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Why Stuttering Occurs

The Role of Cognitive Conflict and Control

Evan R. Usler

The purpose of this article is to provide a theoretical account of the experience of stuttering that incorporates previous explanations and recent experimental findings. According to this account, stuttering-like disfluencies emerge during early childhood from excessive detection of cognitive conflict due to subtle limitations in speech and language processes. For a subset of children who begin to stutter, the development of approach-avoidance motivational conflict likely contributes to a chronic reliance on cognitive control processes during speech. Consequently, maladaptive activation of right hemisphere inhibitory cortices to the basal ganglia via a hyperdirect pathway results in involuntary, episodic, and transient freezing of the motor system during speech initiation. This freeze response, consistent with defensive behavior in threatening situations, may lead to stuttering persistence, tension and struggle, maladaptive speech physiology, and feelings of anxiety and loss of control. **Key words:** *cognitive control*, *disfluency*, *executive function*, *inhibition*, *stuttering*

DEVELOPMENTAL STUTTERING is a neurodevelopmental speech disorder that is characterized by the elicitation of stuttering-like disfluencies (i.e., monosyllabic- and part-word repetitions, prolongations, and blocks) and the perceived loss of control over speech (Bloodstein et al., 2021). Key research findings over recent years have revealed widespread anatomical and physiological abnormalities in brain regions underlying speech perception and production in people who stutter (for review, see Etchell et al., 2018). Neurocomputational models provide an elegant and mechanistic account of stuttering-like disfluency resulting from cortico-basal ganglia-thalamo-cortical (CBGTC) dysfunction (Chang & Guenther, 2019) that is largely congruent with findings of deficits in speech motor control (e.g., Walsh et al., 2015) and sensorimotor integration (e.g., Kim et al., 2020) in people who stutter. However, these advances in knowledge leave critical questions regarding stuttering unanswered. Why is speech fluency so situationally variable? How do stuttering-like disfluencies develop? Why are stuttering-like disfluencies perceived as a loss of control? Why do stuttering-like disfluencies take the form they do?

This article provides a theoretical account explaining the occurrence and development of stuttering-like disfluencies. This account emphasizes recent findings in cognitive neuroscience and motivational theory and is highly influenced by previous theories of stuttering emphasizing the role of self-monitoring (Arenas, 2017; Postma & Kolk, 1992; Vasic & Wijnen, 2005). Although many of our claims are currently speculative and await empirical validation, it is hoped that the arguments presented here will contribute to understanding of the stuttering experience.

The central hypothesis is that developmental stuttering is associated with a

Author Affiliation: *Department of Communication Sciences and Disorders, University of Delaware, Newark.*

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Corresponding Author: *Evan R. Usler, PhD, Department of Communication Sciences and Disorders, University of Delaware, Newark, DE 19716 (eusler@udel.edu).*

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chronic state of heightened cognitive conflict and control during speech. Cognitive conflict refers to inconsistencies between action-based cognitions, such as decisions, motivations, or expectations, that interfere with goal-directed behavior (Harmon-Jones et al., 2009). Cognitive conflict includes "low-level" incongruent representations in language processing (i.e., linguistic conflict) and "high-level" inconsistencies in motivational state (Proulx et al., 2012). Linguistic conflict may result from activation of competing semantic or phonological representations during language processing. For example, adults who stutter exhibit an inhibitory control deficit that impairs lexical selection (Maxfield, 2020). Motivational conflict (i.e., approach-avoidance conflict) involves simultaneous yet opposing motivations to approach and avoid a situation, such as giving a public speech despite fear of social evaluation.

Cognitive control is strategically deployed to reduce adverse effects of cognitive conflict on performance by increasing demands on attention and working memory, which is subjectively perceived as mental effort (Kool et al., 2017). The monitoring and detection of linguistic and motivational conflict engage overlapping controlled processes (Ganushchak & Schiller, 2008) and speech fluency requires the detection and resolution of these conflicts before they lead to speech errors (Gauvin & Hartsuiker, 2020; Nozari & Pinet, 2020). *In brief, here are the basic arguments of how excessive cognitive conflict and control drive the development and elicitation of stuttering behavior:*

1. Young children, especially those with relative difficulties in language processing, may experience high levels of linguistic conflict that result in speech disfluency and require resolution through the chronic activation of controlled processes.
2. For a subset of these children, growing self-awareness of speech disfluency and the difficulty and uncertainty associated with their communicative competence may lead to motivational conflict during speech.
3. Increasing motivational conflict chronically activates the controlled processes of the behavioral inhibition system. If motivational conflict is not resolved before the onset of articulation, an emergency braking of the motor system occurs during speech initiation. This inhibition is perceived by the listener as dysrhythmic phonation (e.g., blocks and prolongations). Over time, anticipatory anxiety, physical tension, and the feeling of loss of control become habitual in response to the chronic cognitive conflict and transient freezing of speech initiation that result in persistent stuttering symptomology.

WHY IS SPEECH FLUENCY SO SITUATIONALLY VARIABLE?

Skilled behavior, such as fluent speech production, likely requires a balance between highly automatic and controlled processes for action (Pacherie & Mylopoulos, 2020; Toner & Moran, 2021). Automatic processes require little effort, whereas controlled processes are often conscious, effortful, and computationally costly (Evans & Stanovich, 2013). Although the balance between these two processes underlying different speaking tasks will vary across individuals, this dichotomy helps to explain the variability of stuttering (Figure 1). Although people who stutter differ in the severity and situational variability of their disfluency, there are types of utterances and speaking situations that tend to elicit a greater or lesser likelihood of stuttering. For example, utterances that are largely automatic and little controlled include vocal outbursts, self-talk, and phatic expressions. In contrast, largely controlled and little automated utterances include novel manners of speech (e.g., fluency-shaping therapy). Extreme levels of either controlled or automatic processing induce fluency because the degree of cognitive conflict is low. On the contrary, highly demanding utterances

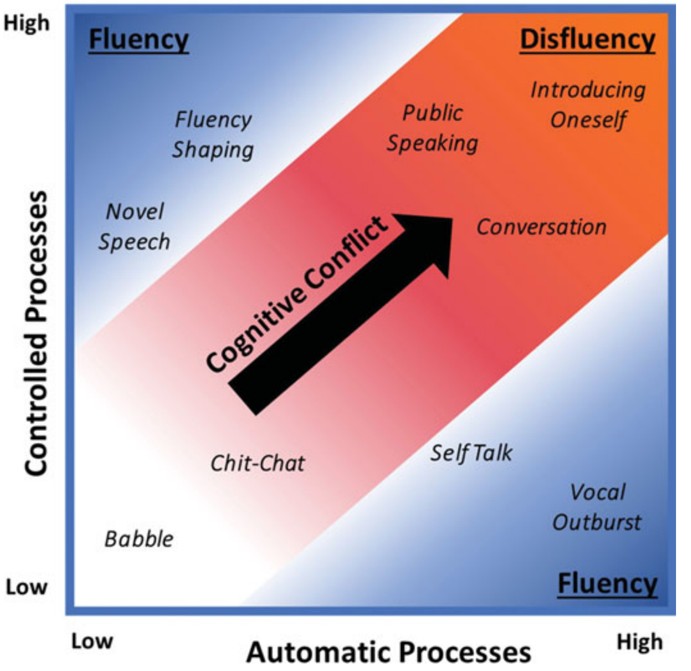

Figure 1. The balance between automatic and controlled processes that facilitate different hypothetical speech utterances in which stuttering-like disfluencies typically are and are not elicited. This figure is available in color online (www.topicsinlanguagedisorders.com).

increase the likelihood of cognitive conflict by requiring the concomitant use of highly automatic and highly controlled processes. For people who stutter, saying one's name on command is a highly automatic, yet highly controlled behavior. Saying one's name should be a well-learned and effortless task, but the communicative responsibility of such an act often results in excessive use of controlled processes for execution. It is during these situations in which stuttering-like disfluencies are most frequently elicited.

Developmental stuttering has been associated with limitations across domains of language and speech motor control (Smith & Weber, 2017). Stuttering has also been associated with subtle deficits in executive functions such as working memory, cognitive flexibility, and inhibitory control (Anderson & Ofoe, 2019). However, not all children who stutter exhibit speech, language, and cognitive abilities below normal limits, and some may even exhibit advanced skills in these domains (Reilly et al., 2009). It is proposed here that these interacting domains contribute to cognitive conflict during the early development of sequencing of speech. Put simply, choosing the right utterance at the right time involves the detection and resolution of linguistic conflict (Gauvin & Hartsuiker, 2020; Nozari & Pinet, 2020). The contribution of linguistic conflict to disfluency may explain why children begin to stutter after a period of typical language development and during a period of rapid growth in language ability (Bloodstein et al., 2021). Child populations prone to heightened linguistic conflict, such as bilingual children or those with language disorders, also exhibit higher levels of disfluency compared to typically developing peers (Byrd et al., 2015; Hall, 1996). Controlled processes are necessary to resolve high linguistic conflict in bilinguals (Green & Abutalebi, 2013), resulting in greater prevalence of disfluency (Bergmann et al., 2015). These disfluencies are largely categorized as

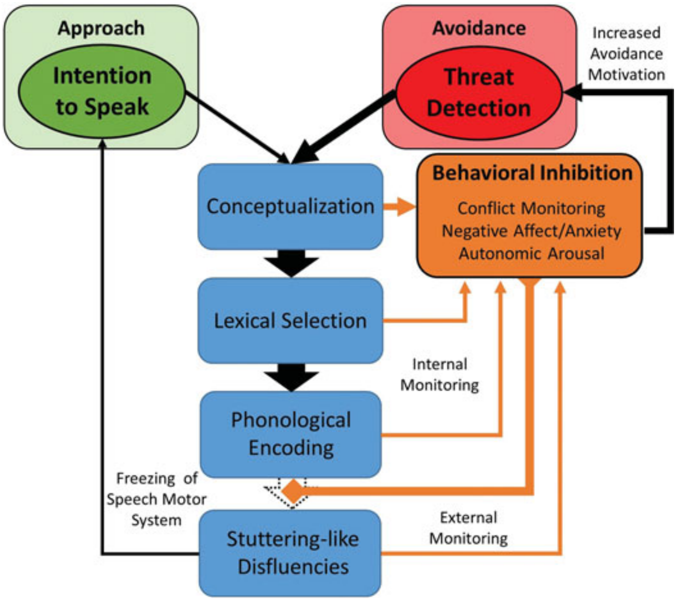

Figure 2. Stuttering-like disfluencies are elicited by the freezing of the speech motor system in response to cognitive conflict associated with speech–language production. This figure is available in color online (www.topicsinlanguagedisorders.com).

"typical" and usually take the form of phrase revisions, filled pauses, and interjections. The distinguishing characteristics of stuttering-like disfluency, such as tension, struggle, and negative affect, require a degree of cognitive conflict beyond that resulting from language difficulty.

HOW DO STUTTERING-LIKE DISFLUENCIES DEVELOP?

The emergence of stuttering-like disfluency requires the presence of cognitive conflict that activates the behavioral inhibition system (BIS),[1] which consists of the hippocampus, dorsal anterior cingulate cortex (dACC), and associated regions (Amodio et al., 2008). As shown in Figure 2, the BIS imposes controlled processes over automatic processes when a high degree of cognitive conflict is detected, resulting in hypervigilance, anxiety, cautiousness, autonomic arousal, and the momentary slowing of behavior (Gray & McNaughton, 2000). For this reason, the emergence of stuttering-like disfluencies occurs gradually in some children and suddenly in others (Yairi & Ambrose, 2004). The activation of the BIS also helps to explain why stuttering-like disfluencies are characteristically associated with higher states of conflict monitoring, anticipatory anxiety, muscular tension and tremor, and autonomic arousal (Bloodstein et al., 2021).

Previous theories of stuttering have linked the disorder to hyperactive self-monitoring of discontinuities in speech (Arenas, 2017; Vasic & Wijnen, 2005). Conflict monitoring and detection processes appear to be hyperactive in adults who stutter (Arnstein et al., 2011). Although empirical evidence that young children who stutter exhibit hyperactive monitoring of their speech is currently lacking, preschool-age children who stutter have been shown to exhibit reduced cognitive flexibility

[1]The term "behavioral inhibition system" is taken from Gray & McNaughton (2000) to represent a widely accepted neuropsychological system governing the resolution of motivational conflict.

and be more cautious to prevent errors when changing behavior compared to typically developing peers (Eichorn et al., 2018). Areas of the brain facilitating conflict detection, such as the dACC, activate before the elicitation of stuttering-like disfluencies when speaking particularly feared sounds or words (De Nil et al., 2000), but dACC activation may not be required for stuttering-like disfluencies to occur (Ingham et al., 2004). After the detection of cognitive conflict, the BIS assesses the severity of the conflict and the appropriate amount of motor inhibition that may be necessary for its resolution (Gray & McNaughton, 2000).

The forward flow of speech becomes involuntary inhibited when the BIS interrupts the functioning of the CBGTC motor network for the initiation of speech motor programs. Although the nature of this inhibition remains unclear, it may occur via two neural mechanisms of inhibitory control that play a role in stuttering (Figure 3). The first mechanism, previously described by Alm (2004) and Chang and Guenther (2019), is the dysfunction in "direct" and "indirect" striatal pathways that alters the balance of inhibition and disinhibition within the CBGTC motor network. Excessive dopamine transmission in the striatum and impaired connectivity between the striatum and left hemisphere cortical regions likely contribute to delayed initiation of speech motor programming (Civier et al., 2013; Wu et al., 1997). A second mechanism of inhibitory control likely associated with stuttering is the transient and episodic inhibition of speech by a "hyperdirect" myelinated pathway linking the inferior frontal gyrus (IFG) in the right hemisphere to the subthalamic nucleus (STN;

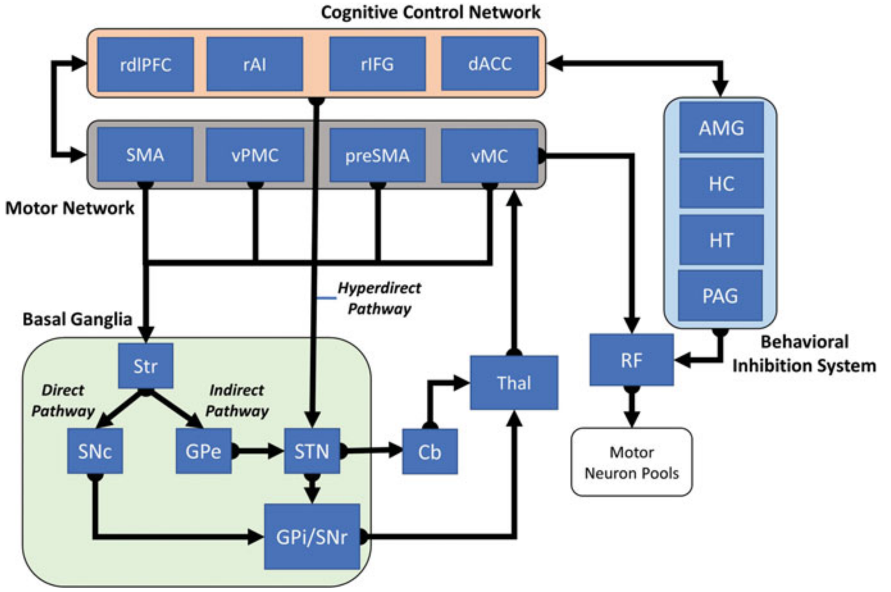

Figure 3. Postulated basal ganglia, motor network, cognitive control network, and behavioral inhibition system facilitating speech-like disfluencies. AMG = amygdala; Cb = cerebellum; dACC = dorsal anterior cingulate cortex; dlPFC = dorsolateral prefrontal cortex; GPe = globus pallidus externus; GPi = globus pallidus internus; HC = hippocampus; HT = hypothalamus; PAG = periaqueductal gray; PMC = premotor cortex; preSMA = presupplementary motor area; rAI = right anterior insula; rIFG = right inferior frontal gyrus; RF = reticular formation; SMA = supplementary motor area; SNc = substantia nigra pars compacta; SNr = substantia nigra pars reticulata; STN = subthalamic nucleus; Str = striatum; Thal = thalamus; vMC = ventral motor cortex. This figure is available in color online (www.topicsinlanguagedisorders.com).

Chen et al., 2020). The hyperdirect pathway allows for sudden and global braking of movement when a high level of cognitive conflict is detected (Aron et al., 2014). Increased right IFG activation is often observed in tasks involving cognitive control during language formulation (Severens et al., 2011) and during the inhibition of speech (Xue et al., 2008).

According to our theoretical account, activation of the BIS in response to "lower-level" linguistic conflict likely fuels direct–indirect striatal pathway dysfunction and results in typical disfluencies and stuttering-like disfluencies that take the form of monosyllabic- and part-word repetitions. This impairment may drive early manifestations of stuttering-like disfluencies in young children who generally lack self-awareness, also known as "borderline stuttering" (Guitar, 2019). Consequently, "borderline stuttering" may be an additional source of cognitive conflict that is further detected and resolved by the BIS. As shown in Figure 4, an orthogonal relationship may exist between the two neural mechanisms of inhibitory control causal to stuttering—greater dysfunction between direct and indirect striatal pathways is likely to result in habitual and maladaptive activation of the hyperdirect pathway. If cognitive conflict passes a threshold, the right prefrontal area, including the dorsal lateral prefrontal cortex (dlPFC) and IFG, sends a signal to the STN that acts as a circuit breaker to shut down initiation of the speech motor program at the onset of articulation. Behavioral inhibition system activation has been associated with lateralization of electroencephalographic (EEG) activity over the right hemisphere (Gable et al., 2018), and activation of right hemisphere regions is a well-established finding in people who stutter (Etchell et al., 2018). Consistent with the account presented here, other researchers have associated this right hemisphere activation during stuttering with activation of the IFG-STN hyperdirect

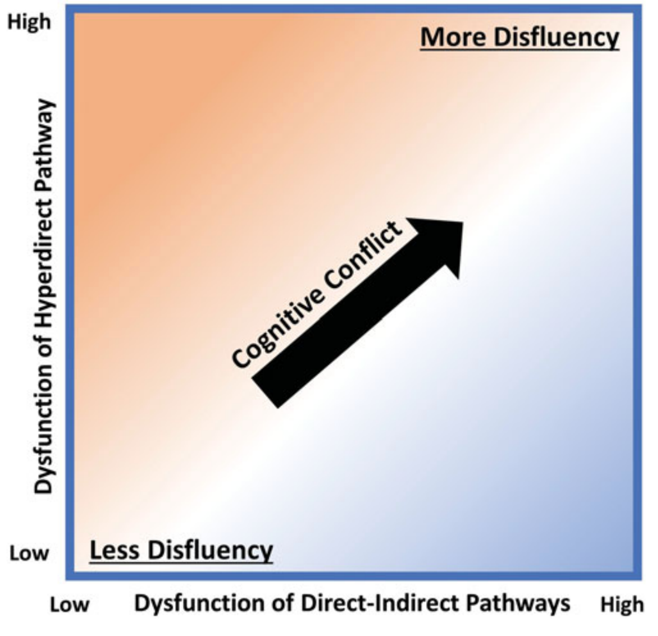

Figure 4. Cognitive conflict increases with the intensity of dysfunction within the cortico-basal ganglia-thalamo-cortical motor network. Dysfunction of direct–indirect striatal pathways increases the likelihood of intervention by maladaptive activation of hyperdirect pathway. This figure is available in color online (www.topicsinlanguagedisorders.com).

pathway (Arenas, 2017; Neef et al., 2018). Adults who stutter are not impaired in their ability to inhibit verbal responses (Treleaven & Coalson, 2021), but may exhibit widespread hyperactivity across neural correlates of inhibitory control (Wiltshire et al., 2020). This hyperactivity of inhibitory control in adults who stutter may explain previous findings of *faster* response times compared to those of fluent controls during cognitive conflict (Subramanian & Yairi, 2006). The global nature of inhibition via the hyperdirect pathway during stuttering-like disfluency includes the stopping of co-speech gesture (Mayberry & Jaques, 2000) and perhaps even cognitive functions such as working memory (Wessel & Aron, 2017), which may explain deficits in executive function such as working memory in individuals who stutter (Bajaj, 2007). This dynamic may create a vicious cycle in which excessive use of cognitive control via the BIS creates more cognitive conflict than it resolves, resulting in an increasingly destabilized speech motor system, increased anxiety and arousal, and greater instances of stuttering-like disfluency.

WHY ARE STUTTERING-LIKE DISFLUENCIES PERCEIVED AS A LOSS OF CONTROL?

Previous studies of the development of persistent stuttering in young children have observed that the frequency of stuttering-like disfluencies tends to decline as children get older, whereas the prevalence of dysrhythmic phonations (i.e., blocks and prolongations), avoidance behaviors, abnormal motor activity (i.e., muscle tension and tremor), and feelings of anxiety may increase with age (Bloodstein et al., 2021). This developmental trajectory is likely driven by the habitual and involuntary activation of the hyperdirect pathway as a mechanism of freezing—a nonconscious and automatic defensive behavior involving the sudden stopping of movement to a perceived threat (Roelofs, 2017). The notion that stuttering-like disfluency may be a freeze response was previously proposed by Alm (Alm, 2004). The freeze response is accompanied by reduced heart rate and motor inhibition that can range from cautious movement to tonic immobility (Hermans et al., 2013). Evidence that stuttering-like disfluency may be characterized as a freeze response includes observations of increased skin conductance and reduced heart rate (i.e., coactivation of sympathetic and parasympathetic arousal) during stuttered speech (Caruso et al., 1994; Weber & Smith, 1990).

This freeze response may best be conceptualized as a hypersensitive and maladaptive emergency brake if articulation begins before cognitive conflict is resolved. It is not a coincidence that stuttering-like disfluency often occurs on feared words, longer words, words with high information content, and words that are seldom spoken (Bloodstein et al., 2021). In typical speakers, the detection of linguistic conflict during speech leads to typical disfluencies rather than stuttering-like disfluencies (Clark & Fox Tree, 2002). A critical difference here is that typical disfluencies are largely proactive and strategically produced to maintain cognitive control over speech. *Stuttering-like disfluencies are reactive and not strategic—often occurring exactly when an individual is motivated to not stutter.* This is likely the loss of control that people who stutter perceive both motorically and psychologically.

This sense of "stuckness" or freeze response is not a secondary behavior to stuttering, but an essential component of stuttering-like disfluencies associated with interference of the BIS on basal ganglia function. This loss of control is similar to basal ganglia-related impairment in other populations, such as freezing of gait and speech in individuals with Parkinson's disease (Park et al., 2014) and the appearance of "choking" or "yips" that characterize involuntary movement under pressure during athletic performance (Philippen & Lobinger, 2012). Prominent explanations of the choking phenomena focus on the ruinous effects of excessive controlled processes (i.e., self-focus) that maladaptively disrupt automatic motor performance (Cappuccio et al.,

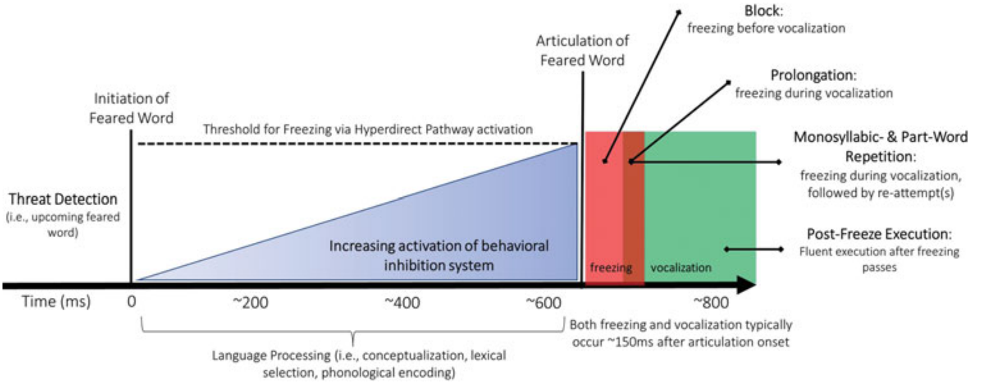

Figure 5. Time course of hypothetical stuttering-like disfluency, associated speech–language processes, and activation of behavioral inhibition system. Overlap between freezing and vocalization may determine the type of stuttering-like disfluency. This figure is available in color online (www.topicsinlanguagedisorders.com).

2019). In a similar fashion, an overreliance on controlled processes by people who stutter during speech likely disrupts speech motor performance (Eichorn et al., 2019). Interestingly, the subjective experience of "yips" is strikingly similar to that of people who stutter during moments of stuttering (Bawden & Maynard, 2001).

Why is this freeze response to cognitive conflict evident in people who stutter, but not in other populations with speech–language difficulties? In this account, the hyperdirect pathway acts as an emergency brake to the speech motor system when the BIS cannot resolve high cognitive conflict past a certain threshold. This threshold may not be generally met by subtle linguistic conflict. Instead, stuttering-like disfluencies are typically elicited when a more salient "high-level" motivational conflict (e.g., speaking an important message to an authority figure) is too strong for the BIS to resolve before the onset of articulation (Figure 5). The idea of linking stuttering to motivational conflict is certainly not a new one. Psychodynamic theories in the early 20th century assumed stuttering was caused by conflicting mental processes (Glauber, 1943). According to Sheehan (1953), stuttering results from moments of conflicting approach and avoidance motivations during speech preparation across multiple contexts (e.g., fear of a word, fear of evaluation).

Motivation in speech represents the willingness and readiness to speak in a specific situation. Motivation drives intended action toward (i.e., approach) or away (i.e., avoidance) a goal (Harmon-Jones & Gable, 2018). Several variables likely influence one's motivation to speak, such as perceived communication competence and sense of self-efficacy. Stuttering-like disfluencies typically appear during a period of emerging self-awareness in young children. Around age four, children develop the ability to introspect how their speech–language ability affects themselves (Rochat, 2003). Self-awareness of stuttering and the preference for fluent over disfluent speech is apparent in the early preschool years (Ambrose & Yairi, 1994; Giolas & Williams, 1958). Individuals are approach-motivated to communicate to fulfill wants and needs (Harmon-Jones et al., 2013). However, speaking may be associated with avoidance motivation for some children who stutter if difficulties in speech and language negatively impact communicative competence (Vanryckeghem & Brutten, 1996). If avoidance motivation increases in salience, children who stutter will develop habitual avoidance behaviors such as circumlocution or word substitution. If avoidance is not

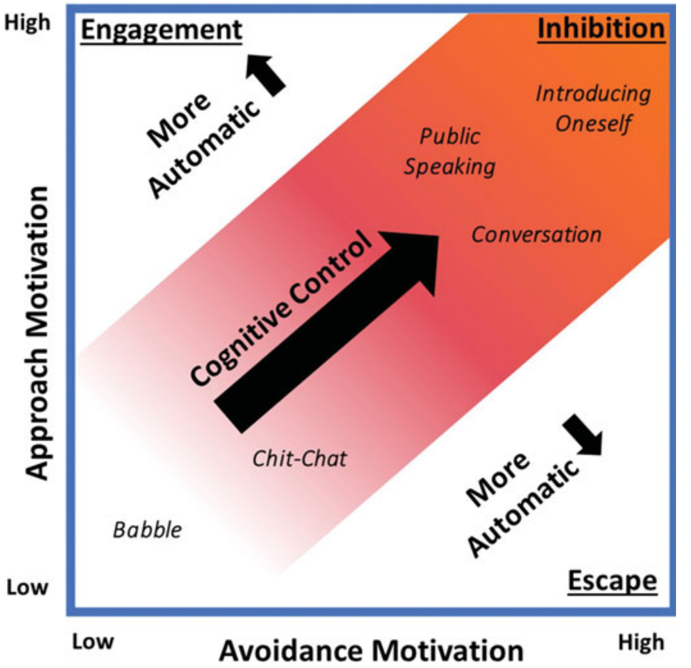

Figure 6. The degree of cognitive control increases with the intensity of conflict between approach and avoidance motivations, resulting in greater elicitation of inhibition and conscious feeling of anxiety. Greater automaticity due to predominant activation of either approach motivation (which leads to an urge to engage) and avoidance processes (which leads to an urge to escape) results in largely fluent speech. This figure is available in color online (www.topicsinlanguagedisorders.com).

possible, such as when communicative responsibility is high (e.g., being asked a direct question), the BIS becomes overwhelmed by motivational conflict, the hyperdirect pathway activates, and freezing occurs (Sagliano et al., 2014). Figure 6 reveals a nuanced dynamic with automatic processes characterized as either approach or avoidance motivations. Even for individuals who stutter severely, stuttering-like disfluencies may not be elicited if approach motivation is exclusively strong (e.g., instances of euphoria) or if avoidance motivation is exclusively strong, such as during a state of panic (Bloodstein et al., 2021).

WHY DO STUTTERING-LIKE DISFLUENCIES TAKE THE FORM THEY DO?

The type and duration of stuttering-like disfluency are influenced by one's attempts to ultimately prevent or get past the freeze response. As shown in Figure 5, approaching a word that one anticipates will result in stuttering presents a salient motivational conflict that activates the BIS. As articulation approaches, behavioral inhibition increases to allow time for cognitive control processes to determine a potential solution to the conflict. If no solution is found before articulation of the anticipated word, the hyperdirect pathway's emergency brake freezes the speech motor system, resulting in a block or prolongation. This dynamic is evident in the observation of increasing word duration leading up to the moment of stuttering-like disfluency (Viswanath, 1989). By giving the BIS more time to resolve conflict before freezing is evoked, consciously slowing speech down is a well-known fluency-enhancing technique (Bloodstein et al., 2021).

Monosyllabic word- and part-word repetitions are produced when the speaker automatically reattempts the production of an utterance that may, or may not, precede freezing. Repetitions are likely the most prevalent form of stuttering-like disfluency in young children because they are natural reactions to self-repair linguistic conflict (Engelhardt et al., 2010, 2013). Furthermore, inhibitory control via the hyperdirect pathway may not mature until the school-age years (Cai et al., 2019). As the hyperdirect pathway develops, blocks and prolongations may become the predominant form of stuttering-like disfluency as children who stutter get older. Therapeutic intervention for stuttering often involves helping those who stutter learn less effortful ways of getting past the freeze response (e.g., stuttering modification techniques such as “pull-outs”; Van Riper, 1982). Because freezing occurs at the onset of articulation, the speaker may be able to say the utterance fluently if speech production occurs after the freezing passes. This idea of postfreeze speech has been long known and conceptualized as “cancellations” by Van Riper (Van Riper, 1982) or use of pausing as a fluency-inducing technique (Reitzes, 2006).

WHAT EXPLAINS VARIABILITY IN TREATMENT EFFECTIVENESS FOR PEOPLE WHO STUTTER?

A hallmark of stuttering is the heterogeneity in which people who stutter respond to different treatment approaches. For many adolescents and adults who stutter, relapse from previous fluency gains is a common occurrence (Craig & Hancock, 1995). The intractable nature of stuttering past the school-age years suggests that treatment approaches are largely not effective at reducing overall cognitive conflict. This account suggests that successful treatment requires (1) reduction of cognitive conflict during speaking situations and/or (2) aiding the BIS in resolving conflict before the hyperdirect pathway freezes the speech motor system. For individuals with severe stuttering, hyperdirect pathway activation may be particularly fast, resulting in high probability that stuttering-like disfluencies occur. Neural connectivity of the right hemisphere inhibitory network underlying hyperdirect pathway activation increases with stuttering severity (Neef et al., 2018). Faster verbal response inhibition in adults who stutter is also associated with greater physical concomitants of stuttering (Treleaven & Coalson, 2021). Stuttering severity may be related to the speed in which the hyperdirect pathway freezes the speech motor system in the face of cognitive conflict. Slowing down one’s rate of speech, which allows the BIS more time to resolve conflict, is a common approach to improve fluency (Bloodstein et al., 2021).

Treatment approaches that focus on motoric fluency (e.g., fluency shaping) may decrease frequency of stuttering-like disfluency in the short-term by increasing use of controlled processes (top left quadrant of Figure 1). However, the spontaneity of real-world speaking situations requires a balance of control and automaticity (top right quadrant of Figure 1) that may reduce the viability of fluency shaping techniques. Furthermore, the excessive cognitive control required for success in fluency shaping may *increase* cognitive conflict, leading to relapse and sense of failure. In contrast, treatment approaches that emphasize communicative competence (Byrd et al., 2021) and acceptance of stuttering (Sisskin, 2018) may reduce motivational conflict over the long-term by increasing approach motivation and decreasing avoidance motivation. These types of treatment approaches are best positioned to reduce cognitive conflict in people who stutter and are thus most congruent with the theoretical account proposed here.

WHAT MAKES MOST CHILDREN RECOVER FROM STUTTERING WHILE A MINORITY DO NOT?

Approximately 20% of young children who stutter will persist into adulthood (Yairi & Ambrose, 2013). The factors that drive stuttering persistence remain largely unclear, but maturational lags in speech and language ability may prevent the remission of stuttering-like disfluency (Smith & Weber, 2017). The frequency and severity of linguistic conflict may dissipate, as these children mature in their speech–language abilities. Little is currently known about how individual differences in cognitive ability and temperament affect the likelihood of recovery (Singer et al., 2019). However, it is reasonable to assume that children with heightened BIS activation may be more at risk for persistence. Atypical self-monitoring of speech and inhibitory control may also be risk factors for persistence. Lastly, given the link between stuttering-like disfluency and freezing behavior, one can speculate that genes influencing the prevalence of specific defense avoidance behaviors may influence developmental trajectories of stuttering. Mice with an engineered *GNPTAB* gene, which has been linked to stuttering in humans, exhibit deficits in the flow of ultrasonic vocalizations (Han et al., 2019). Animal models may shed light on episodic freezing during vocalization that contributes to stuttering-like disfluencies. Dopamine-antagonist antipsychotic medications, such as clozapine, haloperidol, and olanzapine, have anxiolytic effects and reduce the frequency of stuttering-like disfluency (Maguire et al., 2020). These medications also reduce freezing behavior in rats (Inoue et al., 1996; Ohyama et al., 2016.) Young children who develop stuttering-like disfluencies mediated by dysfunctional striatal pathways may be more likely to recover compared to stuttering children who develop more advanced stuttering symptoms that result from freezing of the speech motor system via chronic activation of the hyperdirect pathway.

WHAT MAKES BOYS LESS LIKELY TO RECOVER FROM STUTTERING COMPARED TO GIRLS?

Being biologically male is a key risk factor for stuttering chronicity. The likelihood of stuttering onset appears slightly greater for boys compared to girls, but a greater risk for persistence for boys results in an approximately 4:1 male-to-female ratio in later years (Yairi & Ambrose, 2013). It remains unknown why boys are less likely to recover naturally from stuttering; however, two male-related disadvantages may play a role. First, a recent meta-analysis has shown boys exhibit a more protracted maturation of the basal ganglia and the corpus callosum, which links left and right hemispheres (Etchell et al., 2018). The development of speech motor coordination is also more protracted in typically developing boys compared to girls, especially during the preschool years (Smith & Zelaznik, 2004). Deficits in speech motor control are also more prevalent in boys compared to girls who stutter and their fluent peers (Walsh et al., 2015). Previous research linked bilingualism to increased prevalence and risk of stuttering (Howell et al., 2009). However, recent reviews on bilingualism and stuttering have reported mixed results (e.g., Choo & Smith, 2020). In accordance with our theoretical account, heightened linguistic conflict may result in typical and stuttering-like disfluency, but does not likely cause persistent and severe stuttering behavior. It remains unknown to what degree maturational lags in the development of speech and language influence the development of motivational conflict that may be necessary for more advanced stuttering symptomology.

A second advantage that girls may have over boys in terms of recovery is a reduced tendency to rely on freezing as a defensive behavior. Although defensive behaviors (e.g., freezing, fighting, and running) are similarly elicited in both sexes, females exhibit a greater repertoire of defensive behaviors beyond freezing (Blanchard et al., 2001). Female rats exhibit fewer freeze responses to conditioned stimuli compared to males and exhibit more escape behaviors (Gruene et al., 2015). Gruene et al. (2015) argue that, compared to their freeze-prone male counterparts, female rats "confer a long-term protective or adaptive state that promotes increased cognitive flexibility" (p. 5). Cognitive flexibility, the ability to alter goal-directed thoughts and behaviors when needed, is essential for cognitive control and is more impaired by psychosocial stress in men (Shields et al., 2016). Interestingly, deficits in cognitive flexibility have been observed in children who stutter compared to controls (Anderson & Ofoe, 2019).

LIMITATIONS AND FUTURE DIRECTIONS

The theoretical account presented here attempts to explain various aspects of stuttering disfluency, which is obviously limited by lack of knowledge across numerous fronts. Beyond the scope of this article are recent developments in genetics and cellular biology related to the etiology of stuttering. Stuttering has also been linked to gene variants associated with the intracellular trafficking of lysosomal enzymes. Regions in the speech–motor areas including components of the CBGTC network could be more vulnerable to these variants (Chow et al., 2019). Future theoretical work should associate new discoveries in neurobiology and neuropharmacology with traditional theories of stuttering that attempt to explain the nuances of stuttering behavior. A considerable gap in knowledge pertains to the internal and external self-monitoring of speech and how this ability develops in children who stutter. The focus of this article was limited to the possible role of internal self-monitoring during speech preparation; however, most empirical work on the use of feedback in people who stutter has focused on external monitoring of one's own speech (Chang & Guenther, 2019). How speech and language processes are monitored for cognitive conflict and whether the mechanisms involved are domain-general or specific to speech perception remain largely unexplored questions (Lind & Hartsuiker, 2020).

Many of the claims made in this account can be empirically investigated using research methods currently being used in social psychology and motivation science. For example, research programs are currently identifying the neural correlates of motivational conflict in neurotypical and clinical populations using the latest neuroimaging, EEG, and neuromodulation methods (Chrysikou et al., 2017; Lacey & Gable, 2021; McDermott et al., 2021). Nearly 70 years ago, Joseph Sheehan proposed that stuttering behaviors are elicited by a conflict between simultaneous motivations to approach and avoidance of a speaking situation (Sheehan, 1953). Since that time, the explanatory power of this assumption has driven the increasing use of psychotherapeutic approaches (i.e., cognitive–behavioral) to improve psychological well-being by increasing communicative competence (Byrd et al., 2021) and reduce avoidance behaviors (Sisskin, 2018) in people who stutter. Despite the growing popularity of these treatment approaches, motivational conflict in stuttering has largely not been empirically investigated. There is a critical need to determine the effects of approach and avoidance motivations, and their conflict, on the brain and behavior of individuals who stutter. Some testable/falsifiable predictions, among many, include:

1. Children and adults who stutter should, in general, exhibit brain and behavioral markers of heightened self-monitoring during speaking situations.
2. Older children and adults who stutter should, in general, exhibit brain and behavioral markers of motivational conflict and/or avoidance motivation during speaking situations.
3. Children who (will) persist in stuttering should exhibit heightened brain and behavioral markers of cognitive conflict during speaking situations. The likelihood of stuttering persistence should also increase with high BIS activation and low cognitive flexibility.
4. Children who (will) recover are not likely to develop motivational conflict associated with speech and likely exhibit relatively low BIS activation and high cognitive flexibility.
5. Chronic activation of the hyperdirect pathway should contribute to the emergence of abnormal muscular activation, such as tremor (Shi et al., 2021), associated with advanced stuttering symptomology in adults who stutter (Smith, 1989).

6. Lastly, brain and behavioral markers from the above predictions should be independently predictive of quantitative measures of BIS activation, stuttering severity, and psychosocial well-being. Greater indices of cognitive conflict during speaking situations should be associated with greater frequency and persistency of stuttering disfluency, greater tension and struggle during speech, and greater subjective feelings of uncertainty and anxiety regarding one's ability to effectively communicate.

CONCLUSION

The goal of this article was to explain why and how stuttering-like disfluencies occur. Stuttering-like disfluencies are elicited by, and contribute to, a chronic state of heightened cognitive conflict and control. More specifically, dysfunction of the basal ganglia and associated cortices facilitating cognitive control includes imbalances between activation of direct, indirect, and hyperdirect pathways. The onset of stuttering may be precipitated by heightened cognitive conflict due to inefficiencies across linguistic, cognitive, and motoric domains mediated by genetic and/or developmental factors. Much work needs to be done to empirically examine the claims presented here. Future research programs that investigate the cognitive control of speech and the influence of cognitive conflict on the elicitation of stuttering-like disfluencies will provide fruitful additions to our knowledge of developmental stuttering.

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