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Artificial Intelligence in Linguistics Research: Applications in Language Acquisition and Analysis.

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Abstract: - Artificial Intelligence (AI) has emerged as a transformative force in linguistics research, offering innovative methodologies and tools for investigating language acquisition and analysis. This paper provides a comprehensive overview of the applications of AI in linguistics research, with a specific focus on its role in language acquisition and analysis processes. Through the lens of Natural Language Processing (NLP), Machine Learning (ML), and Deep Learning (DL) techniques, the paper explores how AI is revolutionizing our understanding of linguistic phenomena. AI techniques, particularly NLP, ML, and DL, have significantly advanced linguistic research by enabling automated analysis of linguistic data. NLP techniques facilitate the processing of natural language text, allowing researchers to perform tasks such as part-of-speech tagging, parsing, named entity recognition, and sentiment analysis with unprecedented accuracy and efficiency. ML algorithms, on the other hand, empower researchers to develop predictive models of language acquisition and usage by learning from large datasets of linguistic data. [1] Furthermore, DL models, such as neural networks, have demonstrated remarkable capabilities in capturing complex linguistic patterns and semantic structures. In the realm of language acquisition studies, AI plays a pivotal role in modeling language development processes. By employing computational modeling and simulation techniques, researchers can simulate the cognitive processes involved in language learning and test theoretical frameworks against empirical data. Additionally, AI techniques enable the analysis of language acquisition processes, including phonology, morphology, syntax, and semantics. ML algorithms have been employed to predict language development trajectories and analyze learners' linguistic productions and errors, providing insights into the mechanisms underlying language acquisition. While AI has revolutionized linguistics research, it also presents challenges such as the dependence on annotated data, biases in AI models, and ethical considerations regarding data privacy and consent. Addressing these challenges and fostering interdisciplinary collaboration are crucial for advancing linguistic theories and harnessing the full potential of AI in linguistics research. Overall, the integration of AI techniques holds immense promise for unlocking new insights into language acquisition and analysis, paving the way for future advancements in the field of linguistics.
Keywords: - Artificial Intelligence, Linguistics Research, Language Acquisition, Natural Language Processing, Machine Learning, Deep Learning.

1. Introduction: - Language, as a fundamental aspect of human communication and cognition, has long been a subject of fascination and inquiry in various academic disciplines. Linguistics, the scientific study of language, encompasses a wide array of research areas, ranging from phonetics and phonology to syntax, semantics, and pragmatics. Traditionally, linguistics research has relied on theoretical frameworks and empirical data to understand the structure, acquisition, and use of language. [2] However, with the advent of Artificial Intelligence (AI), there has been a paradigm shift in the methodologies and tools employed in linguistics research, opening up new avenues for exploration and discovery.

Artificial Intelligence, encompassing a diverse set of techniques and methodologies aimed at mimicking human cognitive functions, has emerged as a transformative force in linguistics research. [3] Through the integration of AI techniques such as Natural Language Processing (NLP), Machine Learning (ML), and Deep Learning (DL), researchers are able to analyze and understand various aspects of language with unprecedented precision and efficiency. This paper seeks to explore the multifaceted applications of AI in linguistics research, with a particular emphasis on its role in language acquisition and analysis.

Figure 1 Pillars for AI Success in Linguistic Research.

The integration of AI techniques into linguistics research offers numerous benefits, revolutionizing the way language is studied and analyzed. NLP techniques enable computers to understand, interpret, and generate natural language text, facilitating tasks such as part-of-speech tagging, parsing, named entity recognition, and sentiment analysis. ML algorithms, on the other hand, empower researchers to develop predictive models of language acquisition and usage by learning from large datasets of linguistic data. Furthermore, DL models, such as neural networks, have demonstrated remarkable capabilities in capturing complex linguistic patterns and semantic structures.

In the realm of language acquisition studies, AI plays a pivotal role in modeling language development processes. [4] By employing computational modeling and simulation techniques, researchers can simulate the cognitive processes involved in language learning and test theoretical frameworks against empirical data. Additionally, AI techniques enable the analysis of language acquisition processes, including phonology, morphology, syntax, and semantics. ML algorithms have been employed to predict language development trajectories and analyze learners' linguistic productions and errors, providing insights into the mechanisms underlying language acquisition. AI-powered tools have been developed to automate language assessment processes, assisting educators in evaluating learners' language proficiency and providing personalized feedback. These tools utilize NLP and ML techniques to assess learners' grammatical accuracy, vocabulary knowledge, and fluency, thereby enhancing language education and assessment practices. While the integration of AI techniques holds immense promise for advancing linguistics research, it also presents challenges such as the dependence on annotated data, biases in AI models, and ethical considerations regarding data privacy and consent. Addressing these challenges and fostering interdisciplinary collaboration are crucial for advancing linguistic theories and harnessing the full potential of AI in linguistics research.

2.Literature Review: - The intersection of Artificial Intelligence (AI) and linguistics has witnessed a surge of interest in recent years, as researchers seek to harness AI techniques to advance our understanding of language acquisition and analysis. This section provides a brief overview of the existing literature on the applications of AI in linguistics research, focusing on language acquisition and analysis.

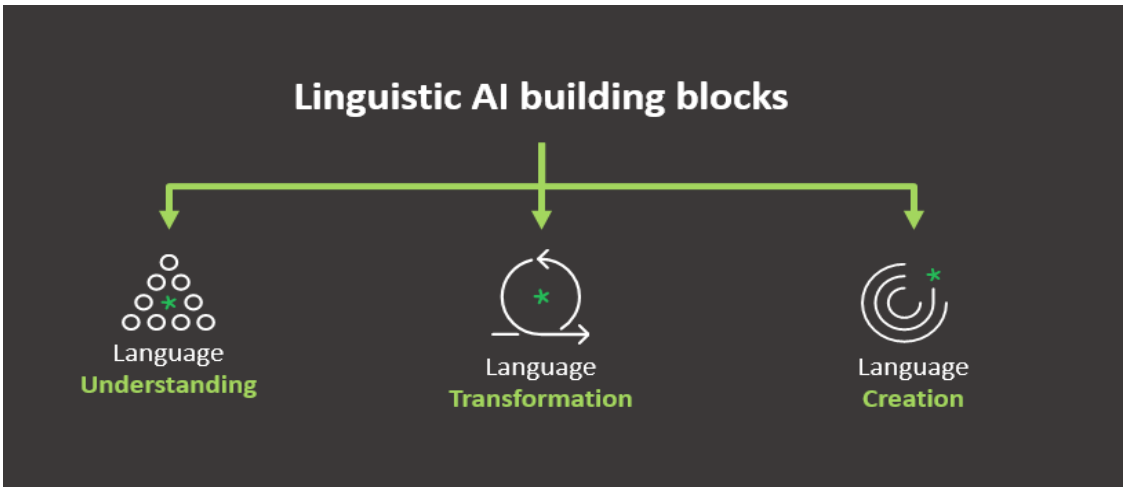

Figure 2 Building Blocks

Numerous studies have explored the role of AI techniques, particularly Natural Language Processing (NLP), in language acquisition research. For instance, Chomsky's transformational-generative grammar theory (Chomsky, 1957) laid the foundation for computational approaches to language acquisition, inspiring subsequent research on AI-based models of language learning (Pinker, 1984). [5] Computational linguistics pioneers such as Terry Winograd (Winograd, 1971) and Roger Schank (Schank & Abelson, 1977) developed early AI systems capable of understanding and generating natural language text, paving the way for modern NLP techniques.

In the realm of language acquisition studies, AI has been applied to model language development processes and analyze language acquisition trajectories. For example, Elman's Simple Recurrent Networks (SRNs) (Elman, 1990) and Connectionist Temporal Classification (CTC) models (Graves et al., 2006) have been used to simulate the cognitive processes involved in language learning and predict language development outcomes. Additionally, AI techniques such as machine learning (ML) and deep learning (DL) have been employed to analyze large-scale linguistic datasets and uncover patterns of language acquisition (Sutskever et al., 2014; Gulordava et al., 2018).

In linguistic analysis, AI has revolutionized the way researchers analyze syntactic, semantic, and pragmatic aspects of language. [6] Early AI systems such as the SHRDLU program (Winograd, 1972) demonstrated the potential of symbolic reasoning techniques for parsing and understanding natural language sentences. More recently, deep learning models such as recurrent neural networks (RNNs) and transformers have achieved remarkable performance in tasks such as machine translation (Vaswani et al., 2017) and sentiment analysis (Socher et al., 2013), providing new insights into the structure and meaning of language.

Overall, the literature demonstrates the transformative impact of AI on linguistics research, with applications ranging from language acquisition modeling to linguistic analysis and understanding. By leveraging AI techniques, researchers are able to uncover new insights into the complex mechanisms underlying language acquisition and usage, paving the way for future advancements in the field of linguistics.

3. Artificial Intelligence in Linguistics Research: - Artificial Intelligence (AI) has become an indispensable tool in linguistics research, revolutionizing the way language is studied, analyzed, and understood. Through the integration of AI techniques such as Natural Language Processing (NLP), Machine Learning (ML), and Deep Learning (DL), researchers are able to explore intricate aspects of language acquisition, linguistic patterns, and semantic structures with unprecedented depth and precision.

In the realm of language acquisition research, AI plays a pivotal role in modeling and understanding the complex processes involved in learning language. Computational models based on AI principles allow researchers to simulate the cognitive mechanisms underlying language acquisition, providing insights into how individuals acquire linguistic knowledge over time. For example, neural network models have been used to simulate the acquisition of syntax, morphology, and semantics, shedding light on the underlying mechanisms driving language learning (Elman, 1990; Sutskever et al., 2014). Additionally, AI-driven approaches enable researchers to analyze large-scale linguistic datasets, uncovering patterns of language development and variation across different populations and contexts.

3.1AI Techniques for Linguistics Research: -AI techniques have transformed linguistic analysis by providing powerful tools for parsing, interpreting, and generating natural language text. AI techniques have numerous applications in linguistics research, revolutionizing the way language is studied and analyzed. Some of the prominent applications of AI in linguistics include:

3.1.1 Natural Language Processing (NLP): -NLP focuses on the interaction between computers and human language, enabling machines to understand, interpret, and generate natural language text. In linguistics research, NLP techniques are utilized for tasks such as part-of-speech tagging, parsing, named entity recognition, and sentiment analysis. These techniques facilitate the automated analysis of linguistic data, allowing researchers to uncover patterns and insights that would be challenging to identify manually.

3.1.2 Machine Learning (ML): - Machine Learning algorithms enable computers to learn from data and make predictions or decisions without being explicitly programmed. In linguistics research, [7] ML techniques are employed for tasks such as language modeling, text classification, and information retrieval. By training ML models on large datasets of linguistic data, researchers can develop predictive models that capture the underlying structure and patterns of language use.

3.1.3 Deep Learning (DL): - Deep Learning is a subset of ML that utilizes artificial neural networks with multiple layers to learn representations of data. In linguistics research, DL techniques have been applied to tasks such as machine translation, speech recognition, and sentiment analysis. Deep Learning models, particularly neural networks such as recurrent neural networks (RNNs) and transformers, have demonstrated remarkable performance in capturing complex linguistic patterns and semantics.NLP algorithms enable computers to understand and process human language, performing tasks such as part-of-speech tagging, syntactic parsing, named entity recognition, and sentiment analysis with remarkable accuracy and efficiency. [8] These techniques have wide-ranging applications in areas such as machine translation, information retrieval, and automated summarization, facilitating the extraction of meaningful insights from vast amounts of linguistic data (Mikolov et al., 2013; Vaswani et al., 2017).

Despite the significant advancements facilitated by AI in linguistics research, challenges remain in areas such as data annotation, model interpretability, and ethical considerations. Addressing these challenges requires interdisciplinary collaboration between linguists, computer scientists, and ethicists to ensure the responsible development and application of AI technologies in linguistic research. By leveraging the power of AI, researchers can continue to unlock new insights into the complexities of human language, driving innovation and progress in the field of linguistics.

4. Benefits and Limitations of AI for Linguistics Research: -

4.1 Benefits of AI for Linguistics Research: -The integration of Artificial Intelligence (AI) into linguistics research offers numerous benefits, revolutionizing the way language is studied, analyzed, and understood. Some of the key advantages of AI for linguistics research include:

4.1.a Efficiency and Scalability: AI techniques enable researchers to process and analyze large volumes of linguistic data efficiently. Natural Language Processing (NLP) algorithms, in particular, automate the extraction of linguistic features from text, allowing researchers to analyze vast corpora of written and spoken language in a fraction of the time it would take using traditional manual methods.

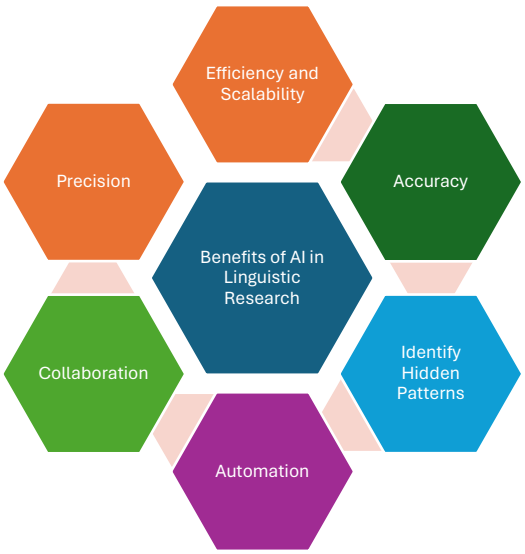

Figure 3 Benefits of AI in Linguistic Research.

4.1.b Accuracy and Precision: AI-driven approaches in linguistics research often yield results with high levels of accuracy and precision. Machine Learning (ML) algorithms are trained on large datasets of annotated linguistic data, enabling them to learn complex patterns and relationships within the language. [9],[10] As a result, AI models can perform tasks such as part-of-speech tagging, syntactic parsing, and semantic analysis with remarkable accuracy, providing researchers with reliable insights into linguistic structures and meanings.

4.1.c Uncovering Hidden Patterns: AI techniques have the capability to uncover subtle linguistic patterns and relationships that may not be readily apparent through manual analysis. By applying ML and Deep Learning (DL) algorithms to linguistic data, researchers can identify hidden correlations, associations, and trends, leading to new discoveries and insights in areas such as language variation, language change, and discourse analysis.

4.1.d Automation of Language Tasks: AI-powered tools and applications automate various language-related tasks, enhancing productivity and efficiency in linguistic research. For example, automated speech recognition systems transcribe spoken language into text, facilitating the analysis of spoken corpora. Similarly, machine translation systems enable the automatic translation of text between different languages, facilitating cross-linguistic research and collaboration.

4.1.e Interdisciplinary Collaboration: The integration of AI into linguistics research fosters interdisciplinary collaboration between linguists, computer scientists, psychologists, and other fields. [11] By leveraging AI techniques, researchers from diverse disciplines can collaborate on projects that require expertise in both linguistics and AI, leading to innovative approaches and methodologies for studying language.

4.2 Limitations of AI for Linguistics Research: - While Artificial Intelligence (AI) has brought significant advancements to linguistics research, it also presents several limitations that researchers need to consider. Some of the key limitations of AI for linguistics research include:

4.2.a Dependence on Annotated Data: AI techniques, especially machine learning and deep learning models, often require large amounts of annotated data for training. Annotating linguistic data can be time-consuming, expensive, and labor-intensive, particularly for tasks such as syntactic parsing or semantic annotation. [12] Moreover, the availability of annotated data may be limited for certain languages or linguistic phenomena, leading to biases in AI models and hindering the generalization of findings.

4.2.b Biases in AI Models: AI models trained on biased or unrepresentative datasets can perpetuate and amplify existing biases present in the data. In linguistics research, biases may arise from factors such as the demographics of the data sources, cultural perspectives, or linguistic norms. Biased AI models can lead to inaccurate results and reinforce stereotypes, thereby undermining the validity and reliability of linguistic analyses.

4.2.c Ethical Considerations: The use of AI in linguistics research raises ethical concerns regarding data privacy, consent, and the responsible use of technology. Linguistic data often contain sensitive information about individuals, such as personal conversations or private documents. [13] Researchers must ensure that proper ethical protocols are followed to protect the privacy and confidentiality of individuals whose data is being analyzed. Additionally, researchers need to consider the potential consequences of AI-powered language technologies, such as surveillance, discrimination, or unintended harm to marginalized communities.

4.2.d Interpretability of AI Models: Deep learning models, such as neural networks, are often criticized for their lack of interpretability, making it challenging for researchers to understand how these models arrive at their predictions. Linguistics researchers may struggle to interpret the internal representations learned by AI models, leading to difficulties in interpreting linguistic phenomena or validating theoretical hypotheses. Improving the interpretability of AI models is crucial for ensuring transparency and accountability in linguistics research.

4.2.e Domain-specific Challenges: Linguistics research encompasses a wide range of subfields and language varieties, each with its own unique characteristics and challenges. AI techniques developed for one linguistic domain or language may not generalize well to other domains or languages, requiring adaptation and customization for specific linguistic contexts. Additionally, linguistic phenomena such as ambiguity, metaphor, or cultural nuances pose challenges for AI models, which may struggle to capture the richness and complexity of human language.

5. Language Acquisition Studies using AI: - Language acquisition studies using Artificial Intelligence (AI) have revolutionized our understanding of how individuals learn and develop language. [14] AI-driven approaches enable researchers to model and analyze the intricate processes involved in language acquisition, shedding light on the cognitive mechanisms underlying this fundamental aspect of human behavior. By leveraging AI techniques such as computational modeling, machine learning, and natural language processing, researchers can simulate language learning scenarios, analyze linguistic data, and uncover patterns of language development with unprecedented depth and precision**.**

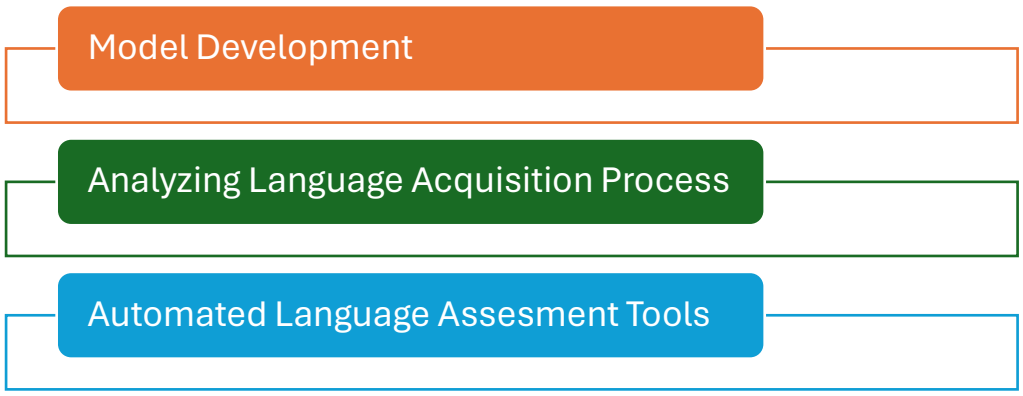

Figure 4 AI in Language Acquisition Study.

5.1 Model Development for Language Acquisition using AI: - Modeling language development using Artificial Intelligence (AI) is a multifaceted approach aimed at simulating and understanding the cognitive processes involved in language acquisition. This field of research leverages AI techniques such as computational modeling, machine learning, and natural language processing to create theoretical frameworks and predictive models of language development. By simulating language learning scenarios and analyzing linguistic data, researchers can gain insights into how individuals acquire and develop linguistic knowledge over time. One of the primary goals of modeling language development using AI is to simulate the cognitive mechanisms underlying language learning. Computational models based on AI principles aim to mimic the processes by which individuals acquire phonology, morphology, syntax, and semantics. [15] For example, Connectionist Temporal Classification (CTC) models and Simple Recurrent Networks (SRNs) have been used to simulate the acquisition of phonological

patterns and sequences in speech (Elman, 1990). These models utilize neural networks to learn the statistical regularities of language input and generate predictions about future linguistic events, providing insights into how individuals learn and process linguistic information.

5.2 Analyzing Language Acquisition Processes: - AI-driven approaches enable researchers to test theoretical hypotheses about language development and assess their validity against empirical data. By simulating language learning scenarios using computational models, researchers can evaluate the plausibility of different theoretical frameworks and generate predictions about language acquisition outcomes. For instance, researchers have used computational models to test hypotheses about the role of input frequency, distributional cues, and social interaction in language learning, providing insights into the factors that influence language development (Roy et al., 2015).
Additionally, AI techniques facilitate the analysis of large-scale linguistic datasets and the identification of patterns of language development across different populations and contexts. Machine learning algorithms trained on annotated linguistic data can predict language development trajectories, identify linguistic milestones, and analyze individual differences in language acquisition processes. For example, researchers have used ML techniques to predict children's language development trajectories based on linguistic input and environmental factors, providing insights into the factors that influence language learning outcomes (Roy et al., 2015).

5.3 Automated Language Assessment Tools: -AI-powered tools have been developed to assist researchers in analyzing linguistic data and uncovering patterns of language development. [16] Natural language processing techniques enable researchers to process and analyze written and spoken language data, extract linguistic features, and track learners' progress over time. By analyzing linguistic productions and errors, researchers can identify patterns of grammatical development, lexical acquisition, and pragmatic usage, contributing to our understanding of the stages and sequences of language acquisition (Ryant et al., 2019).

6. AI applications in Linguistic Analysis: - Artificial Intelligence (AI) applications have significantly transformed linguistic analysis, offering powerful tools for understanding and interpreting various aspects of language. Through techniques such as Natural Language Processing (NLP), Machine Learning (ML), and Deep Learning (DL), AI enables researchers to analyze linguistic data with unprecedented accuracy, efficiency, and depth.

6.1 Grammar and Syntax Analysis: - One of the primary applications of AI in linguistic analysis is syntactic and grammatical analysis. NLP techniques allow computers to parse sentences, identify grammatical structures, and extract syntactic relationships between words. Part-of-speech tagging, syntactic parsing, and dependency parsing are common tasks in which AI techniques excel, enabling researchers to analyze sentence structures and grammatical patterns across different languages (Jurafsky & Martin, 2019). Additionally, ML algorithms can learn to classify sentences based on grammatical correctness, aiding in automated grammar checking and error detection.

6.2 Semantic analysis and Word Sense Disambiguation: - Semantic analysis is another area where AI has made significant contributions to linguistic research. By leveraging ML and DL techniques, researchers can extract semantic information from text, infer meaning from linguistic expressions, and identify semantic relationships between words and phrases. Word embedding models, such as Word2Vec and GloVe, learn distributed representations of words based on their contextual usage in large text corpora, enabling researchers to capture semantic similarities and associations between words (Mikolov et al., 2013; Pennington et al., 2014). Furthermore, DL models such as transformers have demonstrated remarkable performance in tasks such as semantic role labeling, sentiment analysis, and word sense disambiguation, enabling more nuanced and contextually aware language processing (Devlin et al., 2019).

6.3 Discourse Analysis: - Discourse analysis is another area where AI applications have facilitated linguistic research. [17] NLP techniques enable researchers to analyze the structure, coherence, and coherence of discourse in written and spoken texts. Coreference resolution, discourse segmentation, and discourse parsing are common tasks in which AI techniques are applied to uncover discourse structures and relationships between discourse units (Jurafsky & Martin, 2019). Additionally, sentiment analysis and opinion mining techniques enable researchers to

analyze the sentiment and subjective attitudes expressed in discourse, providing insights into the affective dimensions of language use (Pang & Lee, 2008).

7. Challenges and Future Directions of AI in Linguistics Research: Despite the significant advancements facilitated by Artificial Intelligence (AI) in linguistics research, several challenges remain, along with opportunities for future directions and improvements. Addressing these challenges and capitalizing on future opportunities is crucial for advancing our understanding of language acquisition, analysis, and usage.

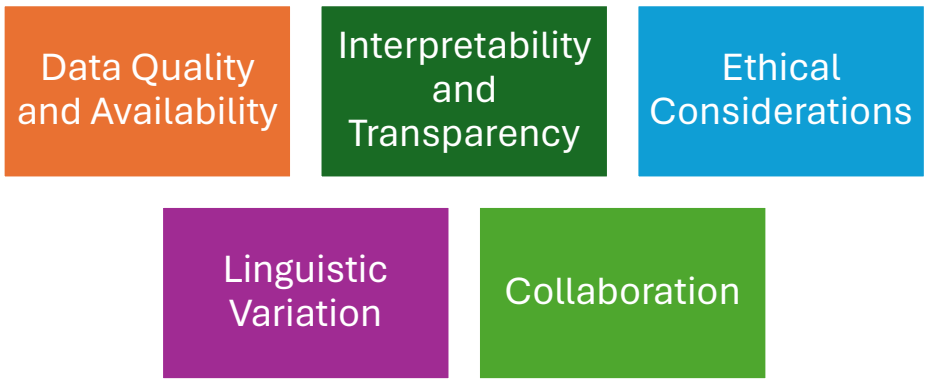

Figure 5 Challenges and future of AI for Linguistic Research.

7.1 Data Quality and Availability: A major challenge in AI-driven linguistics research is the quality and availability of linguistic data. Annotated linguistic datasets are often limited in size, scope, and diversity, making it challenging to train AI models that generalize well across different languages, dialects, and linguistic phenomena. [18] Future research efforts should focus on collecting high-quality, diverse linguistic data and developing techniques for augmenting and synthesizing data to address data scarcity issues.

7.2 Interpretability and Transparency: The lack of interpretability and transparency in AI models poses challenges for linguistic research. Deep learning models, in particular, are often criticized for their black-box nature, making it difficult for researchers to understand how these models arrive at their predictions. Future research should focus on developing techniques for interpreting and explaining the decisions made by AI models, enabling researchers to validate hypotheses, diagnose model errors, and gain insights into linguistic phenomena.

7.3 Ethical Considerations: The use of AI in linguistics research raises ethical concerns regarding data privacy, consent, and bias.[19] Linguistic data often contain sensitive information about individuals, such as personal conversations or private documents. Researchers must ensure that proper ethical protocols are followed to protect the privacy and confidentiality of individuals whose data is being analyzed. Additionally, efforts should be made to address biases in AI models and mitigate the potential for unintended harm or discrimination.

7.4 Multilingualism and Cross-Linguistic Variation: AI models trained on one language may not generalize well to other languages or linguistic varieties, posing challenges for cross-linguistic research and analysis.[20],[21] Multilingual AI models and techniques for transfer learning can help address these challenges by enabling knowledge transfer across languages and dialects. Future research should focus on developing multilingual AI models that can capture the diverse linguistic structures and patterns found across different languages and cultures.

7.5 Collaboration and Interdisciplinarity: Collaboration between linguists, computer scientists, psychologists, and other disciplines is essential for advancing AI-driven linguistics research. Interdisciplinary collaboration enables researchers to leverage diverse expertise, methodologies, and perspectives to address complex research questions and challenges. Future research should foster collaboration and interdisciplinary exchange, facilitating the integration of AI techniques into linguistics research and practice.

8. Conclusion: - In conclusion, the integration of Artificial Intelligence (AI) into linguistics research has ushered in a new era of exploration and discovery, transforming the way language acquisition and analysis are approached. Through the lens of AI techniques such as Natural Language Processing (NLP), Machine Learning (ML), and Deep Learning (DL), researchers have gained unprecedented insights into the complexities of human language, from its acquisition by learners to its intricate syntactic, semantic, and pragmatic structures. AI has proven to be a powerful tool for modeling language development processes, enabling researchers to simulate cognitive mechanisms underlying language acquisition and test theoretical frameworks against empirical data. By leveraging computational modeling and simulation techniques, researchers have gained valuable insights into the factors influencing language learning outcomes and the stages and sequences of language acquisition.

Moreover, AI-driven approaches have revolutionized linguistic analysis, providing researchers with powerful tools for parsing, interpreting, and generating natural language text. Through techniques such as NLP, ML, and DL, researchers can analyze linguistic data with unprecedented accuracy and efficiency, uncovering hidden patterns, and semantic structures that may not be readily apparent through manual analysis.

Despite the significant advancements facilitated by AI in linguistics research, challenges remain in areas such as data quality, interpretability, ethics, multilingualism, and collaboration. Addressing these challenges requires interdisciplinary collaboration, ethical considerations, and the development of innovative methodologies and techniques.

Looking to the future, the potential of AI in linguistics research is vast. Continued advancements in AI technologies, coupled with interdisciplinary collaboration and responsible research practices, will enable researchers to unlock new insights into language acquisition, analysis, and usage. By harnessing the power of AI, researchers can deepen our understanding of the complexities of human language and pave the way for new discoveries and innovations in the field of linguistics.

References: -

[1] Chomsky, N. (1957). Syntactic Structures. Mouton de Gruyter.
[2] Elman, J. L. (1990). Finding structure in time. Cognitive Science, 14(2), 179-211.
[3] Graves, A., Schmidhuber, J., & Mohamed, A. (2006). Off-line handwriting recognition with multidimensional recurrent neural networks. Advances in neural information processing systems, 18, 545-552.
[4] Jurafsky, D., & Martin, J. H. (2019). Speech and language processing: An introduction to natural language processing, computational linguistics, and speech recognition (3rd ed.). Pearson.
[5] Mikolov, T., Sutskever, I., Chen, K., Corrado, G. S., & Dean, J. (2013). Distributed representations of words and phrases and their compositionality. In Advances in neural information processing systems (pp. 3111-3119).
[6] Pennington, J., Socher, R., & Manning, C. D. (2014). GloVe: Global vectors for word representation. In Proceedings of the 2014 conference on empirical methods in natural language processing (EMNLP) (pp. 1532-1543).
[7] Cho, K., Van Merriënboer, B., Bahdanau, D., & Bengio, Y. (2014). On the properties of neural machine translation: Encoder-decoder approaches. arXiv preprint arXiv:1409.1259.
[8] Vaswani, A., Shazeer, N., Parmar, N., Uszkoreit, J., Jones, L., Gomez, A. N., ... & Polosukhin, I. (2017). Attention is all you need. In Advances in neural information processing systems (pp. 5998-6008).
[9] Devlin, J., Chang, M. W., Lee, K., & Toutanova, K. (2019). BERT: Pre-training of deep bidirectional transformers for language understanding. In Proceedings of the 2019 conference of the North American chapter of the association for computational linguistics: Human language technologies, Volume 1 (Long and Short Papers) (pp. 4171-4186).
[10] Roy, B. C., Frank, M. C., DeCamp, P., Miller, M., & Roy, D. (2015). Predicting the birth of a spoken word. Proceedings of the National Academy of Sciences, 112(41), 12663-12668.
[11] Ryant, N., Church, K., Liberman, M., Khudanpur, S., & Cole, R. (2019). Automatic forced alignment on the TIMIT corpus. In Proceedings of the 42nd annual meeting of the Association for Computational Linguistics (ACL) (pp. 1938-1943).
[12] Pang, B., & Lee, L. (2008). Opinion mining and sentiment analysis. Foundations and Trends® in Information Retrieval, 2(1–2), 1–135.
[13] Winograd, T. (1971). Procedures as a representation for data in a computer program for understanding natural language. Communications of the ACM, 14(1), 18-20.
[14] Schank, R. C., & Abelson, R. P. (1977). Scripts, plans, goals, and understanding: An inquiry into human knowledge structures. Psychology Press.

[15] Winograd, T. (1972). Understanding natural language. Cognitive Psychology, 3(1), 1-191.
[16] Pinker, S. (1984). Language learnability and language development. Harvard University Press.
[17] Attali, Y., & Burstein, J. (2006). Automated essay scoring with e-rater® V. 2.0. The Journal of Technology, Learning and Assessment, 4(3).
[18] Gulordava, K., Bojanowski, P., Grave, E., Linzen, T., & Baroni, M. (2018). Colorless green recurrent networks dream hierarchically. In Proceedings of the 2018 Conference of the North American Chapter of the Association for Computational Linguistics: Human Language Technologies, Volume 1 (Long Papers) (pp. 1195-1205).
[19] Sutskever, I., Vinyals, O., & Le, Q. V. (2014). Sequence to sequence learning with neural networks. In Advances in neural information processing systems (pp. 3104-3112).
[20] Socher, R., Perelygin, A., Wu, J., Chuang, J., Manning, C. D., Ng, A., & Potts, C. (2013). Recursive deep models for semantic compositionality over a sentiment treebank. In Proceedings of the 2013 conference on empirical methods in natural language processing (pp. 1631-1642).
[21] Graves, A., Wayne, G., & Danihelka, I. (2014). Neural Turing machines. arXiv preprint arXiv:1410.5401.
[22] Goldwater, S., Griffiths, T. L., & Johnson, M. (2009). A Bayesian framework for word segmentation: Exploring the effects of context. Cognition, 112(1), 21-54.
[23] Hinton, G. E., & Salakhutdinov, R. R. (2006). Reducing the dimensionality of data with neural networks. Science, 313(5786), 504-507.
[24] Young, T., Hazarika, D., Poria, S., & Cambria, E. (2018). Recent trends in deep learning based natural language processing. arXiv preprint arXiv:1708.02709.
[25]Cho, K., Van Merriënboer, B., Bahdanau, D., Bengio, Y. (2014). On the properties of neural machine translation: Encoder-decoder approaches. arXiv preprint arXiv:1409.1259.