**Machine Learning Approach to Predict Communication Disorder Stammering Based on Temperaments of Children**

**Shaikh Abdul Waheed1, Waseem Ahmad Mir1 Hamid Allabuksh Pathan1**

**1GH Raisoni College of Engineering and Management, Pune, India**

**Abstract**

The aim of this chapter is to introduce a machine learning based approach to predict a potential risk of stammering using temperamental traits of pre-school children because previous studies show that these traits have contribution in developmental stammering. Stammering based dataset from Vanderbilt University has been introduced that consist of children aged 3 to 7 years including boys and girls who stutter and who do not stutter.  Predictive models can be created using machine learning algorithms like logistic regression.  The predictive model can be trained by feeding the traits related to temperament and it has produced the good accuracy to predict potential risk of stammering. Findings show that individual’s temperamental traits can be used to predict potential risk of stammering regardless of race and gender of children. Hence, a certain kind of relation between the arousal of stammering and temperamental traits of children can be established if predictive models predicts stammering with optimal accuracy.

**Keywords:** Stammering; stuttering; temperaments; children; prediction

1. **Introduction**

**1.1 Communication disorder stammering**

The stammering is a disorder in the fluency of speech, which constitute of repeated prolongations of audible and inaudible sounds, repetitions of words and phrases, and speech-blocks (Conture 2001; J Anderson, 2003). In the world, nearly 5% of adult population found the victim of this chronicle disorder; among them seventy to eighty percent of adults recover without treatment (Alison Bush, 2006). On the other side, the stammering is also found in children that known as the developmental-stammering (Gerald 2012). Among children who stutter (CWS), 1% of children likely to be stuttered in the next stage of life after the age of 6 years and it harshly affects their social and academic life (Alison Bush, 2006). The temperament can be referred as the biologically based differences found among children that includes their behavioral styles and responses (Rothbart and Derryberry,1981) and, such biologically based differences are stable over time and across all situations of life (Sanson et al., 2004).

The majority of researchers and clinicians say that the temperament is not a singular attribute but it is a group of related attributes (Goldsmith et al. (1987). The seminal research indicates that the temperament has seven to nine dimensions – for instance, self-regulation, emotional reactivity, negative affectivity, difficultness, coping ability to new situation, environment and people, surgency (positive emotionality) and activity-level (Goldsmith et al 1987; Rothbart & Derryberry 1981; Balter; Rothbart & Bates, 1998; Wachs, 1999). Hence, the temperament is conceptualized as the way in which a person reacts to and interacts with their environment (Kefalianos et al., 2012). The other interesting facts of the temperament are that temperamental traits do not remain quietly but they inter-mingle with other developmental factors of childhood especially from social environment to form a total personality Thompson (1999) and these traits act significantly in overall development of human life (Strelau, 1998), mainly in cognitive growth (e.g., Miceli, Whitman, Borkowski, Braungart-Rieker, & Mitchell, 1998; Singer & Fagen, 1992), academic excellence (e.g., Martin, Drew, Gaddis, & Moseley, 1988; Martin, Olejnik, & Gaddis, 1994), behavioral adaptation (e.g., Kyrios & Prior, 1990, Windle, 1989), and language development (e.g., Dixon & Shore, 1997; Dixon & Smith, 2000).

**1.2 Relation between stammering and temperament Traits**

Thus, researchers considered it as important to investigate an relation between temperament-traits and stammering (e.g., Embrechts, Ebben, Franke, & van de Poel, 2000; Lewis & Goldberg, 1997) and other chronicle disorders in language and speech (e.g., Caulfield, Fischel, DeBaryshe, & Whitehurst, 1989; Paul & James, 1990; Paul & Kellogg, 1997).

For stammering research, to assess the temperamental traits of CWS and CWNS, parents or caregiver rating scales are most widespread tools. In this scaling, parents are interviewed or provided a questionnaire to report about their child’s temperament traits. J Anderson (2003) say, since parents monitor their children daily over a long period and they are only to provide a more exhaustive outlook of the child's temperamental traits. The relation between stammering and temperamental traits is discussed in detail in the section of related work.

1. **Features selection methods for stammering**

Pre-selection of a proper subset of features related to temperament is needed to get optimized prediction accuracy because the dataset is having large number of temperamental features. If a model is trained by feeding all thirty three temperamental features at once, it may demonstrates less statistical power because saturated models are not sensible to detect an expected event and moreover, the possibility of drooping significant variables due to low statistical power.

For pre-selection most significant features, this work employed the wrapper method (eg. stepwise methods) because these methods are based on AIC score and AIC is a safeguard against over fitting. The stepwise method works on the principle of dropping of less significant variables at every iteration based on their AIC score by comparing with starting AIC value. Dropping of a variable should not increase model’s AIC value than the model’s starting AIC value.

1. **Machine learning approach to build predictive models**

After dataset cleaning and pre-selection of most significant features, the predictive models can be built using supervised machine learning algorithms like logistic regression (LR) and support vector machine (SVM) by splitting dataset into training and testing datasets with ratio of 80:20. Recently, many studies were performed to predict stammering based on temperaments of children including their emotions and behavioral styles. For example, the research such as S. A. Waheed and P. S. Abdul Khader (2020), S. A. Waheed, et al. (2021), Waheed, S. A., & Khader, P. S. A. (2021), Abdul Waheed, S., Khader, P.S.A., Khan, A.A. et al (2022), Abdul Waheed, S., Abdul Khader, P.S. A (2021).

**3.1 Predictive model building using Machine Learning**

The figure 1 depicts the proposed machine learning model using LR. The LR is a very popular binary classifier which has been widely used in healthcare to predict both diseases and disorders like cancer, diabetic and heart attack (M. Bishop, 2006; Theodora, 2018; Nirmala Devi et al., 2016; Wei Hu, 2015).

A sub-set of most significant preselected features related to temperament-traits

LR

Prediction of potential risk of developmental stammering

Input

Outcome

Figure 1: Architecture of the Machine Learning Model for the prediction of Developmental Stammering

* 1. **Metrics to evaluate predictive models**

The performance of predictive models can be evaluated using notable metrics such as confusion matrix, ROC curve, prediction accuracy, sensitivity, specificity and F1 Score.

**3.3.1 ROC Curve**

The ration of differentiation between positive and negative can be depicted using the ROC curve as shown in Figure 2.

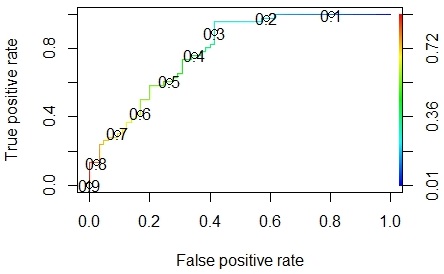


Figure 2 ROC analysis of Logistic Regression

1. **Risk factors from temperaments that could lead towards the onset and recovering of stammering**

**4.1 Mood**

The temperament subsumes quality of mood of an individual, it has two states as positive and negative and either of the moods is long lasting in nature. Mood is subjective in nature and an internal trait but it can be observed from posture and other behaviors. Negative mood is arousal of emotions and, arousal of emotions is a part of emotion reactivity. Robin Jones et al. (2014) states that Emotion reactivity can be one the cause of risk factors for stammering and our result supports that mood has significance role in the risk of stammering.

**4.2 Distraction**

Distraction is state of mind in which diversion of attention of an individual from focusing area. Hence, distraction makes an individual more difficult to focus on singular assigned tasks. The study of Katerina N (2013) observed that CWS is having more attention-regulation problem than CWNS.

In other words, attention regulation subsumes distraction. Due to lack of attention ability, an individual gets distracted. As stated earlier by (Robin Jones et al., 2014) attention-regulation can be one the factor behind the risk of stammering and our result also supports distraction has significance role in predicting the risk of stammering.

**4.3 Sleep problems**

Previous research revealed that some kind of relationship between sleep pattern and stammering. It has been realized that stammering becomes worse after numerous nights of deprived sleeping. When proper sleep hygiene measures has taken then some researchers observed that there are improvements in the recovery of stammering. Having said that, it is not always promising to say that sleep hygiene measures are only solutions to improve stammering (Sandra Merlo, 2012).

Unbalanced sleep timings are measured risk factors for several mental syndromes such as depression and anxiety (Benca et al, 2009) and anxiety and depression may lead to stammering (Katerina N et al., 2013). In other words, unbalanced sleep schedules lead to anxiety and depression and in turn, anxiety and depression leads to stammering. Hence, sleeping problems can have direct and indirect relation with causal of stammering.

A sleep over a night goes into three phases. In its last phase, the 25% of sleep is called REM (rapid eye movement) sleep. Research shows that for preschool children and school-children, it needs a necessary sleep of 14 hours and 10-11 hours respectively (O'Brien, 2009). If child sleeps lesser hours than the sufficient sleep hours, it meddles with their REM phase. Due to this, severe muscle relaxation happens (Guyton & Hall, 1996a). Therefore, following day, an individual potential of immense muscular tension in the speech-musculature (tongue, lips, vocal folds), and stammering may become harsh (Sandra Merlo, 2012).

**4.4 Anxious Depressed**

Recent research showed that in compare to CWNS, CWS had higher rate of anxiety disorder. ([Lisa Iverach](https://www.sciencedirect.com/science/article/pii/S0094730X16300067#!) et al., 2016) stated that CWS exhibited a notably higher percentage of anxiety disorders and they found that 24% of CWS met condition for social anxiety turmoil.

Older research also showed that an anxiety turmoil are linked with variety of negative issues such as low morale and essence of life and high risk of other disorders such as depression and personal abuse (Barrera & Norton, 2009; Costello, Mustillo,Erkanli, Keeler, & Angold, 2003; Kertz & Woodruff-Borden, 2011; Massion, Warshaw, & Keller, 1993; Stevanovic, 2013;Wolitzky-Taylor, Bobova, Zinbarg, Mineka, & Craske, 2012).

And also anxious children are featured by tension, bothered, feared and extremely worried for themselves. Anxious children are characterized by worry, fearfulness, excessive concern for themselves and others and tension (Ameringen, Mancini, & Farvolden, 2003; Crawford & Manassis, 2011; Rapee et al., 2009).

Using Child Behavior Checklist, one the former assessment study by Achenbach (1988) with the sample of 8 children aged 2-5 years on the disorder of childhood stammering revealed that there was a negative effect of psychological disorder like anxiety on severity of stammering and to such children if proper pre-treatment is given, the effect of severity can be reduced. Another study with sample of 45 CWS aged 3-6 showed that stammering participants found more anxious than other like CWNS (Vanryckeghem & Brutten, 2002).

**4.5 Emotion Regulation**

(Katerina Ntourou et al., 2013) in their study found that CWS were more emotionally reactive than their peers of CWNS. Our findings also showed that independent variable related to emotion regulation has significant contribution in model’s accuracy.

**4.6 Attention Problems**

Attention problem is concerned with lack of attention regulation. Our finding is persistent with previous outcomes of empirical studies which they investigated a relation between attention, emotion and childhood stammering (e.g., Anderson et al., 2003; Eggers et al., 2012; Embrechts et al., 2000; Felsenfeld et al., 2010; Karrass et al., 2006).

**4.7 Temperament traits scale (TCS)**

TCS measures an overall temperament-traits of an individual that describes a child by examining the temperamental, [fallibility](https://www.thesaurus.com/browse/fallibility) to people and environmental of a child which subsumes emotional sensitivity and reactivity, stress awareness and coping ability, and environmental sensitivity to noise, light, touch, time pressure and touch (Oyler, 1999). Our findings also show that TCS has significance role in accuracy of our model.

**4.8 Negative Affectivity (NA)**

NA is a worry to sensitivity to punishment, danger, and novelty that brings anxiety and depression in the person’s mind. **David Watson et al., 1988** broadly correlated NA with symptoms and identification of both anxiety and depression, and acted as a common forecaster of psychiatric disorder. As NA brings anxiety (David Watson et al., 1988) and in turn an anxiety is one of the causal factors for stammering. As stated earlier ([Lisa Iverach](https://www.sciencedirect.com/science/article/pii/S0094730X16300067" \l "!) et al., 2016) stated that CWS exhibited a notably higher percentage of anxiety disorders. They also found that 24% of CWS met condition for social anxiety turmoil.

1. **Conclusion**

This chapter introduced a machine learning based approach to predict a potential risk of stammering using temperamental traits of pre-school children. In addition, stammering based dataset from Vanderbilt University was also introduced. This dataset contains features about stammering and non-stammering children.  The predictive model can be trained by feeding the traits related to temperament and it has produced the good accuracy to predict potential risk of stammering. Findings show that individual’s temperamental traits can be used to predict potential risk of stammering regardless of race and gender of children.

**References**

1. Ameringen, M., Mancini, C., & Farvolden, P. (2003). The impact of anxiety disorders on educational achievement. Journal of Anxiety Disorders, 17(5), 561–571.
2. Crawford, A. M., & Manassis, K. (2011). Anxiety, social skills, friendship quality, and peer victimization: An integrated model. Journal of Anxiety Disorders, 25(7), 924–931.
3. Rapee, R. M., Schniering, C. A., & Hudson, J. L. (2009). Anxiety disorders during childhood and adolescence: Origins and treatment. Annual Review of Clinical Psychology, 5, 311–341.
4. Kefalianos, E., Onslow, M., Block, S., Menzies, R., & Reilly, S. (2012). Early stammering, temperament and anxiety: Two hypotheses. Journal of Fluency Disorders,37(3), 151–163.
5. Anderson J, Pellowski M, Conture E, Kelly M. Temperamental traits of young children who
6. stutter. Journal of Speech, Language and Hearing Research. 2003; 46:1221–1233.
7. Eggers K, De Nil LF, Van den Bergh BR. Temperament dimensions in stammering and typically
8. developing children. Journal of Fluency Disorders. 2010; 35(4):355–372. [PubMed: 21130269]
9. Embrechts, M.; Ebben, H.; Franke, P.; van de Poel, C. Temperament: A comparison between children
10. who stutter and children who do not stutter. In: Bosshardt, JS.; Yaruss, JS.; Peters, HFM., editors.
11. Proceedings of the third world congress on fluency disorders: Theory, research, treatment, and
12. self-help. Nijmegen, The Netherlands: University Press Nijmegen; 2000. p. 557-562.
13. Howell, P.; Davis, S.; Patel, H.; Cuniffe, P.; Downing-Wilson, D.; Au-Yeung, J.; Williams, R. Fluency
14. development and temperament in fluent children and children who stutter. In: Packman, A.;
15. Ntourou et al. Meltzer, A.; Peters, HFM., editors. Theory, research and therapy in fluency disorders. Proceedings of the fourth world congress on fluency disorders. Nijmegen, The Netherlands: University Press Nijmegen; 2004. p. 250-256.
16. Fowlie GM, Cooper EB. Traits attributed to stammering and nonstammering children by their mothers.
17. Journal of Fluency Disorders. 1978; 3:233–246.
18. Karrass J, Walden T, Conture E, Graham C, Arnold H, Hartfield K, Schwenk K. Relation of emotional
19. reactivity and regulation to childhood stammering. Journal of Communication Disorders. 2006;
20. 39:402–423. [PubMed: 16488427]
21. Lewis KE, Goldberg LL. Measurements of temperament in the identification of children who stutter.
22. European Journal of Disorders of Communication. 1997; 32:441–448. [PubMed: 9519118]
23. McDevitt SC, Carey WB. A measure of temperament in 3 – 7 year old children. Journal of Child
24. Psychology and Psychiatry and Allied Disciplines. 1978; 19:245–253.
25. Van den Bergh B, Ackx M. Een Nederlandse versie van Rothbarts ‘Children’s Behavior
26. Questionnaire’. [The Dutch version of Rothbart’s Children’s Behavior Questionnaire]. Kind en
27. Adolescent. 2003; 24:77–78.
28. Kefalianos E, Onslow M, Block S, Menzies R, Reilly S. Early stammering, temperament and anxiety: Two hypotheses. Journal of Fluency Disorders. 2012; 37(3):151–163.10.1016/j.jfludis.2012.03.002 [PubMed: 22682317]
29. Conture, EG. Dreams of our theoretical nights meet the realities of our empirical days: Stammering theory and research. In: Bosshardt, HG.; Yaruss, JS.; Peters, HFM., editors. Fluency disorders: theory research, treatment and self-help. Proceedings of the Third World Congress on Fluency Disorders. Nijmegen, The Netherlands: Nijmegen University Press; 2001. p. 3-29.
30. Seery CH, Watkins RV, Mangelsdorf SC, Shigeto A. Subtyping stammering II: Contributions from language and temperament. Journal of Fluency Disorders. 2007; 32(3):197–217.10.1016/j.jfludis.2007.07.001 [PubMed: 17825669]
31. Wakaba, Y. Research on temperament of children who stutter with early onset. In: Healey, EC.; Peters,
32. HFM., editors. Stammering: Proceedings of the second world congress on fluency disorders. Vol.
33. Volume 2. Nijmegen, The Netherlands: University Press Nijmegen; 1998.
34. Williams, MJ. Childhood stammering and temperament. Reno: Unpublished doctoral dissertation,
35. University of Nevada; 2004.
36. O'Brien, L. M. (2009). The Neurocognitive Effects of Sleep Disruption in Children and Adolescents. Child and Adolescent Psychiatric Clinics of North America, 18 (4), 813-823.
37. Bencaa, R.; Duncanb, M. J.; Frankc, E.; McClungd, C.; Nelsone, R. J. & Vicenticf, A. (2009). Biological rhythms, higher brain function, and behavior: Gaps, opportunities, and challenges. Brain Research Reviews, 62 (1), 57-70.

# [Lisa Iverach](https://www.sciencedirect.com/science/article/pii/S0094730X16300067#!) 2016, Prevalence of anxiety disorders among children who stutter

1. The Efficiency of Attentional Networks in Children Who Stutter
2. Anderson, J. D., Pellowski, M. W., Conture, E. G., & Kelly, E. M. (2003). Temperamental traits of young children who stutter. Journal of Speech, Language, and
3. Hearing Research, 46, 1221–1233 <http://dx.doi.org/10.1044/1092-4388(2003/095)>.
4. Embrechts, M., Ebben, H., Franke, P., & van de Poel, C. (2000). Temperament: A comparison between children who stutter and children who do not stutter. In H. G. Bosshardt, J. Yaruss, & H. Peters (Eds.), In Proceedings of the third world congress on fluency disorders: Theory, research, treatment, and self-help (pp. 557–562). Nijmegen, The Netherlands: University Press Nijmegen.
5. Felsenfeld, S., van Beijsterveldt, C., & Boomsma, D. (2010). Attentional regulation in young twins with probable stammering, high nonfluency and typical fluency. Journal of Speech, Language and Hearing Research, 53, 1147–1166 <http://dx.doi.org/10.1044/1092-4388(2010/09-0164)>.
6. Karrass, J., Walden, T. A., Conture, E. G., Graham, C. G., Arnold, H. S., Hartfield, K. N., et al. (2006). Relation of emotional reactivity and regulation to childhood stammering. Journal of Communication Disorders, 39, 402–423 <http://dx.doi.org/10.1016/j.jcomdis.2005.12.004>.
7. S. A. Waheed and P. S. Abdul Khader, "IoT based approach for detection of dominating emotions in persons who stutter," *2020 Fourth International Conference on I-SMAC (IoT in Social, Mobile, Analytics and Cloud) (I-SMAC)*, Palladam, India, 2020, pp. 14-18, doi: 10.1109/I-SMAC49090.2020.9243392.
8. S. A. Waheed, S. Revathi, M. A. Matheen, A. Khan Lodhi, M. Ashrafuddin and G. S. Maboobatcha, "Processing of Human Motions using Cost Effective EEG Sensor and Machine Learning Approach," 2021 1st International Conference on Artificial Intelligence and Data Analytics (CAIDA), Riyadh, Saudi Arabia, 2021, pp. 138-143, doi: 10.1109/CAIDA51941.2021.9425088.
9. Waheed, S. A., & Khader, P. S. A. (2021). Healthcare Solutions for Children Who Stutter Through the Structural Equation Modeling and Predictive Modeling by Utilizing Historical Data of Stuttering. SAGE Open, 11(4). <https://doi.org/10.1177/21582440211058195>
10. Abdul Waheed, S., Khader, P.S.A., Khan, A.A. et al. Feature extraction from behavioral styles of children for prediction of severity of stuttering using historical stuttering data. Int J Speech Technol 25, 803–815 (2022). https://doi.org/10.1007/s10772-021-09868-2
11. Abdul Waheed, S., Abdul Khader, P.S. A machine learning approach for managing the potential risk of odds of developmental stuttering. Int J Syst Assur Eng Manag (2021). <https://doi.org/10.1007/s13198-021-01151-6>
12. S. A. Waheed and P. Sheik Abdul Khader, "A Novel Approach for Smart and Cost Effective IoT Based Elderly Fall Detection System Using Pi Camera," *2017 IEEE International Conference on Computational Intelligence and Computing Research (ICCIC)*, Coimbatore, India, 2017, pp. 1-4, doi: 10.1109/ICCIC.2017.8524486.