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Saccades and Phonological Coding

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ABSTRACT

Purpose: This phenomenological study aimed to investigate how saccade behavior influences the precision of pronunciation in non-native English speakers during loud reading. A cohort of 20 non-native English speakers participated in the research. **Methodology:** Through open-ended questions, participants were probed on various dimensions, including challenges encountered during oral reading, strategies employed to overcome these obstacles, experiences related to saccade behavior, individual variations in saccade behavior, and factors influencing pronunciation accuracy. Thematic analysis was conducted to identify recurring themes that aligned with the research inquiries. **Findings:** A notable connection exists between non-native speakers' eye movements and their pronunciation accuracy during vocalized reading, particularly at higher volumes. The eye movement patterns and reading style significantly influence their pronunciation proficiency. These findings bear relevance in devising strategies aimed at refining saccade control capabilities and addressing the challenges confronted by non-native speakers when reading aloud in noisy environments. **Implications:** Consequently, this endeavor can lead to improved accuracy in pronunciation.

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Introduction

Psycholinguistic experts have consistently exhibited a profound interest in elucidating the cognitive mechanisms that underlie language comprehension, with a specific emphasis on reading. One of these mechanisms is saccades, characterized by their rapid and transient nature, frequently manifest during the act of reading and are recognized as a pivotal component of the auditory reading process. Saccades are rapid, ocular transitions that abruptly shifts the center of gaze from one visual field to another. They can vary in amplitude from small movements like while reading to much larger movements like while gazing the moon and stars. When reading is concerned, saccades assume a vital role in the cognitive process by facilitating swift ocular transitions between words, thereby expediting the scanning process and augmenting comprehension (Rayner & Duffy, 1986). This effective comprehension of written language hinges upon the critical coordination between saccades and language processing, enabling readers to accurately perceive and comprehend written text (Kowler, 2011).

Empirical investigations have evidenced that the phonological attributes of lexical items, notably encompassing their orthographic and phonemic features, exert an influence on saccadic eye movements. For instance, lexical items characterized by irregular spelling-to-phonology mappings can elicit prolonged fixations and heightened reading durations, necessitating adjustments in saccadic amplitude for effective comprehension of such terms (Rayner & Duffy, 1986). Moreover, the movement of saccadic eye motions can influence the enunciation of words while engaged in the act of reading. As revealed by Henderson and Ferreira (2004) research, saccades may potentially serve as a trigger for speech sound generation, thereby influencing the reader's interpretation and understanding of the written material. Particularly, non-native English speakers should attend to the correlation between saccades and pronunciation in the context of audible reading, as emphasized by Shen et al. (2012).

Empirical evidence provided by Wydell et al. (2003) further substantiates that any alterations in saccade characteristics, encompassing amplitude and duration, can exert a substantial influence on pronunciation precision during oral reading among non-native speakers. The accurate perception and production of speech sounds hold paramount importance for proficient language acquisition, thereby rendering the understanding of saccades' function within this domain a matter of significant interest for psycholinguistic scholars. Moreover, disparities in language backgrounds or levels of proficiency among non-native speakers may engender modifications in the relationship between saccade behavior and pronunciation accuracy during oral reading. Individuals who possess advanced language proficiency may demonstrate improved regulation of saccades, leading to increased precision in pronunciation during oral reading (Shen et al., 2012).

Comprehending these individual differences assumes crucial significance in formulating efficacious strategies and interventions for language acquisition. Given that saccades constitute a crucial component of the auditory reading process, exerting influence over both the speed and precision of linguistic comprehension, unraveling the association between saccades and pronunciation during audible reading assumes paramount importance from a psycholinguistic standpoint, especially with regards to non-native speakers. Extensive research endeavors within this realm may consequently contribute to the development of efficient language acquisition techniques and interventions, thereby ultimately bolstering linguistic proficiency and communicative abilities.

Although prior studies have explored the correlation between saccades and pronunciation within the context of reading, the exact nature of this connection remains enigmatic. Additional research is essential to acquire a comprehensive comprehension of the underlying mechanisms that govern the interaction between saccades and pronunciation during the reading process. Consequently, the present study endeavors to examine the relationship between saccades and pronunciation in the context of reading through a comprehensive analysis of both eye movements and speech production. The primary objective of this study, employing a psycholinguistic framework, was to determine the specific contribution of saccades in the auditory reading process.

The following research questions were formulated for the study:

1. What are the differences in saccadic behavior during loud reading among non-native speakers, and how does this behavior impact their accuracy in pronunciation?
2. To what extent do variations in saccade properties affect the precision of pronunciation during vocalized reading among individuals who are not native speakers?
3. Can the relationship between saccade behavior and pronunciation accuracy during loud reading among non-native speakers be influenced by individual differences in language background or proficiency levels?

To test these questions, the following research hypotheses were established:

H1: Non-native speakers who exhibit superior saccade control will demonstrate greater accuracy in pronunciation during loud reading as compared to those with inferior saccade control.
H2: Among non-native speakers, variations in saccade characteristics, such as amplitude and duration, will significantly impact pronunciation accuracy during loud reading.
H3: The interrelationship between saccade behavior and pronunciation accuracy during loud reading among non-native speakers may be influenced by factors such as language proficiency, age of acquisition, and duration of exposure to the language.

Theoretical Underpinnings and Literature Review

The present study delves into the intricate theoretical underpinnings of psycholinguistics, an expansive field of inquiry meticulously explored by Rayner and Juhasz (2004). It elucidates the cognitive mechanisms intricately entwined with language comprehension, specifically within the realm of reading. Reading, an intricate and multifaceted activity, necessitates the harmonious orchestration of diverse cognitive processes, including attention, perception, and language comprehension. Extolling the significance of effective coordination between eye movements and the language processing system, Kuperman et al. (2010) assert its indispensable role in the triumphant realm of reading. As expounded upon by Rayner and Juhasz (2004), the process of seamlessly shifting one's gaze from one word to another is abetted by the rapid and consequential eye movements commonly referred to as saccades. Previous research ventures have shed light upon the profound influence of saccades, intrinsically linked to the phonological attributes of words, thereby potentially impacting pronunciation during the reading endeavor. However, the precise nature and magnitude of the correlation between saccades and pronunciation remain enigmatic, as aptly noted by Rayner and Juhasz (2004) and Kuperman et al. (2010).

The present investigation endeavors to delve deeper into this intricate association by scrutinizing ocular movements alongside verbal expression in the context of a meticulously crafted reading assignment. The primary thrust of this study centers around examining the nuanced variations characterizing saccade behavior and discerning their far-reaching ramifications on pronunciation accuracy within the purview of non-native speakers engaged in vociferous reading. Furthermore, the research ambitiously endeavors to unravel the potential moderating effects of language proficiency, in conjunction with other associated factors, upon the aforementioned complex relationship.

It is imperative to note that saccades, owing to their indispensable role within the realm of comprehension, have attracted substantial scrutiny and unwavering research focus. Scholars have diligently embarked upon an extensive and intricate exploration of myriad studies, aiming to unravel the multifaceted nature of eye movements. These scholarly endeavors have scrutinized an array of factors, encompassing the distinct patterns, durations, and frequencies characterizing saccades, thereby revealing their intricate interplay with diverse reading strategies and the manifold cognitive processes intricately interwoven with this domain. Hence, the present study makes noteworthy strides in augmenting our comprehension of the neural and cognitive processes deeply enmeshed within the realm of reading. Notably, these valuable insights gleaned from the study have far-reaching implications, engendering the development of bespoke interventions tailored to address the challenges faced by individuals grappling with reading difficulties, while concurrently facilitating the creation of highly efficacious reading materials.

- ***Eye movements in reading***

The exploration of ocular movements during the act of reading has garnered substantial interest within the field of cognitive psychology. Various research endeavors have contributed to the understanding of the intricate mechanisms implicated in these movements. In 2009, Blais et al. (2009) conducted a laboratory experiment with the primary objective of scrutinizing the mechanisms involved in extracting information from written text during eye fixations and saccades in the reading process. Their study shed light on readers' ability to extract both semantic and syntactic information during saccades prior to fixating on a given word. Furthermore, it elucidated that saccades between words are not arbitrary but rather influenced by readers' comprehension of the text.

Bouma and De Voogd (1974) findings emphasized the significance of eye movement patterns in unraveling the cognitive mechanisms underpinning reading. These patterns can offer valuable insights into the comprehension process. In 1987, Henderson, Pollatsek, and Rayner (1987) discovered that the positive impact of extrafoveal preview was contingent on the degree of similarity between the preview and the target. Inhoff's (1989) study illustrated the influence of parafoveal word processing on the computation of saccades during eye fixations in reading contexts.

The research conducted by Jacobson and Dodwell (1979) disclosed the consequential role of saccadic movements in the reading process, as they facilitate readers' fixation on specific words, thereby aiding in the extraction of meaningful information. Kuperman et al. (2010) investigated that the placement of a word within a sentence or paragraph exerts a discernible influence on eye movements. Specifically, words positioned at the sentence

or paragraph outset tend to elicit lengthier fixations and shorter saccades compared to those situated toward the end. Moreover, the authors propose that contextual information may wield a more substantial impact on reading comprehension when assessed at the paragraph level. Liversedge and Findlay's (2000) literature review posited the indispensability of saccadic eye movements for perception and cognition, particularly in the domains of visual search and reading. In accordance with Morrison and Rayner's (1981) examination, the regulation of eye movements during reading is governed by cognitive factors, specifically lexical and contextual processing, rather than being solely determined by visual factors.

O'Regan's (1979) study confirmed the linguistic control hypothesis by revealing that passages characterized by more intricate syntax elicited shorter saccade lengths. Parker, Slattery, and Kirkby's (2019) study scrutinized the presence of return-sweep saccades during reading across individuals of varying ages, including adults and children. Collectively, these studies have significantly contributed to the comprehension of the intricate mechanisms entailed in eye movements during the reading process. The research findings unequivocally indicate that eye movements are not haphazard but rather meticulously regulated, with saccades intentionally directed toward the subsequent fixation point. Moreover, these findings imply that parafoveal processing holds the potential to amplify foveal information processing. Furthermore, it is posited that contextual information may exert a more substantial impact on reading comprehension when examined at the paragraph level. These studies underscore the vital and foundational role of saccades within the realm of visual perception.

- ***Language comprehension***

Extensive research has been conducted in the fields of psychology and linguistics on the complex cognitive processes that underlie language and reading comprehension. The investigations carried out by Ferreira, Bailey, and Ferraro (2002), Henderson, Pollatsek, and Rayner (1987), and Kendeou et al. (2014) have yielded significant findings regarding diverse facets of said processes. The study conducted by Ferreira and colleagues investigated the potential of language processing to depend on "good-enough" sentence representations, and demonstrated that these representations can enhance processing efficiency. The study conducted by Henderson et al. aimed to explore the potential benefits of parafoveal information in enhancing foveal processing during a visual lexical decision task. Finally, Kendeou et al. (2014) conducted a study examining the process by which readers incorporate textual information with their pre-existing knowledge in order to achieve comprehension. The results of this investigation demonstrated that this integration is a critical component of effective comprehension and is compromised in individuals who experience difficulties with reading. In general, the aforementioned studies highlight the importance of cognitive mechanisms in both language and reading comprehension, and the potential ramifications for those who experience challenges with reading.

- ***Saccades and Saccadic Inhibition***

The criticality of eye movements in visual perception and attention has been acknowledged within scholarly discourse. Scholars have employed diverse

methodological approaches, including mathematical modeling and eye-tracking technology, to probe the influence of eye movements. Engbert, Longtin, and Kliegl (2002) employed a mathematical model as a means to replicate saccades and ascertain their pivotal role in conveying essential visual information to the fovea, the central area of the retina responsible for acute vision. In a study conducted by Rayner et al. (2004), the influence of word predictability and frequency on eye movements during reading was explored. The findings illuminated that such words that possess greater predictability and frequency, also elicited reduced fixation duration and regression frequency, suggesting that these linguistic properties impact the dynamics of eye movements. Reingold and Stampe (2004) conducted an investigation to delve into the impact of oculomotor control on the interpretation of ambiguous visual stimuli. The results revealed that participants exhibited divergent eye movement patterns based on their perception of the stimuli, signifying that the processing of ambiguous visual information involves the regulation of oculomotor behavior. These studies collectively accentuate the paramount importance of eye movements in both visual perception and attention. Moreover, they underscore the salience of language-related factors in shaping eye movements, particularly within the realm of reading.

- ***Spoken word recognition***

Eye-tracking technology has become a valuable tool for investigating the cognitive mechanisms underlying the comprehension of spoken language, specifically the intricate process of recognizing spoken words. Several research studies have utilized this technology to further investigate the complexities of spoken word recognition. Allopenna, Magnuson, and Tanenhaus (1998) conducted a study to examine the temporal dynamics of spoken word recognition. The researchers utilized eye-tracking technology to monitor participants' eye movements while they processed spoken words within sentences. The research employed a visual-world paradigm and manipulated the phonetic similarity of target words to evaluate the continuous mapping models of spoken word recognition. The sample of the research consisted of U.S. undergraduate students. The results of the study provided support for the continuous mapping models of spoken word recognition. Specifically, the participants demonstrated an early onset of processing for the target words upon hearing the phonetically similar prime. This finding serves as evidence for the incremental processing approach in spoken word recognition.

The amalgamation of visual and linguistic information in the comprehension of spoken language was investigated by Tanenhaus et al. (1995) through a study employing advanced eye-tracking technology. Employing a visual-world paradigm, the researchers purposefully manipulated the visual context surrounding the presentation of spoken words. The participants in this study were undergraduate students originating from the United States. The empirical findings of the study provided compelling evidence that individuals effectively integrated both visual and linguistic cues during the comprehension of spoken language. Notably, the assimilation of these two types of information occurred swiftly and in a simultaneous manner.

Tanenhaus et al. (1995) conducted an investigation into the eye movements that are conceptually-mediated during the recognition of spoken words. They employed a visual-world paradigm to manipulate the plausibility of the visual context. The study population

consisted of undergraduate students hailing from the United States. The study's results indicate that the process of spoken word recognition is interactive, as participants' eye movements were affected by both the phonological features of spoken words and the credibility of visual context. Altmann and Kamide (2007) conducted a study to investigate the temporal dynamics of prediction during incremental sentence processing using a visual-world paradigm that involved anticipatory eye movements. The research experiment involved the manipulation of word predictability within sentences and utilized undergraduate participants hailing from the United States. The study's findings suggest that the participants exhibited anticipatory eye movements towards the expected upcoming words, providing evidence for the notion that prediction is a vital component of the gradual processing of sentences. In general, the aforementioned studies provide noteworthy perspectives on the cognitive mechanisms implicated in the comprehension of spoken language, and emphasize the efficacy of eye-tracking methodology in exploring these mechanisms.

- ***Phonological Coding Process***

Phonological coding, a pivotal cognitive process integral to the intricate tapestry of language comprehension and production, encompasses the enigmatic orchestration of mental representations and manipulations involving the multidimensional phonological structure of words, seamlessly interweaving their constituent phonemes and syllables (Goswami, 2015). The phonological coding hypothesis, with its labyrinthine intricacy, postulates that individuals endowed with virtuosic mastery of phonological coding skills transcend the ordinary bounds of reading prowess, adroitly traversing the aural terrain of spoken language and seamlessly transmuting its sonorous cadences into the visual realm of written symbols (Wagner & Torgesen, 1987). This esoteric adeptness finds its harmonious synergy with the maturation of phonemic awareness, an ethereal realm of linguistic cognition wherein the discernment and manipulation of elusive phonemes within lexical tapestries become second nature (Ehri, 2014). The inception of phonological coding skills, an epoch of profound significance during the nascent stages of literacy acquisition, assumes the mantle of a catalyst, propelling the unfolding narrative of reading proficiency (Goswami, 2015). She adds that the intricate interplay between phonological coding and the symphony of reading, a symphony resplendent with myriad cognitive mechanisms, unequivocally underscores its indelible imprint upon the rich tapestry of language processing, a tapestry woven with threads of ingenuity and enigmatic mastery.

Phonological coding through saccade constitutes a labyrinthine process unfolding concurrently with the act of reading, subtly orchestrating the metamorphosis of visual cues into auditory linguistic representations. This mechanism thrives at the nexus of intricate oscillations of saccadic eye movements, an expansive perceptual span, and a deeply embedded linguistic processing paradigm (Rayner, 1998). In this context, we venture into an analytical dissection of this convoluted process, drawing upon seminal insights from pertinent literature in the field.

The intricate process of phonological coding through saccade manifests itself as a dynamic intersection between the facilitative elements of phonological discernment and potential challenges that may arise during this process. Initially, the enhancement of phonological discernment is seen through sequential synthesis, where the choreographed

nuances of saccadic transitions encourage a harmonious and orderly amalgamation of phonological codes, serving as gateways to integrate fragments of textual data into a burgeoning linguistic structure, thus enriching the fluidity of the reading journey (Pollatsek et al., 1992; Vasilev, Yates, & Slattery, 2019). However, this journey is not devoid of potential obstacles in phonological processing, marked by occasional discrepancies in the trajectories of saccadic movements, which can disrupt the harmony with established phonological boundaries, inciting the onset of regressive saccades that momentarily inhibit the rhythmic flow of phonological assimilation (Pollatsek et al., 1992; Rayner, 1998). Adding complexity to this process are the idiosyncratic variations manifested as individualized saccadic patterns, which, upon discernment, can pave the way for the formulation of customized reading strategies that amplify the effectiveness of phonological coding (Bulling, Ward, & Gellersen, 2012). Moreover, readers often employ corrective approaches to counter potential disturbances brought forth by saccadic variations, adopting flexible strategies that might involve altering the reading speed or utilizing tactile guidance to bolster the precision of phonological coding, thus demonstrating a resilient and adaptive response to the multifaceted nature of reading (Bulling, Ward, & Gellersen, 2012).

To encapsulate, phonological coding through saccade epitomizes a profound and multifaceted process, firmly entrenched within the linguistic cognitive machinery operative during reading. The meticulous orchestration of this interaction, punctuated by both facilitative and inhibitive elements, heralds a promising avenue for ensuing scholarly pursuits, tasked with elucidating the sophisticated interconnections between saccade and phonological coding (Vasilev, Yates, & Slattery, 2019).

- ***Ocular Exercises Technique***

In the discerning study conducted by Megino-Elvira, Martín-Lobo, and Vergara-Moragues (2016), the researchers embarked on an analytical expedition to scrutinize the intricate interrelationships between eye movements, auditory perception, and phonemic awareness in the reading process, as delineated in their publication in The Journal of Educational Research. Steering towards fostering an enriched understanding of the reading mechanism, the study adeptly utilized a rigorous research paradigm to delve into the nuanced interplays and consequential influences of eye movements and auditory perception in the scope of phonemic cognition. By harnessing a methodologically sound sample structure, the investigation shed light on the critical synergies at play, consequently facilitating a deeper comprehension of the inherent complexities governing the reading procedure. The study's findings elucidated that a symbiotic interaction between the auditory perceptual framework and phonemic awareness significantly predicates the dynamism and efficiency of eye movements during reading, thereby offering pivotal insights into the transformative potentials embedded within this multifaceted process. Consequently, this paves the pathway for fostering innovative educational strategies, grounded in an acute understanding of the harmonized interaction between auditory cognition and phonemic sensitivity, thereby potentially enhancing the efficacy and profundity of the reading process.

Turning our attention to the latest developments in the sphere of computer-assisted pronunciation training, we spotlight the significant research undertaken by Shi, Huo, and Jin (2020). This group embarked on a detailed investigation to elucidate the efficacy of

context-aware goodness of pronunciation (GoP) in the specific domain of computer-assisted pronunciation training. Endeavouring to finesse existing pedagogical methodologies in pronunciation tutelage, the investigation adeptly utilized a nuanced research design to scrutinize the repercussions of implementing context-aware strategies on the outcomes of pronunciation training. Through a meticulous selection of a representative sample cohort, the study illuminated the intricate subtleties underpinning context-aware GoP, thereby elucidating its transformative role in enhancing phonetic capabilities. The study unearthed that the adroit incorporation of context-aware GoP substantially augments the depth of vocabulary comprehension whilst simultaneously bolstering the precision in pronunciation. These findings, standing as a testament to the evolutionary trajectory in computer-assisted pronunciation tutelage, underscore an impending paradigm shift, necessitating the assimilation of context-aware methodologies, thereby cultivating a refined and integrative linguistic learning paradigm, astutely attuned to the complex interplay between vocabulary mastery and phonetic accuracy.

- ***Saccade and External Factors***

In the insightful research article published in the "ACM Transactions on Applied Perception (TAP)" in 2012, Bulling, Ward, and Gellersen present a comprehensive study examining the multifaceted aspects of reading activity recognition, particularly in transit scenarios, utilizing body-worn sensors. This pioneering study distinctly aims to uncover patterns and intricacies in reading activities as perceived through various sensor modalities. By employing a multimodal approach that leverages the capabilities of body-worn sensors, the research successfully identifies distinctive markers and characteristics associated with reading activities during transit, thereby offering an innovative lens to perceive and analyze reading behaviors in dynamic environments. The authors, through their meticulous investigation, underscore the potential of using advanced sensor technologies to augment the understanding of reading activities in real-world scenarios. The study, thus, not only extends the frontier of knowledge in applied perception but also potentially catalyzes advancements in the development of responsive and adaptive systems attuned to human reading behaviors.

Methodology

- ***Research Design***

In this study, the researchers utilized a phenomenological research design to delve into the intrinsic nature of the phenomenon under scrutiny, as experienced and interpreted by distinct individuals. The investigation of irrational feelings and perceptions is emphasized in phenomenology as a qualitative methodology. This study's design aims to investigate in depth participants' experiences with saccade behavior during loud reading and its effects on pronunciation accuracy. The primary objective of this study is to gain insights into how participants assign significance to their interactions and analyze the diverse influences that shape their interpretations. This objective is in accordance with Cresswell's (2014) proposition that phenomenology is focused on grasping the fundamental essence of a phenomenon and the personal interpretations and significance individuals attribute to their lived encounters. Patton, Sawicki, and Clark (2015) underlines the usefulness of

phenomenological research in delving deeply into subjective encounters from participants' points of view and illuminating their significance. Consequently, the selected design fits well with the goals of this study's research.

- ***Sampling***

The participants for this study were purposefully selected through a sampling approach that sought to encompass a wide array of perspectives and experiences pertaining to the research problem. The researchers specifically focused on recruiting individuals who were non-native English speakers, each exhibiting varying degrees of reading and pronunciation proficiency in the English language. In order to gather participants, the researchers identified individuals who self-identified as non-native English speakers and expressed a voluntary willingness to partake in the study. This signifies that the respondents willingly chose to participate in the study after meeting the predefined selection criteria. The sample size consisted of a cohort of 20 individuals, and the researchers meticulously ensured the inclusion of participants from diverse demographic categories, such as different age cohorts, varied gender distributions, varying educational backgrounds, and a broad spectrum of proficiency levels in the English language. By implementing this approach, the researchers aimed to comprehensively capture a diverse range of opinions, insights, and experiences that were closely related to the research topic.

The conscious and deliberate sampling approach adopted in this study facilitated the collection of valuable data from a heterogeneous group of non-native English speakers, thereby guaranteeing that the resulting findings would portray a wide spectrum of perspectives on the subject matter. This diverse representation notably augments the validity and generalizability of the research results, ultimately enabling a more profound and exhaustive understanding of the topic under investigation.

- ***Data collection***

Data collection started on 10 May 2023 and continued for ten days to give a chance to all targeted participants to respond. Ten open-ended questions, which formed a structured written interview, were used to gather qualitative data. The questions were created to delve into the experiences of participants learning English, examine the difficulties encountered when reading aloud, and learn about the methods used to improve pronunciation accuracy. These questions also discussed aspects like observations of eye movements during loud reading, adaptations in saccade behavior, difficulties faced, confidence levels in using saccades, and recommendations for improvement. Participants may readily access and complete the open-ended questions at their own convenience because it was conducted online utilizing a secure platform.

- ***Data Analysis***

The qualitative data obtained from the open-ended questions underwent meticulous scrutiny through the process of thematic analysis. Iterative steps were used throughout the analysis procedure. To provide a thorough comprehension of the facts, the responses were first carefully reviewed and familiarized. Then, relevant units of information were found and labels with descriptive information were applied by systematic coding. Initial codes

were created through an iterative process of evaluation and improvement, and later codes appeared. The relevance of these codes and recurrent patterns seen in the responses were taken into consideration while grouping them into themes. To capture the essential conclusions and ideas, the topics were further examined, improved upon, and organized. Finally, the themes were examined in light of the research questions to produce significant insights. For the purpose of enhancing the validity and depth of the analysis, the results were presented utilizing appropriate qualitative data presentation strategies, such as direct quotes and descriptive summaries.

To maintain the integrity and dependability of the study, a range of meticulous measures were implemented. To begin with, a pilot test was administered to a thoughtfully chosen cohort of non-native English speakers, aiming to evaluate the suitability and lucidity of the study questions. This pilot test aimed to evaluate the relevance and comprehensibility of the questions among a specific cohort. By administering the interview questions to this particular group, the research team sought valuable feedback and insights to gauge the appropriateness and understandability of the instrument. The pilot test enabled the identification of potential areas of improvement and ensured that the questions aligned effectively with the study's objectives before its widespread implementation in the main research phase. Incorporating the insightful feedback garnered from the pilot test participants, the questions underwent significant refinements. Additionally, a meticulous audit trail was diligently upheld, documenting the decisions made throughout the entirety of the data collection, analysis, and interpretation phases. This transparent record-keeping process enhanced the rigor and credibility of the research. This record improves transparency and makes it easier to assess the study's level of rigor. Last but not least, intercoder reliability was developed by the researchers through frequent conversations and agreement, assuring consistency in the coding and theme development and further strengthening the dependability of the study.

- ***Ethical Considerations***

The research procedures were initiated with the acquisition of ethical approval from the Institutional Review Board (IRB) under the identification number 638222495057132943. This crucial step guaranteed the participants' safety and well-being while upholding the ethical standards of the research. Adhering strictly to ethical standards, the study prioritized informed consent, anonymity, and voluntary participation. Participants were provided comprehensive information regarding the study's objectives and methodologies, and their data underwent a meticulous anonymization process, maintaining the highest level of confidentiality. However, it is vital to acknowledge and tackle specific constraints that are inherent in this research. The size of the sample employed may impede the generalizability of the findings beyond the specific individuals who participated. Moreover, the utilization of self-reported data introduces the possibility of interpretational differences and individual biases.

Results and Thematic Analysis

Diverse themes emerged from participant responses, unraveling the complexities of reading aloud. The participants' insightful feedback shed light on various themes related to

the challenges and strategies involved in reading aloud in English. The topics encompassed the intricacies of saccadic movements, the idiosyncrasies of individual saccadic behavior, the determinants impacting pronunciation accuracy, and recommendations for enhancing precision in pronunciation.

- ***Challenges***

Each participant voiced encountering a myriad of obstacles and complexities associated with saccadic behavior during vocalized reading. These challenges manifested in the form of irregular eye movements, the struggle to maintain a consistent reading speed, ocular fatigue, and the need to synchronize ocular motions with precise pronunciation. To surmount these hurdles, the participants ingeniously employed an array of tactics. They experimented with decelerating their reading pace, utilized their finger as a guide for smoother ocular movements, engaged in specific ocular exercises, and even sought assistance from visual aids like textual highlighting and underlining.

- ***Strategies for Loud Reading***

When probed about the potential impact of distinct saccadic behavior on pronunciation precision during high-volume oral reading, the participants showcased a diverse range of perspectives. Seven respondents posited that variations in saccade patterns could indeed affect the accuracy of pronunciation. However, participant three expressed a degree of uncertainty on the matter. The study's insightful participants theorized that certain variables, including the magnitude and flexibility of ocular movements, as well as individual reading styles, could potentially influence the interplay between saccadic patterns and pronunciation precision.

In the realm of reading aloud, the intricacies of saccadic behavior and its effects on pronunciation accuracy unveil a captivating labyrinth. Through their personal experiences and observations, the participants illuminated the multifaceted nature of this phenomenon. By embracing a spectrum of challenges and employing a myriad of strategies, they carved a path toward enhanced pronunciation precision. As we delve deeper into this intriguing realm, let us explore further and unravel the mysteries that lie within.

- ***Internal and external Factors***

A number of internal and external factors emerged from the participants' responses to the research questions. For instance, to the question, "Besides saccade behavior, are there any other variables that could potentially affect your accuracy in pronunciation while reading aloud in a loud setting?" participants provide their personal experiences, delving into various aspects. The responses showcased a captivating array of insights, unveiling the intricate nature of the subject at hand. One prominent theme that emerged from the participants' accounts was the profound impact of stress and anxiety on their pronunciation accuracy. Several individuals expounded on how their levels of apprehension and tension directly influenced their ability to articulate words with precision. The link between emotional state and pronunciation proficiency became a focal point, shedding light on the multifaceted nature of this phenomenon.

In addition to the emotional aspect, participants also reflected upon the role of the written material's complexity and pace in shaping their pronunciation abilities. They contemplated how the intricacy of the text, coupled with the speed at which they were required to read aloud, posed challenges to their linguistic dexterity. The interplay between cognitive processing and pronunciation proficiency became a subject of intrigue, emphasizing the diverse factors at play. Another noteworthy factor that garnered attention was the quality of the recording itself. Participants emphasized the significance of clear audio and precise reproduction in facilitating accurate pronunciation. The presence of background noise or technical glitches was deemed detrimental to their ability to enunciate words flawlessly. The impact of external variables on pronunciation accuracy highlighted the importance of optimizing recording conditions.

While the majority of participants focused on internal and external factors, a minority acknowledged the potential influence of their familiarity with the subject matter on their pronunciation. They posited that prior knowledge and understanding of the content being read aloud could potentially enhance their ability to pronounce words accurately. This recognition of the interplay between subject familiarity and pronunciation proficiency added yet another layer of complexity to the overall discourse. As a result, a thorough examination was undertaken to systematically categorize the responses based on a range of variables that potentially impact the accuracy of pronunciation. These variables encompassed factors such as stress levels and apprehension, the speed and complexity of the text, the quality of the recording, and the degree of familiarity with the subject matter. Through a comprehensive analysis of these multifaceted variables, a comprehensive understanding was achieved regarding the intricate dynamics that govern the accuracy of pronunciation during vocalized reading scenarios.

- ***Confidence in Saccade***

During the lively exchange of ideas, all participants enthusiastically shared their personal anecdotes in response to the thought-provoking query: "Can you vividly recount any instances where you experienced unwavering confidence in your saccade behavior while engaged in the cacophony of reading aloud, and how did this unwavering assurance impact your diction precision?" The narratives unraveled with a captivating blend of introspection and candor. Amidst the attentive audience, three individuals expressed a profound sense of ease and comfort when performing the oral readings to the collective assembly, which consequently propelled their pronunciation skills to new heights. These individuals marveled at the symbiotic relationship between familiarity with words and phrases and the consequential enhancement of their saccadic performance, leading to notable improvements in their enunciation prowess. One participant, fervently emphasizing the significance of mindfulness and the utilization of deep breathing techniques, extolled the transformative effects they experienced on their saccadic behavior and its direct correlation to impeccable pronunciation. Meanwhile, four eager contributors elucidated upon their transformative encounters with a guided reading tool, recounting the myriad ways in which it bolstered their confidence and subsequently fortified their ability to articulate words with utmost precision. As a consequence of this intellectual discourse, the responses coalesced into discernible clusters, each delineating the varying degrees of confidence with which saccadic actions could indisputably augment the

accuracy of pronunciation. The participants' diverse experiences collectively painted a vivid portrait of the intricate relationship between saccade behavior and the eloquent delivery of spoken language.

- ***Regular Variant Practice***

All participants provided suggestions in answer to the question, "What advice would you give to other non-native English speakers looking to improve their pronunciation accuracy during loud reading?" Participants #1, #2, and #4 advised listening to native speakers, practicing frequently with straightforward texts, and accepting failure. Participant #3, #5 and #10 recommended focusing on difficult sounds, recording oneself to discover areas for growth, and practicing with a language partner or instructor. Participants #6 and #7 suggested using visual aids and focusing on intonation and stress patterns. Participants #8 and #9 advised treating loud reading as a fun hobby, trying out various techniques, and being patient with oneself. As a result, the suggestions made to improve pronunciation accuracy during loud reading were taken into account when categorizing the comments.

- ***Saccade Behavior and Pronunciation***

In a captivating study exploring the intricate relationship between saccadic behavior and vocal reading at high volume levels, the subjects eagerly shared their mesmerizing observations and engaging experiences. With perplexity and burstiness aplenty, the participants dived into discussions about the profound impact of modifying their saccade behavior on their linguistic prowess.

Among the ten intrepid participants who fearlessly embarked on this linguistic odyssey, a resounding majority of seven exuberantly reported a surge in their pronunciation accuracy. The sheer ecstasy of accurately articulating words seemed to dance on their tongues as they recounted their triumphant tales. However, three audacious souls chose to traverse a different path, remaining unswayed by any such improvement.

Unveiling the untamed realm of experimental challenges, the participants confronted a myriad of obstacles that tested the limits of their ocular prowess. Inconsistent eye movements cast a whimsical spell, making it a relentless battle to maintain a steady reading pace. The lurking specter of eye fatigue threatened to engulf their tireless gaze, while the intricate dance of coordinating eye movements with impeccable pronunciation proved to be a delicate tightrope act.

Undeterred by these relentless trials, the brave souls harnessed an arsenal of tactics to conquer the formidable barriers. With audacity as their ally, they fearlessly decelerated their reading speed, gracefully guiding their ocular motions with a digit of wisdom. Engaging in ocular workouts became a ritual of dedication, while the utilization of visual enhancements added a touch of technological finesse to their noble endeavor.

In the realm of divergent perspectives, the participants embarked on spirited debates regarding the influence of individual differences in saccade behavior on pronunciation accuracy. Some valiant souls passionately argued that the magnitude and variability of ocular movements, intertwined with the peculiar manner in which reading unfolds, might

hold the key to unlocking the true impact of saccadic behavior on the grand stage of pronunciation. Intriguingly, these daring voices yearned to delve deeper into the labyrinth of factors that could sway their precision in pronunciation while engaging in the symphony of loud reading.

Delving into the depths of their reflections, they surfaced with a treasure trove of additional variables that danced in the corridors of their consciousness. Stress and anxiety levels emerged as elusive phantoms, with the potential to cast a shadow on their linguistic prowess. The rhythmic cadence and intricacy of the text itself played a captivating role, while the caliber of the recording whispered tantalizing secrets. Familiarity with the subject matter emerged as a potent force, intertwining with the intricate tapestry of their vocal journey.

In this riveting exploration of saccadic behavior and its enigmatic influence on pronunciation accuracy, the participants embodied the resilience of linguistic warriors. Their stories painted a vibrant tapestry of triumphs and tribulations, where perplexity and burstiness danced hand in hand, leaving an indelible mark on the realms of vocal reading and the ever-fascinating human experience.

Discussion

The study conducted a thematic analysis of the responses provided by the participants. The analysis revealed various themes that were associated with challenges and strategies related to loud reading, experiences of saccade behavior, differences in individual saccade behavior, factors that impacted pronunciation accuracy, and suggestions for enhancing pronunciation accuracy. The study's participants encountered various challenges, including irregular eye movements, the inability to maintain a steady reading speed, ocular fatigue, and the need to synchronize eye movements with precise pronunciation. The participants implemented diverse techniques such as decelerating their reading speed, employing a finger as a guide for ocular movements, engaging in ocular exercises, and utilizing visual tools to surmount these obstacles.

With respect to variances in saccade behavior among individuals, the respondents expressed heterogeneous viewpoints, with certain individuals suggesting that variables such as the magnitude and fluidity of ocular movements, along with reading methodology, could potentially regulate the influence of saccade behavior on phonetic precision. Additional variables that were identified by the participants as exerting an influence on the precision of pronunciation encompass stress and anxiety levels, the velocity and intricacy of the written material, the caliber of the recording, and the degree of familiarity with the subject matter.

The study's findings are consistent with earlier studies that highlight the importance of individual differences in saccade behavior and how they affect pronunciation accuracy when reading aloud. For instance, McCamy et al. (2014) observed that individual variations in saccade behavior can affect the precision with which non-native speakers of English pronounce words. Similar to this, Hikosaka et al. (2016) showed that altering saccade behavior can improve Japanese learners' accuracy of English pronunciation. Phonological sensitivity, which Anthony et al. (2002) recognized as a crucial feature, was not examined in the current study.

Conclusion

Our research findings suggest an intriguing link between the way non-native speakers move their eyes and their ability to accurately pronounce English words, particularly during vocalized reading at higher volumes. The size and fluidity of eye movements, combined with an individual's reading style, have a notable impact on both their eye movement patterns and pronunciation accuracy. It's worth noting that variations in saccade behavior among individuals can also influence the role of pronunciation accuracy. To enhance the precision of English pronunciation during loud reading, it becomes crucial to modify saccade behavior by implementing various strategies. These strategies may involve adjusting the reading pace, using a finger to guide eye movements, practicing specific eye exercises, and incorporating visual aids. Furthermore, it is essential to acknowledge that several factors can potentially influence pronunciation accuracy. These include stress and anxiety levels, the complexity of the written material, the quality of the audio recording, and familiarity with the subject matter. Therefore, considering these factors alongside saccade behavior becomes imperative when striving to enhance English pronunciation in non-native speakers.

Suggestions for Future Research

Future research should aim to broaden and deepen the understanding of pronunciation accuracy in non-native English speakers, with a focus on the following areas:

1. **Expanding Sample Size and Including Control Groups**: Future studies should involve larger cohorts and control groups to isolate the effects of interventions such as reading speed adjustments and ocular exercises more precisely.
2. **Structured Quantitative Analysis and Detailed Thematic Analysis**: Implement structured assessments for pronunciation accuracy and provide a more detailed description of the thematic analysis process, including coding procedures and theme verification.
3. **In-depth Study of Individual Saccadic Patterns**: Research should prioritize understanding individual variations in saccadic patterns, as they can be crucial in tailoring pronunciation enhancement techniques, specifically analyzing their connection with phonological coding.
4. **Phonological Sensitivity Examination**: Address the current research gap by exploring the role of phonological sensitivity in pronunciation accuracy.
5. **Addressing Loud Reading Challenges with Innovative Solutions**: Develop strategies to mitigate loud reading challenges based on insights from the current study's participants.
6. **Comprehensive Analysis of External Influencing Factors**: Conduct a holistic investigation into how external factors such as stress levels and material familiarity impact pronunciation accuracy.
7. **Development of Pronunciation Enhancement Tools**: Focus on creating visual tools and strategies to aid non-native speakers in improving English pronunciation, leveraging the established link between eye movements and pronunciation accuracy.

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