An Actor-Network Theory Analysis of the SpeechEasy Device's Underperformance

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On my honor as a University student, I have neither given nor received unauthorized aid on this assignment as defined by the Honor Guidelines for Thesis-Related Assignments.

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Introduction

In the early 2000s, Dr. Andrew Stuart, along with Dr. Joseph Kalinowski and Dr. Michael Rastatter, developed a device known as SpeechEasy. SpeechEasy's goal was to eliminate disfluent speech for stutterers (Sayewich, 2019). Developed and manufactured by the Janus Development Group, the SpeechEasy device employs both delayed auditory feedback (DAF) and frequency altered feedback (FAF) in an attempt to recreate the choral effect, the phenomenon in which one's stutter is reduced or even eliminated when speaking in unison with others (Janus Development Group, 2019b). However, in Joy Armson et al's (2006) investigation into SpeechEasy's effectiveness in reducing disfluencies among stutterers, Armson et al discovered that stuttering was only reduced by 74% for read speech, 36% for monologue speech, and 49% during conversational speech.

Research surrounding the effectiveness of auditory altered feedback (AAF) is extensive, however, little discussion exists about the SpeechEasy device and how it operates as an actor-network, as described in Michael Callon's Actor-Network Theory. Using Callon's Actor-Network Theory and his concept of Translation as an analytical framework, I will demonstrate how the SpeechEasy device, operating as an actor-network, failed to identify all of the necessary factors, specifically the speech techniques of diaphragmatic breathing, the gentle onset technique, and the psychosomatic effect of anxiety, which resulted in its underperformance and inability to fully eliminate stuttered speech among its users. By exclusively investigating the shortcomings of auditory altered feedback (AAF) as the primary flaw in the SpeechEasy device, students cannot understand the effect that the lack of other techniques and factors have on the SpeechEasy's efficacy. To support my argument, I will use research and statistics collected by

Hollins Communications Research Institute, the Del Ferro Method, and several scholarly investigations involving anxiety and stuttering.

Literature Review

While there is no known cure for stuttering, extensive research has been performed on the technology employed by the SpeechEasy device, specifically that which targets delayed auditory feedback and frequency altered feedback, and its effect on reducing stuttered speech. Scholars have focused efforts on understanding the function of various variables and their ability to reduce stuttering, including the amount of auditory delay and the impact of monaural versus binaural feedback. However, these studies focus only on improvement from auditory altered feedback, failing to consider the role that other actors, specifically muscle movement techniques and psychosomatic disorders, play in reducing stuttered speech among patients.

In the article "Effect of monaural and binaural altered feedback on stuttering frequency," which was published in *The Journal of the Acoustical Society of America*, researchers discovered a statistically significant reduction of $p = 0.028$ in stuttering frequency for binaural (both ears) versus monaural (single ear) altered feedback (Stuart et al., 1997). However, while significant differences between binaural and monaural altered feedback were observed, overall stuttering reduction among the eleven participants was only 60-75%. Despite uncovering the role of binaural versus monaural feedback, researchers did not investigate additional factors beyond auditory altered feedback that could have affected the suboptimal stuttering reduction rate observed in participants of the study.

In a similar vein of research, Joseph Kalinowski et al (1996) analyzed stuttering reductions observed under a non-altered auditory feedback (NAF) compared to three levels of delayed auditory feedback (DAF) of 25, 50, and 75ms. Results from the study revealed that statistically significant improvements were observed at the 50 and 75ms DAF as compared to the NAF and 25ms DAF, however, stuttered speech was not completely eliminated among patients. Researchers were also able to debunk the long-standing belief that slowed speech was necessary for stuttering reduction, finding that stuttering improvement occurred among patients at both normal and fast speech rates. In conclusion, the study proposed continued examination of the neurophysiological characteristics of improved fluency from AAF devices in hopes to discover the cause of SpeechEasy's underperformance, failing to propose an examination of factors not currently considered in the network.

Both Kalinowski et al and Stuart et al, offer valuable insights into the impact of auditory altered feedback on fluency. However, these studies limit their investigation to the role that AAF plays in stuttering reduction, failing to consider the absence of additional factors and their role in SpeechEasy's underperformance. Using the actor-network framework, this paper will investigate the additional physical and psychological actors that the SpeechEasy device and AAF network currently fail to employ, in an attempt to understand the reason for the network's inability to eliminate 100% of disfluencies among patients.

Conceptual Framework

Michel Callon's Actor-Network Theory provides a productive framework to systematically examine why the SpeechEasy device is underperforming in its ability to fully eliminate stuttered speech among its users. At its root, Actor-Network Theory (ANT) is a tool that allows for detailed analysis of individual actors and their role in socio-technical systems. Rather than analyzing interactions between individuals in a system, ANT seeks to “map the way in which [actors] define and distribute roles, and mobilize or invent others to play these roles" (Law & Callon, 1988). Callon’s ANT employs the idea of an actor-network, in which components of a system cannot be reduced to either an actor or a network, but should be treated simultaneously as, “an actor whose activity is networking heterogeneous elements and a network that is able to redefine and transform what it is made of” (Bijker et al., 2012, p. 93). The actor-network relationship provides analytical insight into understanding how both human and non-human actors of a sociotechnical system interact with each other to form a cohesive network. ANT explains that the power in a sociotechnical system does not reside in any single actor, but rather in the strength of connections between actors and their ability to work towards a common purpose. While ANT’s role as both a tool and concept are essential to understanding the framework’s broader implications, Callon provides more specific insight into the process of forming and sustaining an actor-network, known as translation.

Callon’s concept of translation, the process of forming and maintaining an actor-network, includes five interconnected phases: problematization, interessement, enrolment, mobilization, and “black-box.” During the first stage of problematization, the primary actors, or network builders, identify the problem and the actors needed to solve it. The primary actors then define the role of each actor within the entire network, and establish how each actor must move through the “obligatory passage point.” This phase establishes the primary actors as the central component of the network. Next, during interessement, the primary actors recruit the actors to participate in the network and align the actors’ interests with their own goal. In enrolment, the primary actors assign the designated role to each actor, to which they accept and begin to execute their assigned role. In mobilization, the primary actors assume their role of the network leader and mobilize the other actors for action. If the primary actors are able to successfully complete the four previous stages, the actor-network then functions as an integrated, reliable system, known as a "black-box." Drawing on the ANT framework and Callon's concept of translation, I will reveal how the SpeechEasy actor-network failed to identify and therefore recruit all of the necessary actors to completely eliminate stuttered speech among its users. In the following sections, I will analyze how the failure of SpeechEasy's creators and designers to recruit the necessary actors, specifically the psychosomatic effect of anxiety, the speech technique of diaphragmatic breathing, and the gentle onset technique, resulted in the network's underperformance in eliminating stuttered speech.

Analysis

SpeechEasy Network Formation

Understanding the SpeechEasy device's current actor-network is a necessary step for analyzing the reasons for the device's underperformance. SpeechEasy's primary actors, Dr. Andrew Stuart, Dr. Joseph Kalinowski, and Dr. Michael Rastatter, began researching and building the SpeechEasy's network in the 1990s (Sayewich, 2019). During what Callon labels as the problematization stage of translation, Dr. Stuart and his companions began studying the effects of auditory altered feedback on stuttered speech. What they ultimately discovered was the need for a practical, everyday device that was able to manipulate a stutterer's voice without bulky laboratory equipment (Sayewich, 2019). Since SpeechEasy's product launch in 2001, Dr. Stuart and his team have continued building and expanding the SpeechEasy network, recruiting both human and non-human actors (Janus Development Group, 2018).

The human actors that Dr. Stuart and his team have recruited to participate in the SpeechEasy network are defined as follows: (i) the *stutterer*, who actively uses the SpeechEasy device in his or her daily life; (ii) the *Speech Language Pathologists*, who work directly with the stutterer to provide care and ensure proper use of the SpeechEasy device; (iii) the *engineers*, who helped directly design the SpeechEasy device; and (iv) the *Janus Development Group*, who helps manufacture and market the device (Janus Development Group, 2018).

In addition to the human actors, there are multiple non-human actors in the SpeechEasy network, including the following: (v) the *SpeechEasy device* itself (including the four models: Comfort Fit, Completely in Canal, In the Canal, and Behind the Ear); (vi) *altered auditory feedback* (specifically *delayed auditory feedback* and *frequency altered feedback*), which is the main stuttering treatment SpeechEasy employs; (vii) the *Choral Effect*, which is the natural phenomenon that occurs when a patient's stutter is reduced or eliminated when speaking in unison with others; (viii) *vowel prolongation*, which is a supplementary speech technique; and lastly (ix) the *ear*, including the physical anatomy and functions of the outer, middle, and inner parts (Janus Development Group, 2019a).

Despite recruiting close to a dozen actors, Dr. Stuart, Dr. Kalinowski, Dr. Rastatter and the SpeechEasy actor-network have failed to consistently and fully eliminate stuttered speech across its patients. In other words, the SpeechEasy network has failed to enter what Callon labels as the final "black box" stage, during which the network operates as a cohesive, integrated, and reliable system. When analyzing the SpeechEasy device and its progression through forming and maintaining a successful actor-network (Callon's Concept of Translation), it is evident that the primary actors (Dr. Stuart and his team) failed to identify all of the relevant actors during the problematization stage, ultimately resulting in the device's underperformance.

Diaphragmatic Breathing Technique

The first actor that Dr. Stuart and his fellow researchers failed to recruit for the SpeechEasy actor-network is the diaphragmatic breathing technique. According to the Cleveland Clinic, diaphragmatic breathing is simply defined as correctly using the diaphragm during respiration (Cleveland Clinic, 2018). The diaphragm is the largest, most efficient muscle used during speech formation, making it the easiest muscle to control while speaking (Cleveland Clinic, 2018). Correct diaphragmatic breathing, shown in Figure 1, is achieved by allowing the diaphragm to slowly and smoothly contract during an inhalation, followed by a relaxation of the diaphragm during exhalation (Del Ferro, 2019; Buzzle.com, n.d.). Fluent speech can only be achieved by first ensuring correct diaphragmatic breathing is performed (Mount Sinai, 2013).

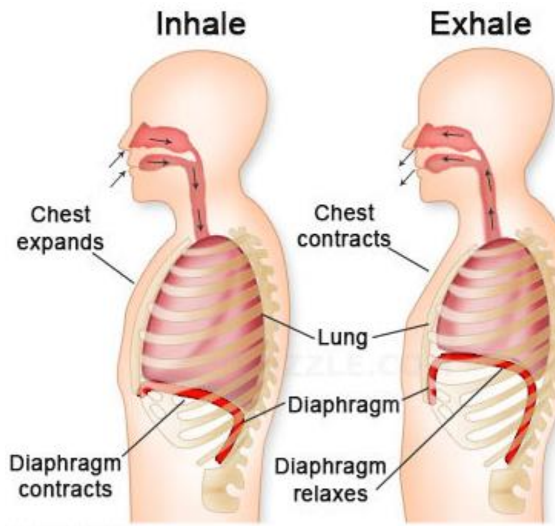

Figure 1: Diaphragmatic Breath

In the 1970's, Leonard del Ferro developed what is known as the Del Ferro Method, in which the diaphragmatic breathing technique is used to attain fluent speech (Del Ferro, 2019). According to Del Ferro (2019), "Stuttering resembles a scare where also a (small) inhalation takes place. During this inhalation the diaphragm shoots down, interrupting the fluent airflow to the vocal cords," which results in a variety of speech disfluencies (para. 7). In order for fluent speech to be achieved, stutterers must be taught how to exercise proper control over their diaphragm, to avoid the sharp downward movement of the diaphragm during inhalation that causes stuttered speech.

The Del Ferro approach to obtaining fluent speech differs from Dr. Stuart and his team's approach, as the SpeechEasy device was designed around FAF and DAF research, or altering the way a stutterer hears his or her own voice (Sayewich, 2019). However, through the Del Ferro Method and similar research, it is evident that correct diaphragmatic breathing must be used by the stutterer as the foundation for attaining completely fluent speech. During the problematization stage of the SpeechEasy actor-network formation, however, Dr. Stuart and his team failed to identify the diaphragmatic breathing technique as a foundational component to producing fluent speech. Instead of diaphragmatic breathing, Dr. Stuart and his team centered their research around the non-human actor previously mentioned, known as the choral effect. According to SpeechEasy, the choral effect is the natural phenomenon in which one's stutter is reduced or even eliminated while speaking in unison with other people (Janus Development Group, 2019b). While the research surrounding the choral effect is accurate in the phenomenon's ability to reduce a stutter's disfluencies, the Del Ferro method reveals that it does not address the foundational component of fluent speech, or correct diaphragmatic breathing. By refusing to identify diaphragmatic breathing as a necessary component of fluent speech production, the SpeechEasy network will continue to underperform, with stuttering reduction stagnating at 30-70%, as seen in Armson et al's (2006) study on the device.

Gentle Onset Technique

Similar to the diaphragmatic breathing technique, Dr. Stuart and his team failed to recruit another actor during the problematization stage of actor-network building known as the gentle, or easy onset technique. While fluent speech production must begin with proper diaphragmatic breathing, fluent speech is equally as reliant on the smooth and controlled movement of the vocal folds between open and closed positions ("Easy Onset", n.d.). However, during speech production of a stutterer, voicing is often initiated with too much force or tension in the vocal folds, resulting in a greater likelihood of disfluency or stuttered speech (Blomgren, 2013). The gentle onset technique helps to teach stutterers how to avoid tension and force in their vocal folds, and instead, initiate voicing in a smooth, controlled manner (Blomgren, 2013).

The gentle onset technique is highly researched and utilized in the Stuttering Treatment Center at Hollins Communications Research Institute (Blomgren, 2013). With a therapy approach driven by science, Hollins states that "[their] research demonstrates that speech distortions of stuttering are produced by faulty contractions within the muscles of the tongue, lips, jaw, and vocal folds" (Hollins Communications Research Institute, n.d.-a). With the gentle onset technique and other muscle movement-based techniques, Hollins reports that 93% of their patients achieve fluency in only 12 days (Hollins Communications Research Institute, n.d.-b). Gloria Borden et al's research reveals that when monitoring the electroglottographic waveforms or voice source of a stutterer's speech, moments of fluent speech by the stutterer mimic the speech of fluent control subjects, lending additional support for the gentle onset technique (Borden et al., 1985).

Despite the evidence for use of the gentle onset technique as a critical, supplementary actor in the SpeechEasy network, Dr. Stuart and his team only recruited a technique known as vowel prolongation for use in conjunction with the SpeechEasy device. Armson et al's (2006) clinical study on the SpeechEasy device found a greater reduction in all areas of reading, monologue, and conversation when participants used the SpeechEasy device in conjunction with the vowel prolongation technique as opposed to only the SpeechEasy device. However, because Armon et al's (2006) study of the vowel prolongation technique only reduced stuttering by 40 – 70%, further investigations into the SpeechEasy device are thus warranted. By analyzing the

SpeechEasy device through the ANT lens, as well as analyzing the success of research performed by Hollins and Borden et al on the gentle onset technique, it becomes clear that part of the SpeechEasy network's underperformance was from failing to recruit the gentle onset technique as an actor in conjunction with the vowel prolongation technique. Hollins's success in utilizing the gentle onset technique to help stutterers attain fluency, combined with Borden et al's analysis of the similarities of the electroglottographic waveforms during fluent speech of a stutterer and fluent speech of a control subject, provide clear evidence that the gentle onset technique plays a critical role in fluent speech production (Hollins Communications Research Institute, n.d.-b; Borden et al., 1985). Dr. Stuart's failure to recruit the gentle onset technique to supplement the vowel prolongation technique while building the SpeechEasy network was yet another actor whose absence played a role in the device's poor performance.

Psychosomatic Effect of Anxiety

The last actor that Dr. Stuart and his team failed to recruit and identify during the problematization stage of the SpeechEasy network is the psychosomatic effect of anxiety. Psychosomatic disorders are conditions that concern both the body and mind, meaning that one's negative mental state can have detrimental physical impacts on their body (Willacy, 2020). The psychosomatic effects of anxiety have an extensive range of physical impacts on one's body, however when it comes to speech production, symptoms including tension, muscle trembling, and rapid breathing are the focus of my analysis ("Everything you Need", n.d.). Scholars have long debated whether or not anxiety causes stuttering, however, Ashley Craig's investigations into anxiety and stuttering reveal several critical insights into the relationship of the two disorders. While Craig's investigation found that general levels of anxiety were matched across gender and occupation for stutterers and fluent speakers, she reported that stutterers had significantly higher levels of anxiety in demanding speech situations as compared to fluent speakers (Craig, 1990). Moreover, in Craig's report with Yvonne Tran, Craig and Tran note that the higher levels of anxiety seen in stutterers can have psychosomatic effects, writing that "anxiety can overload the capacity of the speech motor system and thus disrupt speech processing" (Craig & Tran, 2014). Heightened levels of anxiety and the resulting muscle tension or trembling can greatly increase the occurrence of stuttering, as it affects both diaphragmatic breathing and the movement of the vocal folds. Increased anxiety during speech situations often results in rapid, sharp breathing of the stutterer, which as revealed through the Del Ferro Method, interrupts the fluent airflow to the vocal cords and causes speech disfluencies (Del Ferro, 2019). Anxiety can also cause muscle trembling and tension, and because fluent speech is reliant on the smooth, relaxed movement of the vocal folds, initiating one's voice with tension in the vocal tract is also likely to result in stuttering ("Easy Onsets", n.d.). Craig's analysis of the psychosomatic effect of anxiety on speech production reveals that the failure to incorporate anxiety management strategies in the SpeechEasy actor-network played a critical role in the device's inability to eliminate stuttering.

During the problematization stage of translation, Dr. Stuart and his team yet again failed to identify anxiety and its psychosomatic effect on speech production as a necessary actor to recruit for the SpeechEasy device. Rather, Dr. Stuart and his team limited their research to frequency altered feedback and delayed auditory feedback (Sayewich, 2019). While I have argued that the lack anxiety management strategies play a crucial role in the SpeechEasy network's underperformance, it is worth noting that some scholars disagree on the importance of the role that anxiety plays in speech production. In Per Alm and Jarl Risberg's study on anxiety and stuttering, they concluded that the increased anxiety found in stutterers is simply a physiological result of the stutters' past experiences (Alm & Risberg, 2007). While this is likely true, the study does not address the physical effects of anxiety on the human body. In her findings, Craig is not suggesting that anxiety and stuttering are psychologically related, but rather that the impact of anxiety on stuttering is merely physical. By causing muscle tension and rapid, short breathing, anxiety's effect on speech production is a physical impact that can be eliminated through anxiety management strategies (Craig & Tran, 2014). The lack of both the incorporation and understanding of the psychosomatic effect of anxiety on stuttering into the SpeechEasy network is the final actor, whose absence contributes to the SpeechEasy device's stagnation at only 40-70% reduction in stuttering in its users (Armson et al., 2006).

Conclusion

Using Callon's Actor-Network Theory as a sociotechnical framework, I have systematically analyzed why the SpeechEasy actor-network has failed to consistently and fully eliminate stuttered speech across its patients. Through my analysis, it is evident that the primary actors (Dr. Stuart and his team) of the SpeechEasy network failed to identify all of the relevant actors during the problematization stage of translation, or network building. By failing to identify and recruit several actors, specifically the speech technique of diaphragmatic breathing, the gentle onset technique, and the psychosomatic effect of anxiety, the SpeechEasy network not only failed to operate as a cohesive, integrated system, but it was unable to eliminate all stuttered speech among its patients. If we continue to believe that the shortcomings of auditory altered feedback are the primary flaw in the SpeechEasy device, clinicians and experts will be unable to identify the additional actors, which are not currently being considered in the network, yet are crucial to its success. Therefore, proper implementation of the speech technique of diaphragmatic breathing, the gentle onset technique, and the psychosomatic effect of anxiety into the SpeechEasy actor-network is necessary in order for the device to be 100% effective in eliminating stuttered speech.

Word Count: 3457

References

Alm, P. A., & Risberg, J. (2007). Stuttering in adults: The acoustic startle response, temperamental traits, and biological factors. *Journal of Communication Disorders*, *40*(1), 1–41. https://doi.org/10.1016/j.jcomdis.2006.04.001

Armson, J., Kiefte, M., Mason, J., & Croos, D. D. (2006). The effect of SpeechEasy on stuttering frequency in laboratory conditions. *Journal of Fluency Disorders*, *31*(2), 137–152. https://doi.org/10.1016/j.jfludis.2006.04.004

Bijker, W. E., Hughes, T. P., Pinch, T., & Douglas, D. G. (2012). *The social construction of technological systems, anniversary edition: New directions in the sociology and history of technology*. The MIT Press.

Blomgren, M. (2013). Behavioral treatments for children and adults who stutter: A review. *Psychology Research and Behavior Management*, *6*, 9–19. https://doi.org/10.2147/PRBM.S31450

Borden, G. J., Baer, T., & Kenney, M. K. (1985). Onset of voicing in stuttered and fluent utterances. *Journal of Speech, Language, and Hearing Research*, *28*(3), 363–372. https://doi.org/10.1044/jshr.2803.363

Buzzle.com. (n.d.). *Diaphragm function* [Diagram]. For the Love of Body. http://www.fortheloveofbody.com/blog/371

Cleveland Clinic. (2018, September 14). *Diaphragmatic breathing exercises & techniques*. https://my.clevelandclinic.org/health/articles/9445-diaphragmatic-breathing

Craig, A. (1990). An investigation into the relationship between anxiety and stuttering. *Journal of Speech and Hearing Disorders*, *55*(2), 290–294. https://doi.org/10.1044/jshd.5502.290

Craig, A., & Tran, Y. (2014). Trait and social anxiety in adults with chronic stuttering: Conclusions following meta-analysis. *Journal of Fluency Disorders*, *40*, 35–43. https://doi.org/10.1016/j.jfludis.2014.01.001

Del Ferro. (2019, July 5). *Stuttering and breathing: What happens during a stutter?* https://stuttering-delferro.com/media/2019/07/05/stuttering-and-breathing-what-happens-during-a-stutter

Easy onsets (also known as gentle voice onsets). (n.d.). Stuttering Therapy Online. https://www.stutteringtherapyonline.com/easy-onsets.html#:%7E:text=Easy%20onsets%20(also%20known%20as,of%20voiced%20and%20voiceless%20sounds.

Everything you need to know about anxiety. (2016, September 8). Healthline. https://www.healthline.com/health/anxiety-symptoms#symptoms

Hollins Communications Research Institute. (n.d.-a). *HCRI stuttering therapy*. Hollins Communications Research Institute: Stuttering Treatment Center. https://www.stuttering.org/index.php

Hollins Communications Research Institute. (n.d.-b). *HCRI's therapy approach - Driven by science*. Hollins Communications Research Institute: Stuttering Treatment Center. https://www.stuttering.org/stuttering-therapy-stuttering-therapy-at-HCRI.php

Janus Development Group. (2018, December 20). *Our history*. SpeechEasy. https://speecheasy.com/our-history/

Janus Development Group. (2019a, February 4). *Devices*. SpeechEasy. https://speecheasy.com/devices/

Janus Development Group. (2019b, March 20). *How it works*. SpeechEasy. https://speecheasy.com/how-it-works/

Kalinowski, J., Stuart, A., Sark, S., & Armson, J. (1996). Stuttering amelioration at various auditory feedback delays and speech rates. *International Journal of Language & Communication Disorders*, *31*(3), 259–269. https://doi.org/10.3109/13682829609033157

Law, J., & Callon, M. (1988). Engineering and sociology in a military aircraft project: A network analysis of technological change. *Social Problems*, *35*(3), 284–297. https://doi.org/10.2307/800623

Mount Sinai. (2013, August 28). *The interrelationship of breathing and speaking*. https://health.mountsinai.org/blog/the-interelationship-of-breathing-and-speaking/

Sayewich, N. (2019, March 22). *Inventor honor*. ECU: News Services. https://news.ecu.edu/2019/03/22/inventor-honor/

Stuart, A., Kalinowski, J., & Rastatter, M. P. (1997). Effect of monaural and binaural altered auditory feedback on stuttering frequency. *The Journal of the Acoustical Society of America*, *101*(6), 3806. https://doi.org/10.1121/1.418387

Willacy, H. (2020, June 30). *Psychosomatic disorders*. Patient. https://patient.info/mental-health/psychosomatic-disorders