept in infants to a structure with more emphasis on self-regulatory processes in older children. For example, when infants are distressed, they will cry, much to the dismay of their parents; older children, on the other hand, can deal with distress using a broader range of tools, such as shifting their attention away from that which they find distressing (Putnam et al., 2001).

Rothbart (1989) developed a framework specifying the role and interactional patterns of reactivity and self-regulation. When a child is confronted with a stimulus, this stimulus might lead to positive (e.g., smiling) or negative (e.g., fear, anger) reactivity within the child. As the child grows older, s/he will be able to consciously modulate this reactivity by using self-regulation processes to increase positive reactivity and/or decrease negative reactivity. These are not necessarily related, in other words, children can gradually become less fearful without an increase in smiling and laughter.

Self-regulation, also referred to as emotion regulation, relates to "the ways individuals influence which emotions they have, when they have them, and how they experience and express these emotions" (Gross, 1999, p. 557). Self-regulation processes include executive attention variables (e.g., consciously driven attention shifting) and effortful control (the ability to inhibit a dominant [motor] response in order to perform a subdominant response, detect errors, and engage in planning) (Rueda & Rothbart, 2009). The successful use of these self- regulation strategies is highly dependent on age and maturation (Gullone et al., 2010), given that they depend on the development of the prefrontal cortex, executive

function skills (e.g., inhibitory control) (Carlson & Wang, 2007), and linguistic skills (Sala et al., 2014).

Children have different levels of reactivity - some react with more intense feelings of distress or pleasure, whereas others react more mildly. Children also differ in the ease with which they are able to apply attentional (e.g., looking towards [attentional orienting] or away from [attentional shifting] an exciting or distressing event) and motor control processes (e.g., self-soothing) to regulate their reactivity (Rothbart, 1989; 2011).

Executive functioning is an umbrella term, governing goal-directed action and adapted responses to novel or complex situations (Hughes, 2013). It encompasses a number of subdomains derived from empirical studies, some more consistently endorsed than others (Baron, 2004), such as attentional control, working memory, attentional flexibility, inhibitory control, verbal fluency (not speech fluency), planning and organization (Jurado & Roselli, 2007; Najdowski et al., 2014). While the exact nature and the relationships between all of these processes are not yet completely understood (Collette et al., 2001), working memory, attentional flexibility, and inhibitory control seem to be given central importance in some theoretical models of executive functioning (Barkley, 1997; Garon et al., 2008; Miyake et al., 2000; Roberts & Pennington, 1996; Sereno et al., 2009). Executive functioning emerges already early in childhood (Kalbfleisch, 2017). While the different components seem to vary somewhat in their developmental trajectories (Best et al., 2009), many processes keep developing and continue to strengthen throughout adolescence into young adulthood (Best & Miller, 2010).

Within the scope of the current manuscript, only studies on executive functioning processes linked to Rothbart's self-regulation component of temperament are discussed.

QUESTIONNAIRE-BASED STUDIES IN TEMPERAMENT AND CHILDHOOD STUTTERING

A growing number of studies have been investigating the relationship between temperament and stuttering (for an overview, see Jones et al., in press). Using Rothbart's triad of positive/negative reactivity versus self-regulation, many of the findings in children who stutter (CWS) can be understood as pointing toward increased reactivity or reduced self-regulation or a combination of both. Some of these temperament questionnaire-based studies have also yielded differences on

attentional and inhibitory control-related processes between stuttering and non-stuttering groups and seem to suggest these processes may be involved in the development and/or maintenance of developmental stuttering.

In one of our first studies in this domain we used the Children's Behavior Questionnaire (Rothbart et al., 2001), a caregiver rating scale based on Rothbart's temperament model, to evaluate differences between children who stutter (CWS) and children who do not stutter (CWNS). CWS, as a group, scored higher on negative reactivity and lower on self-regulation (Eggers et al., 2009; 2010). Analysis of the individual temperament scales showed that CWS scored significantly lower on the scales of 'Inhibitory Control' and 'Attentional Shifting' and higher on the scales of 'Anger/Frustration', 'Approach' and 'Motor Activation'. Stuttering severity and months of therapy were not associated with either of the temperament dimensions.

In a recent series of studies, we started to explore the associations between temperament, anxiety and the impact of stuttering. Higher negative reactivity scores (i.e., more fearful children) and lower positive reactivity (i.e., less extraverted children) and self-regulation scores were associated with elevated levels of anxiety and depression in CWS (Eggers et al., accepted). Also, the impact that stuttering has on an individual is likely to be affected by temperament and one's ability to cope, since the experience of stressors and the ability to cope can directly impact children's and adolescents' well-being. Children with higher positive reactivity scores experienced a lower overall impact of their stuttering while children with higher negative reactivity experienced a higher overall impact (Eggers et al., 2021).

BEHAVIORAL (COMPUTER) PARADIGM-BASED STUDIES IN SELF-REGULATION, EXECUTIVE FUNCTIONING AND CHILDHOOD STUTTERING

While several approaches can be used for assessing temperament, self-regulation, and executive functioning (e.g., questionnaires, behavioral observations, psychophysiological indicators, behavioral tasks), each approach has its benefits and pitfalls (Baron, 2004; Kagan, 1998). Although questionnaires tap into the vast knowledge of caregivers who have experienced the child's reactions in different situations and over a long period of time, they can be susceptible to parental bias and inaccuracy (Strelau, 1998; Vaughn et al., 2002). Therefore, the use of computer paradigm-based studies allows (a) to test experimentally previous findings of parent-reported differences between CWS and CWNS and (b) for more fine-

grained analyses of these different components. The studies that are discussed focus respectively on attentional networks, attentional processes (e.g., attentional shifting) and on inhibitory control. These studies always include a group of CWS (without any other speech, language, hearing and/or developmental disorders apart from stuttering) matched (age and gender) to a group of CWNS. The children's ages range between 4 and 10 years of age.

The efficiency of ***attentional networks*** was evaluated (Eggers et al., 2012) using the Attention Network Test (Fan et al., 2002; Rueda et al., 2004), a combination of a cued reaction time task and a flanker task. This task measures the efficiency of three distinct attentional networks, i.e. alerting (the component of attention that increases vigilance to an impending stimulus), orienting (the component of attention that supports the selection of specific information from numerous sensory inputs) and executive attention (the component of attention involving more complex mental operations in detecting and resolving conflict between computations in different parts of the brain). Results indicated that CWS had a significantly lower efficiency of the orienting network compared to CWNS. No differences were found on the alerting or executive control network, although the latter did show a trend ($p = .06$) towards a lower efficiency for CWS. Current findings corroborate the previously found questionnaire-based differences in self-regulatory behavior and were taken to suggest a possible role for attentional processes, i.e. attentional orienting, in developmental stuttering.

The efficiency of ***inhibitory control*** was evaluated using a Go/NoGo task (Eggers et al., 2013) and a Stopsignal Task (Eggers et al., 2018). Both tasks measure the inhibition of prepotent responses. During each trial of the Go/NoGo task (De Sonneville, 2009), one of two different stimuli was presented randomly and with equal frequency: a Go-stimulus (a green walking man) or a NoGo-stimulus (a red standing man). Results indicated that CWS, compared to CWNS, a) exhibited more false alarms (when a NoGo-stimulus was followed by pressing the response button) and premature responses (when the response button was pressed between 0 and 200 ms after stimulus onset), b) showed lower reaction times for false alarms, and c) were less able to adapt their response style after experiencing response errors. Some of these findings were also replicated in adults who stutter (Eggers, 2012). These findings provide further support for the hypothesis that CWS and CWNS differ on inhibitory control. CWS, as a group, were lower in inhibitory control pointing towards a lowered ability to inhibit prepotent response tendencies. However, these findings cannot be generalized to all types of response inhibition since the use of the Stopsignal task (Verbruggen et al., 2008), a primary choice reaction time task where on a random selection of

trials an auditory stop signal appeared, indicating participants to withhold their response, did not reveal any between-group differences.

In a final study (Eggers & Jansson-Verkasalo, 2017), the Auditory Set-Shifting Task of the Amsterdam Neuropsychological Tasks (De Sonneville, 2009) was used to evaluate ***attention shifting*** and ***inhibitory control*** in a combined manner. The core feature of this task is mixed stimulus-response (SR) mapping, which consisted of a random combination of low- and high-pitched stimuli. The pitch (low or high) determined the required type of SR mapping; a low pitch meant compatible SR mapping (press once when one tone is presented and twice when two tones are presented), whereas a high pitch meant incompatible SR mapping (press twice when one tone is presented and once when two tones are presented). This mixed SR mapping requires participants to continuously shift their attentional set and inhibit prepotent responses. Results indicated no group differences for the speed of auditory attention shifting or inhibitory control. However, CWS, as a group, scored significantly lower on the accuracy (error percentage) of auditory attention shifting. In addition, CWS, compared to the CWNS, showed a higher increase in error percentages under attention shifting and inhibitory control conditions. These findings on error percentages partly corroborate earlier questionnaire-based findings showing difficulties in CWS on attention shifting and inhibitory control. Moreover, it also seems to imply that CWS are less able to slow down their responses in order to achieve higher accuracy rates.

THEORETICAL AND CLINICAL IMPLICATIONS

Our studies have shown that CWS, as a group, differ from CWNS on temperamental constellation, more specifically they are higher in negative reactivity and lower in self-regulation. With regard to self-regulation, differences emerged on attentional regulation and inhibitory control. There are several possible pathways by which these processes might exude their influence on the onset and development of stuttering (e.g., via a role in generating emotional reactions, in stress-related situations, in conditioning processes, in error-detection and error-processing during speech production processes), however, it is less evident to make any strong statements about the exact nature of the underlying relation.

Our findings map onto recent multifactorial models (e.g., Conture et al., 2006; Conture & Walden, 2012; Smith & Weber, 2017) that have considered a

combination of genetic, neurobiological, behavioral, emotional, and environmental components as predisposing, precipitating and persisting factors in the etiology of stuttering. For example, Conture and Walden's recent Dual Diathesis-Stressor Model of Stuttering suggests that some CWS have vulnerabilities (i.e., diathesis), such as heightened negative emotional reactivity and decreased self-regulation, that can be activated by challenging environmental situations or events (i.e., stressors) and that these processes contribute to the onset and development of stuttering. Children exhibiting these emotional diatheses may be more likely to have their attention and other cognitive resources diverted during emotionally-arousing speaking situations (social-emotional stressor) and, consequently, be more likely to stutter. These children may also be more likely to react to difficulties with speech production, leading to a worsening of stuttering. Another example is Anderson and Ofoe's (2020) Executive Function Model of Developmental Stuttering, in which they consider how executive functioning deficits could explain not only the multifactorial nature of developmental stuttering but also the considerable amount of variability that exists among CWS.

Until the underlying mechanisms associated with temperament, self-regulation, and stuttering have been fully unraveled, formulating treatment recommendations based on these associations may be premature. However, several approaches developed for working with children's temperaments (Kristal, 2005) are applicable to children who stutter (Eggers, 2017). Examples are strategies for creating a better parent-child alliance such as anticipating how children will react in certain circumstances and changing/adjusting environmental contexts, or providing problem solving/coping strategies such as teaching parents to co-regulate the child's emotions (Eggers, 2020).

CONCLUSION

There have been significant advances to the empirical study, theoretical understanding, and potential clinical application of temperament, self-regulation, and executive functioning to developmental stuttering. Initially, this work focused, almost predominantly, on caregiver report. Currently, this work has focused on using a broad range of methodological approaches to comprehensively study these concepts. Both past and present work have provided evidence to suggest that increased reactivity and decreased self-regulation are associated with developmental stuttering.

REFERENCES

Anderson, J. D., & Ofoe, L. C. (2019). The role of executive function in developmental stuttering. *Seminars in Speech and Language*, *40*(4), 305–319.

Barkley, R. A. (1997). Behavioral inhibition, sustained attention, and executive functions: Constructing a unified theory of ADHD. *Psychological Bulletin, 121*, 65–94.

Baron, I. S. (2004). *Neuropsychological Evaluation of the Child*. Oxford University Press.

Best, J. R., & Miller, P. H. (2010). A developmental perspective on executive function. *Child Development*, *81*(6), 1641–1660.

Best, J. R., Miller, P. H., & Jones, L. L. (2009). Executive functions after age 5: Changes and correlates. *Developmental Review*, *29*(3), 180–200.

Carlson, S. M., & Wang, T. S. (2007). Inhibitory control and emotion regulation in preschool children. *Cognitive Development*, *22*(4), 489–510.

Collette, F., Van der Linden, M., Delfiore, G., Degueldre, C., Luxen, A., & Salmon, E. (2001). The functional anatomy of inhibition processes investigating the hayling task. *Neuroimage*, *14*, 258–267.

Conture, E. G., & Walden, T. A. (2012). Dual diathesis-stressor model of stuttering. In L. Beliakova and Y. Filatova (Eds.), *Theoretical issues of fluency disorders* (pp. 94–127). Vlados.

Conture, E. G., Walden, T. A., Arnold, H. S., Graham, C. G., Hartfield, K. N., & Karrass, J. (2006). A communication-emotional model of stuttering. In A. Bernstein Ratner & J. Tetnowski (Eds.), *Current issues in stuttering research and practice* (pp. 17–46). Lawrence Erlbaum Associates, Publishers.

De Sonneville, L. M. J. (2009). *Amsterdamse Neuropsychologische Taken. [Amsterdam Neuropsychological tasks].* Boom Test Publishers.

Eggers, K. (2012). Responsinhibitie bij volwassen personen die stotteren versus niet stotteren [Response inhibtion in adults who stutter versus adults who do not stutter]. *Logopedie [Logopedics]*, July-August Issue, 76–83.

Eggers, K. (2017, September). *Working with temperament styles with children who stutter and their families.* Preconference workshop presented at the Oxford Disfluency Conference, Oxford.

Eggers, K. (2020, December). *Emotional regulation in children who stutter.* On-demand-streaming Video Library of the Stuttering Foundation (https://thestutteringfoundation.vhx.tv/products/emotional-regulation-in-children-who-stutter).

Eggers, K., De Nil, L., & Van den Bergh, B. (2009). Factorial temperament structure in stuttering, voice disordered, and normal speaking children. *Journal of Speech, Language, and Hearing Research, 52*, 1610–1622.

Eggers, K., De Nil, L., & Van den Bergh, B. (2010). Temperament dimensions in stuttering and typically developing children. *Journal of Fluency Disorders, 35*, 355–372.

Eggers, K., De Nil, L., & Van den Bergh, B. (2012). The efficiency of attentional networks in children who stutter. *Journal of Speech, Language, and Hearing Research, 55*, 946–959.

Eggers, K., De Nil, L. F., & Van Den Bergh, B. R. H. (2013). Inhibitory control in childhood stuttering. *Journal of Fluency Disorders, 38*, 1–13.

Eggers, K., De Nil, L., & Van den Bergh, B. (2018). Exogenously triggered response inhibition in developmental stuttering. *Journal of Fluency Disorders, 56*, 33–43.

Eggers, K., & Jansson-Verkasalo, E. (2017). Auditory attentional set-shifting in developmental stuttering. *Journal of Speech, Language, and Hearing Research, 60*, 3159–3170.

Eggers, K., Millard, S., & Kelman, E. (2021). Temperament and the impact of stuttering in adolescents. *Journal of Speech, Language, and Hearing Research, 64*, 417–432.

Eggers, K., Millard, S., & Kelman, E. (Accepted). Temperament and anxiety in school-age children who stutter. *Journal of Communication Disorder*s.

Fan, J., McCandliss, B. D., Sommer, T., Raz, A., & Posner, M. I. (2002). Testing the efficiency and independence of attentional networks. *Journal of Cognitive Neuroscience, 14*, 340–347.

Garon, N., Bryson, S., & Smith, I. M. (2008). Executive function in preschoolers: A review using and integrative framework. *Psychological Bulletin, 134*, 31–60.

Goldsmith, H. H, Buss, A. H., Plomin, R., et al. (1987). Roundtable: What is temperament? four approaches. *Child Development, 58*(2), 505–529.

Gross, J. J. (1999). Emotion regulation: past, present, future. *Cognition and Emotion, 13*(5), 551–573.

Gullone, E., Hughes, E. K., King, N. J., & Tonge, B. (2010). The normative development of emotion regulation strategy use in children and adolescents: a 2-year follow-up study. *Journal of Child Psychology and Psychiatry, 51*(5), 567–574.

Halverson, C. F. & Deal, J. E. (2001). Temperamental change, parenting and the family context. In T. D. Wachs and G. A. Kohnstamm (Eds.) *Temperament in context* (pp. 61–80). Lawrence Erlbaum Associates, Publishers.

Hughes, C. (2013). Executive function: Development, individual differences, and clinical insights. In J. Rubenstein & P. Rakic (Eds.), *Neural circuit development and function in the healthy and diseased brain: comprehensive developmental neuroscience 1st Edition* (pp. 429–445). Academic Press, Oxford.

Jones, R., Eggers, K., & Zengin-Bolatkale, H. (In press). Temperamental and emotional processes. In P. Zebrowski, J. Anderson, and E. Conture (Eds.), *Stuttering: Characteristics, assessment, and treatment (4th Ed.)*. Thieme Medical Publishers.

Jurado, M. B., & Roselli, M. (2007). The elusive nature of executive functions: A review of our current understanding. *Neuropsychological Review, 17*, 213–233.

Kagan, J. (1998). Biology and the child. In W. Damon & N. Eisenberg (Eds.), *Handbook of child psychology. Volume 3: Social, emotional and personality development* (pp.177–235). John Wiley & Sons, Inc.

Kalbfleisch, L. (2017). Neurodevelopment of the executive functions. In E. Goldberg (Ed.), *Executive functions in health and disease* (pp. 143–167). Academic Press.

Kristal, J. (2005). *The temperament perspective. Working with children's behavioral styles.* Brookes.

Miyake, A., Friedman, N. P., Emerson, M. J., Witzki, A. H., & Howerter, A. (2000). The unity and diversity of executive functions and their contributions to complex 'frontal lobe' tasks: A latent variable analysis. *Cognitive psychology, 41*, 49–100.

Najdowski, A. C., Persicke, A., & Kung, E. (2014). Chapter 18: Executive functions. In D. Granpeesheh, J. Tarbox, A. C. Najdowski, & J. Kornack (Eds.), *Practical resources for the mental health professional: Evidence-based treatment for children with autism* (pp. 355–387). Academic Press, Oxford.

Plomin, R., & Dunn. J. (1986). *The study of temperament: Changes, continuities, and challenges.* Lawrence Erlbaum Associates.

Posner, M. I., & Rothbart, M. K. (1998). Attention, self-regulation, and consciousness. *Philosophical transactions of the Royal Society B: Biological Sciences, 353*(1377), 1915–1927.

Putnam, S. P., Ellis, L. K., & Rothbart, M. K. (2001). The structure of temperament from infancy through adolescence. In A. Eliasz, and A. Angleitner

(Eds.) *Advances/proceedings in research on temperament* (pp. 165–182). Pabst Scientist Publishers.

Rueda, M. R., Fan, J., McCandliss, B. D., Halparin, J. D., Gruber, D. B., Lercari, L. P., & Posner, M. I. (2004). Development of attentional networks in childhood. *Neuropsychologica, 42*, 1029–1040.

Rueda, M. R., & Rothbart, M. K. (2009). The influence of temperament on the development of coping: The role of maturation and experience. *New Directions for Child and Adolescent Development*, 124, 19–31.

Roberts, R. J., & Pennington, B. F. (1996). An interactive framework for examining prefrontal cognitive processes. *Developmental Cognitive Neuropsychology, 12*, 105–126.

Rothbart, M. K. (1989). Temperament in childhood: A framework. In G. Kohnstamm, J. Bates, and M. K. Rothbart (Eds.), *Temperament in childhood* (pp. 59–73). Wiley.

Rothbart, M. K. (2011). *Becoming who we are: Temperament and personality in development.* Guilford Press.

Rothbart, M. K., Ahadi, S. A., Hershey, K. L., & Fisher, P. (2001). Investigations of temperament at three to seven years: The Children's Behavior Questionnaire. *Child Development*, *72*(5), 1394–1408.

Sala, M. N., Pons, F., & Molina, P. (2014). Emotion regulation strategies in preschool children. British *Journal of Developmental Psychology, 32*(4), 440–453.

Saudino, K. J. (2005). Behavioral genetics and child temperament. *Journal of Devopmental and Behavioral Pediatrics, 26*(3), 214–223.

Sereno, A. B., Babin, S. L., Hood, A. J., & Jeter, C. B. (2009). Executive functions: Eye movements and neuropsychiatric disorders. In L. R. Squire (Ed.), *Encyclopedia of neuroscience* (pp. 117–122). Academic Press, Oxford.

Smith, A., & Weber, C. (2017). How stuttering develops: The multifactorial dynamic pathways theory. *Journal of Speech, Language, and Hearing Research*, 60(9), 2483–2505.

Strelau, J. (1998). *Temperament: A psychological perspective.* New York.

Vaughn, B. E., Taraldson, B.J., Cuchton, L., & Egeland B. (2002). The assessment of infant temperament: A critique of the Carey infant temperament questionnaire. *Infant Behavior & Development, 25*, 98–112.

Verbruggen, F., Logan, G. D., & Stevens, M. A. (2008). Stop-it: Windows executable software for the stop-signal paradigm. *Behavior Research Methods, 40*, 479–483.