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SCIENTIFIC PRESS PTE.LTD.

Molecular & Cellular Biomechanics 2025, 22(4), 1434.
https://doi.org/10.62617/mcb1434

Article

Translation process in the biological and biomechanical context: Resources, methods and trends (2013–2023)

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CITATION

Liu T. Translation process in the biological and biomechanical context: Resources, methods and trends (2013–2023). Molecular & Cellular Biomechanics. 2025; 22(4): 1434.
https://doi.org/10.62617/mcb1434

ARTICLE INFO

Received: 22 January 2025
Accepted: 27 February 2025
Available online: 24 March 2025

Abstract: Over the past decade, translation process research has undergone significant evolution, driven by advancements in cognitive science related to the neural mechanisms underlying language processing in biological systems, technology with applications in biological research translations, and data-driven methodologies considering the unique characteristics of biological data. Recently, there has been an emerging connection between this translation process research and biomechanics. For instance, the cognitive strategies in translation, such as chunking and bilingual control, which are influenced by the brain's biological architecture involved in language processing, may also be related to the body's mechanical responses. The neural pathways responsible for these translation strategies could potentially interact with the body's mechanical systems. In terms of technological tools, neural machine translation (NMT) and computer-assisted translation (CAT) systems, which play a crucial role. in biological translating research papers, could be further optimized by considering biomechanical factors. For example, understanding how the body's physical movements during long-term translation tasks (like sitting posture and muscle fatigue) affect cognitive performance and translation accuracy. Data resources, including parallel corpora and community-driven initiatives, have become foundational to supporting both high- and low-resource languages. However, integrating these with biomechanical considerations, such as how data collection and use impact the physical well-being of translators, adds a new layer of complexity. Challenges persist in integrating diverse tools, addressing cultural and contextual subtleties, and developing comprehensive evaluation metrics that capture creativity and cultural fidelity. Ethical considerations, such as data privacy and representation of marginalized languages, underscore the need for inclusive and responsible practices. Future research directions focus on context-aware technologies, cross-cultural studies, and hybrid human-machine workflows while also incorporating biomechanical insights to enhance translation quality and cultural sensitivity. By integrating interdisciplinary approaches, including biomechanics, translation process research aims to bridge linguistic divides and foster global understanding.

Keywords: translation process; cognitive strategy; cross-cultural; neural machine translation; computer aided translation

1. Introduction

Over the past decade, translation process research has undergone a significant transformation, driven by advancements in technology, interdisciplinary collaboration, and a deeper understanding of cognitive, cultural, and contextual factors. This field, at the intersection of linguistics, cognitive science, and technology, seeks to unravel the intricate processes that underpin the act of translation, offering insights into both the human and technological dimensions of this complex activity.

Key developments have illuminated the cognitive strategies employed by translators, emphasizing the pivotal role of bilingual cognitive control, decision-making mechanisms, and socio-cognitive interactions. Cognitive strategies have been a central focus, as they are fundamental to managing the mental workload inherent in translation tasks. Studies such as those by Xie and Li (2022, p. 15, specifically focusing on strategies for coherence) build on earlier foundational work to demonstrate how translators employ chunking, pattern recognition, and anticipatory strategies to maintain coherence and mitigate errors. This aligns with research by Schwieter and Ferreira (2017, p. 56, discussing task-switching mechanisms), which underscores the role of bilingual cognitive control—specifically inhibition and task-switching mechanisms—in ensuring linguistic accuracy and reducing source-language interference. The findings from these studies converge on a crucial insight: cognitive efficiency distinguishes expert translators from novices, as confirmed by Whyatt's (2021, p. 621, focusing on cognitive effort in complex units) exploration of cognitive effort in complex translation units.

Simultaneously, technological advancements have revolutionized the translation landscape. Neural machine translation (NMT), computer-assisted translation (CAT) tools, and adaptive workflows have introduced unprecedented efficiency and accuracy while raising critical questions about the interplay between human creativity and machine assistance. The integration of data resources, such as large-scale parallel corpora and domain-specific terminological databases, has further accelerated progress, offering new avenues for both research and practical application. However, these innovations are not without challenges, particularly in addressing the limitations of current tools in capturing cultural nuances and contextual subtleties, as well as in ensuring inclusivity for low-resource languages.

In parallel, the focus on educational methodologies has led to significant advancements in translator training, emphasizing cognitive apprenticeship, collaborative learning, and simulation-based approaches. These methods aim to equip future translators with the skills necessary to navigate the evolving demands of the industry, fostering adaptability and expertise in hybrid human-machine workflows.

Despite these advancements, translation process research faces persistent challenges, including the fragmentation of technological tools, ethical considerations in data usage, and the underrepresentation of low-resource languages. Addressing these issues requires a concerted effort to develop integrated, inclusive, and ethical solutions that align with the diverse needs of the global translation community.

This paper explores these multifaceted dimensions of translation process research, examining the cognitive and technological resources at play, the role of data in shaping modern practices, and the challenges that lie ahead. By bridging theoretical insights with practical applications, this study aims to contribute to a comprehensive understanding of translation as a dynamic and evolving discipline, poised to navigate the complexities of an interconnected world.

2. Key resources in translation processes

2.1. Cognitive and human resources

In the last decade, scholarly attention to the cognitive and human aspects of translation processes has grown significantly, fueled by advancements in empirical methodologies and interdisciplinary collaboration. This research sheds light on how translators harness cognitive resources and decision-making strategies to navigate the complexities of their work while adapting to evolving tools and technologies.

Cognitive strategies have been a central focus, as they are fundamental to managing the mental workload inherent in translation tasks. Studies such as those by Xie and Li (2022, p. 15, specifically focusing on strategies for coherence) build on earlier foundational work to demonstrate how translators employ chunking, pattern recognition, and anticipatory strategies to maintain coherence and mitigate errors. This aligns with research by Schwieter and Ferreira (2017, p. 56, discussing task-switching mechanisms), which underscores the role of bilingual cognitive control—specifically inhibition and task-switching mechanisms—in ensuring linguistic accuracy and reducing source-language interference. The findings from these studies converge on a crucial insight: cognitive efficiency distinguishes expert translators from novices, as confirmed by Whyatt's (2021, p. 621, focusing on cognitive effort in complex units) exploration of cognitive effort in complex translation units.

Further expanding this understanding, Risku et al. (2019, p. 603) emphasized the socio-cognitive dimensions of translation, revealing how context, collaboration, and external resources influence decision-making. These findings are supported by Dragsted et al. (2020, p. 295), whose eye-tracking studies mapped the interplay between visual attention and textual ambiguity resolution, offering a dynamic view of how translators allocate cognitive resources in real-time.

At the intersection of human and machine interaction, research has illuminated the profound impact of technology on cognitive processes. O'Brien (2017, p. 360) articulated how the integration of human translation and machine translation workflows necessitates the development of hybrid cognitive skills. This is echoed in Krüger's (2016, p. 415) work on post-editing, which highlighted how cognitive adjustments enable translators to balance creative autonomy with the efficiency demanded by machine-generated content. Carl and Schaeffer's (2017, p. 23) keystroke logging analyses further enriched this narrative by documenting how translators adapt their strategies when navigating technology-assisted environments.

Neuroscientific methods, such as those employed by Hervais-Adelman et al. (2015, p. 4690), have taken the exploration of cognitive resources to new depths, revealing how professional translators activate distinct brain regions associated with executive control and linguistic processing. Dragoy et al. (2017, p. 42) added to this by using EEG to examine neural efficiency in expert translators, showing faster processing speeds compared to non-experts. This body of work is complemented by De Groot's (2020, p. 872) findings on bilingual neural efficiency, which highlight how professional translators outperform non-professional bilinguals in neural coordination during translation tasks.

Educational research has also evolved, integrating these empirical findings to enhance translator training. For instance, Massey and Ehrensberger-Dow (2017, p. 162) introduced cognitive apprenticeship models that immerse students in expert-guided practice to develop problem-solving and adaptive strategies. Kiraly's (2016, p. 8) constructivist approaches, emphasizing collaborative learning, align with this trend by

fostering real-world cognitive skills in translation students. These pedagogical innovations are increasingly supported by simulation-based training, as Malmkjær (2020, p. 465) demonstrated, wherein authentic tasks replicate the complexities of professional translation work.

Across these domains, a recurring theme has emerged: the importance of emotional and social factors in cognitive processes. Hubscher-Davidson's (2018, p. 238) exploration of the emotional dimensions of translation has revealed how feelings such as stress, motivation, and empathy influence decision-making and creative outcomes. Similarly, Göpferich and Jääskeläinen's (2020, p. 374) work on adaptive expertise highlights how emotional regulation and cognitive flexibility empower translators to respond effectively to novel challenges.

Collectively, these interconnected studies offer a multidimensional perspective on the resources translators employ, underscoring the critical interplay between cognitive, emotional, and technological factors. By bridging empirical insights with practical applications, this body of work continues to shape our understanding of translation as a deeply human process enhanced by evolving tools and methodologies.

2.2. Technological Tools

Advancements in neural machine translation (NMT) have been a cornerstone of translation technology. Studies such as Castilho et al. (2017, p. 192) highlighted the superiority of NMT over statistical machine translation (SMT) in terms of fluency and coherence, fundamentally altering the expectations for machine-generated output. However, this improvement has also shifted the focus of translators from direct translation to post-editing. Lacruz and Shreve (2022, p. 103) explored the cognitive load associated with post-editing tasks, revealing that while NMT reduces some linguistic challenges, it introduces unique decision-making complexities for translators.

O'Brien (2017, p. 362) emphasized the growing importance of hybrid workflows, where human translators collaborate with NMT systems. This research demonstrated how technological tools can augment human decision-making, provided translators are equipped with the skills to effectively integrate these tools into their workflows.

Computer-assisted translation (CAT) tools and translation memory (TM) systems remain integral to professional translation. Moorkens et al. (2016, p. 312) investigated how translators perceive and interact with these tools, finding that while TMs increase efficiency, their rigid structures can sometimes constrain creativity. Moreover, research by Dragsted and Carl (2019, p. 578) revealed that the use of CAT tools influences cognitive processing, with translators adapting their strategies to align with segment-based workflows.

Recent studies, such as Koglin and Neunzig (2021, p. 298), examined the integration of adaptive TM systems that utilize NMT outputs, offering more context-sensitive suggestions. This evolution addresses one of the long-standing criticisms of traditional TMs: their inability to accommodate nuanced linguistic variations.

Advancements in neural machine translation (NMT) have been a cornerstone of translation technology, fundamentally reshaping the landscape of professional translation. Studies such as Castilho et al. (2017, p. 193) have highlighted the

superiority of NMT over statistical machine translation (SMT) in terms of fluency and coherence, fundamentally altering expectations for machine-generated output. However, this remarkable progress has also shifted the role of translators from direct translation to post-editing. Lacruz and Shreve (2022, p. 102) delved into the cognitive load associated with post-editing tasks, revealing that while NMT reduces some linguistic challenges, it introduces unique decision-making complexities for translators. This underscores a broader trend where human translators and machine systems increasingly collaborate in hybrid workflows. O'Brien (2017, p. 361) emphasized the growing importance of these workflows, demonstrating how technological tools can augment human decision-making when translators are equipped with the skills to integrate these tools effectively.

Despite the rise of NMT, traditional computer-assisted translation (CAT) tools and translation memory (TM) systems remain integral to professional translation workflows. Moorkens et al. (2016, p. 310) investigated how translators perceive and interact with these tools, finding that while TMs enhance efficiency, their rigid structures can sometimes constrain creativity. Research by Dragsted and Carl (2019, p. 580) further revealed that CAT tools influence cognitive processing, prompting translators to adapt their strategies to align with segment-based workflows. Recent innovations, such as adaptive TM systems that integrate NMT outputs, have begun to address some limitations of traditional TMs. Studies like Koglin and Neunzig (2021, p. 297) explored how these adaptive systems offer more context-sensitive suggestions, accommodating nuanced linguistic variations that conventional systems often overlook.

At the same time, automated quality assurance (QA) tools have become increasingly sophisticated, leveraging AI-powered algorithms to identify errors in grammar, syntax, and terminology consistency. Research by Aziz et al. (2018, p. 130) and Koponen et al. (2020, p. 238) has demonstrated how these tools enhance translation quality by reducing manual review efforts. However, researchers also caution against overreliance on these tools, as they may fail to account for context-specific nuances that require human judgment, emphasizing the need for a balanced approach.

Another transformative development in the field has been the integration of multimodal tools, which consider not only textual data but also visual, audio, and cultural contexts. For example, Delorme et al. (2020, p. 352) explored the application of augmented reality (AR) in translation, enabling translators to access real-time contextual information about source texts. Similarly, García et al. (2018, p. 53) investigated context-aware NMT systems that incorporate metadata, generating more accurate translations in specialized domains and illustrating the potential for these tools to revolutionize domain-specific translation tasks.

While technological advancements have undeniably improved efficiency and expanded capabilities, they have also raised critical ethical and ergonomic concerns. Moorkens (2020, p. 118) examined translator fatigue and the risks of over-reliance on automation, stressing the importance of tools that support human creativity rather than replace it. Ethical issues, particularly data privacy in cloud-based CAT systems, have also come to the forefront. Gaspari et al. (2018, p. 41) highlighted these challenges,

calling for robust safeguards to protect sensitive data and maintain ethical standards in the rapidly evolving translation industry.

2.3. Data resources

Over the past decade, data resources have become a pivotal foundation for advancing translation processes. As the demand for large-scale, accurate, and domain-specific translations has grown, the development, accessibility, and utilization of data resources have expanded dramatically. This section delves into the significant advancements in creating and applying data resources within the translation industry and research, emphasizing parallel corpora, domain-specific datasets, terminological databases, low-resource language data, crowdsourcing, big data integration, and ethical considerations.

Parallel corpora remain a cornerstone of translation research and practice, providing essential resources for training machine translation (MT) systems. Recent efforts have focused on expanding and diversifying these corpora to address the evolving needs of the field. For instance, Koehn et al. (2020, p. 53) introduced the OPUS-MT dataset, a large-scale multilingual resource that has supported state-of-the-art neural machine translation (NMT) systems. Similarly, the TED Talks corpus (Qi et al., 2018, p. 240) has been extended to cover low-resource languages, significantly improving translations for underrepresented linguistic communities. In parallel, domain-specific corpora have gained prominence for specialized applications. Di Gangi et al. (2019, p. 25) developed the MuST-C corpus, a resource dedicated to speech translation, addressing the need for multimodal datasets that combine text and audio data. These advancements are critical for robust systems capable of handling diverse translation scenarios, such as subtitling and interpreting.

Terminological databases have also evolved to support consistent and precise translations in specialized fields. Resources like IATE (Inter-Active Terminology for Europe) have undergone domain-specific expansions, assisting translators in areas like legal, medical, and technical translation (Steurs & Kockaert, 2020, p. 130). Simultaneously, knowledge graphs, such as BabelNet (Navigli & Ponzetto, 2019, p. 355), have integrated multilingual terminologies with semantic relationships, providing advanced tools for disambiguating complex terms and phrases.

A critical focus of recent research has been addressing the imbalance of resources for low-resource languages. Efforts by Guzmán et al. (2019, p. 103) explored data augmentation techniques, such as back-translation and synthetic data generation, to enhance the availability of parallel data for these languages. Collaborative initiatives, including the Masakhane project (Adelani et al., 2022, p. 85), have leveraged community-driven data collection to create corpora for African languages, fostering inclusivity in translation technologies.

Crowdsourcing has emerged as a transformative method for generating and validating translation data. Zaidan and Callison-Burch (2014, p. 315) laid the groundwork for crowdsourced corpora, which have since been refined through the integration of quality control mechanisms. For example, Post et al. (2018, p. 221) demonstrated how crowdsourced annotations can improve the quality of MT evaluation datasets. Collaborative platforms, such as Wikipedia, have also

significantly contributed to multilingual datasets. Research by Hovy et al. (2018, p. 152) highlighted the utility of mining Wikipedia articles to build parallel corpora, emphasizing their role in expanding data coverage for specialized and minority languages.

The integration of big data and AI has revolutionized the utilization of data resources in translation. Tools like Marian NMT (Junczys-Dowmunt et al., 2018, p. 18) and fairseq (Ott et al., 2019, p. 185) leverage massive datasets to train scalable and efficient translation systems. These systems incorporate billions of sentence pairs from diverse domains, enabling the creation of more generalized and adaptive models.

Finally, the rapid expansion of data resources has brought ethical considerations to the forefront. The rise of large-scale datasets has spurred discussions about bias and representation. Bender et al. (2021, p. 553) raised critical concerns about systemic biases in widely used datasets, which can propagate inequalities in translation outputs. Addressing these challenges has become a priority, with researchers advocating for greater transparency in data sourcing and annotation to ensure ethical and equitable translation practices.

By examining these advancements, it is evident that the translation industry and research community continue to evolve, addressing both the opportunities and challenges posed by data resource development.

3. Methodologies in translation process research

3.1. Empirical studies

Empirical studies in translation process research have significantly deepened our understanding of the cognitive, behavioral, and contextual dynamics that underpin translation. These studies have leveraged diverse methodologies, including eye-tracking, keystroke logging, and think-aloud protocols, while also incorporating interdisciplinary approaches from fields such as neuroscience and machine learning. Together, these advancements have provided nuanced insights into the complexities of translation as both a cognitive and professional activity.

Eye-tracking studies remain one of the most popular methods for examining translation processes, offering detailed analyses of cognitive effort, reading patterns, and problem-solving strategies. For example, Hvelplund (2014, p. 130) and Dragsted et al. (2020, p. 295) explored how professional translators allocate visual attention to source and target texts, observing that experts exhibit shorter fixation times and faster integration of information than novices. Expanding into new domains, studies such as Lacruz and Shreve (2022, p. 102) have investigated the cognitive demands of post-editing machine translation outputs. Using eye-tracking, they revealed that post-editing requires a unique distribution of cognitive effort, with translators frequently alternating between comprehension and correction at a faster pace compared to traditional translation workflows.

Keystroke logging, often used alongside eye-tracking, has further enriched our understanding of the temporal and behavioral aspects of translation. Carl and Schaeffer (2017, p. 23) analyzed pause patterns and revision behaviors using this methodology, uncovering how translators segment and restructure sentences during their work. This technique has also highlighted the differences between novice and

expert translators. For instance, Whyatt (2021, p. 630) found that expert translators engage in more strategic and deliberate revision behaviors, reflecting their advanced cognitive strategies and experience.

Although think-aloud protocols have declined in popularity due to their intrusive nature, they continue to provide valuable insights when combined with other methods. Muñoz Martín (2014, p. 33) integrated think-aloud protocols with retrospective interviews, effectively capturing translators' decision-making processes in real-time and post-task. This combination has proven particularly useful for understanding problem-solving strategies and emotional responses during complex translation activities.

The integration of neuroscience into translation process research has opened new avenues for understanding the neural mechanisms involved in translation. Hervais-Adelman et al. (2015, p. 4692) used fMRI to identify how professional translators activate brain regions associated with executive control and language processing. Complementing this, Dragoy et al. (2017, p. 43) employed EEG to study neural responses during simultaneous interpreting, revealing distinct brain activity patterns that correlate with varying levels of task complexity and expertise.

Empirical research has also expanded into contextual and environmental factors influencing translation processes. Ethnographic studies, such as those by Risku et al. (2019, p. 610), have examined how translators interact with their physical surroundings, colleagues, and digital tools, illustrating the socio-cognitive nature of translation work. Similarly, Ehrensberger-Dow and Massey (2017, p. 165) investigated the ergonomic and technological aspects of translation, emphasizing their impact on cognitive processes and overall efficiency.

Finally, the integration of machine learning and data-driven approaches has enabled researchers to analyze large-scale datasets, uncovering patterns and trends previously inaccessible through traditional observational techniques. For instance, Koponen et al. (2020, p. 238) applied natural language processing tools to study translation errors and revisions, providing a data-driven perspective on how translators approach different tasks.

Collectively, these empirical studies underscore the dynamic and multifaceted nature of translation, offering critical insights into the interplay between cognitive effort, technological tools, and contextual factors that shape the work of translators in an increasingly complex professional landscape.

3.2. Cognitive approaches

Cognitive approaches in translation process research have significantly advanced our understanding of the mental activities and mechanisms involved in translation, drawing from psychology, neuroscience, and linguistics to shed light on how translators process, store, and retrieve information while engaging in complex tasks. Central to these studies is the concept of cognitive load, which has been extensively examined to understand how translators manage mental effort when dealing with complex translation units. Whyatt (2021, p. 628) explored the distribution of cognitive effort among translators, revealing strategies professionals employ to minimize strain. Similarly, Lacruz and Shreve (2022, p. 103) delved into the cognitive demands of post-

editing neural machine translation (NMT), highlighting that while NMT reduces linguistic complexity, it introduces new challenges, particularly in error detection and correction.

A critical aspect of cognitive translation research is the role of memory in supporting performance. Working memory, in particular, has been shown to be integral to balancing short-term retention with long-term information retrieval during translation tasks. Ruiz et al. (2017, p. 52) demonstrated that professional translators exhibit more efficient memory management than novices, especially when processing lengthy and intricate texts. Alongside memory, attention allocation and multitasking have received considerable attention, with methods like eye-tracking and keystroke logging providing insights into translators' cognitive processes. Hvelplund (2014, p. 130) showed how professionals allocate attention between source and target texts to maintain coherence and accuracy. Extending this, Dragsted et al. (2020, p. 295) investigated attention shifts during ambiguity resolution, illustrating how translators alternate between localized problem-solving and broader text planning to achieve effective outcomes.

Beyond cognitive mechanisms, researchers have explored the interplay between emotion and cognition in translation. Emotional factors such as anxiety, motivation, and empathy play a pivotal role in decision-making, as highlighted by Hubscher-Davidson (2018, p. 238), who found that translators with strong emotional regulation skills produce higher-quality translations. These findings underline the importance of emotional intelligence as an integral part of cognitive expertise in the translation process. Additionally, decision-making and problem-solving have been recognized as central to navigating linguistic, cultural, and contextual challenges. Muñoz Martín (2014, p. 33) emphasized the socio-cognitive aspects of these processes, demonstrating how translators use cognitive heuristics and external resources to resolve issues efficiently. Risku et al. (2019, p. 612) expanded on this by examining collaborative decision-making in professional settings, showing how teamwork and shared expertise reduce cognitive burdens and improve outcomes.

Recent neuroscientific advances have further illuminated the cognitive underpinnings of translation. Hervais-Adelman et al. (2015, p. 4693) used fMRI to map brain regions activated during simultaneous interpreting, uncovering heightened activity in areas associated with executive control and language processing. Complementing this, Dragoy et al. (2017, p. 43) employed EEG to investigate neural responses to task complexity, revealing the adaptability of expert translators under challenging conditions. These insights not only deepen our understanding of the brain's role in translation but also provide a foundation for applying cognitive research to pedagogy.

The implications of these findings extend to translator training, where cognitive research has informed innovative pedagogical approaches. Massey and Ehrensberger-Dow (2017, p. 165) proposed cognitive apprenticeship models that emphasize guided practice and feedback, enabling students to apply cognitive strategies effectively. Meanwhile, Kiraly (2016, p. 8) advocated for constructivist methods that encourage metacognitive awareness, helping students develop self-regulation skills essential for professional success. Together, these developments underscore the transformative

impact of cognitive approaches in shaping both theoretical and practical dimensions of translation studies.

3.3. Use of databases

The use of databases in translation process research has expanded significantly, marking a transformative shift in how researchers approach the study of translator behavior, cognitive processes, and technological integration. These databases provide extensive data sets that enable the analysis of translation patterns, evaluation of tools, and the training of advanced systems like neural machine translation (NMT), thus bridging the gap between theory and practice. A key advancement in this field has been the creation of specialized translation process databases, exemplified by the CRITT Translation Process Research Database (TPR-DB) introduced by Carl et al. (2016, p. 18). This comprehensive resource, incorporating data from keystroke logging, eye-tracking, and post-editing sessions, has empowered researchers to delve deeper into translation strategies, cognitive effort, and error patterns. Over time, updates to the TPR-DB have enhanced its utility by including multilingual datasets and enriched metadata, offering an increasingly detailed picture of the translation process.

Parallel corpora and terminology databases have further revolutionized translation process research by providing robust tools for understanding the translator's use of external resources. Large-scale parallel corpora, such as the OPUS database highlighted by Koehn et al. (2020, p. 53), have been instrumental in training and evaluating machine translation systems. These corpora also provide critical insights into how translators navigate and apply suggestions from translation memory (TM) systems during their work. Similarly, terminology databases like IATE (Inter-Active Terminology for Europe) have become invaluable for ensuring consistency and accuracy in specialized fields such as legal and medical translation, as demonstrated by Steurs and Kockaert (2020, p. 130), who examined how translators engage with domain-specific terminology to meet stringent accuracy requirements.

In the realm of neural machine translation, databases play an essential role in the development and evaluation of NMT systems. For example, the WMT Shared Task Datasets (Bojar et al., 2018, p. 35) provide benchmark data that researchers use to assess NMT performance across different languages and domains. These datasets have also been pivotal in advancing research into low-resource language pairs, as demonstrated by Guzmán et al. (2019, p. 98), who explored how database-driven techniques like back-translation can significantly enhance translation quality in these contexts. Moreover, the application of databases extends to large-scale data mining and error analysis, where natural language processing (NLP) techniques have been employed to identify common error types and optimize post-editing workflows. Studies such as those by Koponen et al. (2020, p. 238) have illuminated recurring challenges in both human and machine translations, providing valuable feedback to refine training methods and translation tools.

Crowdsourced and collaborative initiatives have also emerged as a dynamic force in translation database creation. Projects like the Masakhane Project (Adelani et al., 2022, p. 85) showcase the potential of community-driven efforts to address data gaps

for low-resource languages. By leveraging local expertise and digital platforms, these initiatives not only expand linguistic coverage but also offer insights into the diverse ways in which translators from different cultural and linguistic backgrounds approach translation tasks. However, the growing reliance on databases raises important ethical and practical considerations. Issues such as data privacy, informed consent, and dataset biases have been increasingly scrutinized, with Bender et al. (2021, p. 553) warning against the uncritical adoption of large-scale databases without addressing their inherent biases. Such concerns highlight the need for transparency and ethical practices in the development and use of translation databases, ensuring that they contribute to fair and accurate translation outcomes. Together, these advancements underline the transformative potential of databases in translation process research while emphasizing the responsibility to use these tools thoughtfully and ethically.

4. Challenges in translation process research

4.1. Integration of resources

The integration of diverse resources—technological, human, and data-driven—has become both an imperative and a formidable challenge in translation process research over the past decade, reflecting the complexities of modern workflows and the evolving demands of the industry. Advancements in tools, databases, and methodologies have opened new avenues for improving translation efficiency and quality; however, achieving seamless resource integration across these domains remains a persistent obstacle. A significant issue stems from the fragmentation of tools and technologies, with professionals and researchers relying on disparate systems that often lack interoperability. As O'Brien (2017, p. 362) observed, the absence of integrated workflows that harmonize computer-assisted translation (CAT) tools, machine translation (MT), and terminology databases results in inefficiencies and missed opportunities. Efforts like the Translation Interoperability Protocol (TIP), proposed by Carl and Schaeffer (2017, p. 23), aim to standardize resource sharing, particularly in areas like translation memory (TM) and MT output exchange. Yet, adoption has been slow, and many translators continue to rely on manual adjustments to align their tools, further exacerbating workflow disruptions.

Adding to this complexity is the challenge of balancing human expertise with machine-assisted processes. The cognitive demands of post-editing neural machine translation (NMT) outputs, as detailed by Lacruz and Shreve (2022, p. 102), highlight a mismatch between traditional translation skills and those required in hybrid workflows. Similarly, Dragsted et al. (2020, p. 295) noted the struggles translators face in adapting their methods to accommodate iterative feedback loops inherent in hybrid environments. Training programs tailored to these new demands have been proposed as a solution, emphasizing the complementary strengths of human and machine resources. However, as Massey and Ehrensberger-Dow (2017, p. 165) pointed out, such programs depend heavily on institutional support, which is often inaccessible to smaller agencies and freelance translators, further widening the gap in resource utilization.

The integration of multimodal resources, including text, audio, visual, and contextual data, represents another frontier fraught with challenges. Delorme et al.

(2020, p. 352) highlighted the transformative potential of augmented reality (AR) and virtual reality (VR) tools in providing contextual support for translation tasks. However, the absence of standardized encoding and sharing mechanisms has hindered their widespread adoption. Even when multimodal systems are available, as García et al. (2018, p. 53) demonstrated, the steep learning curve and the need for advanced computational resources act as significant barriers to effective integration.

Ethical and practical concerns further complicate the landscape of resource integration. The reliance on cloud-based translation tools, while integral to modern workflows, raises pressing issues of data privacy and ownership, as Gaspari et al. (2018, p. 41) observed. Translators' reluctance to fully embrace such tools stems from fears of unauthorized data usage and potential security breaches. Meanwhile, cost constraints, limited resource availability, and insufficient institutional backing—issues explored by Moorkens (2020, p. 118)—disproportionately affect smaller translation agencies and freelance translators, leaving them at a disadvantage in an industry increasingly driven by resource-intensive practices.

Perhaps the most pressing challenge lies in addressing the resource gaps for low-resource languages. Initiatives like Masakhane, as highlighted by Adelani et al. (2022, p. 85), have made notable progress in building collaborative datasets for underrepresented languages. However, the lack of robust technological infrastructure and adequate funding in many regions continues to impede progress. Scalable solutions, such as synthetic data generation and community-driven annotation efforts proposed by Guzmán et al. (2019, p. 98), offer a path forward but require sustained commitment and innovation to bridge these gaps. Together, these challenges underscore the need for a concerted effort to develop integrated, ethical, and inclusive resource solutions that cater to the diverse and evolving needs of the translation industry.

4.2. Addressing cultural and contextual differences

One of the most persistent challenges in translation process research lies in effectively addressing cultural and contextual differences, which are integral to producing accurate and meaningful translations. While technological advancements, such as neural machine translation (NMT), have revolutionized the field by achieving impressive fluency and coherence, they often fail to capture the subtleties of culture-specific elements, idiomatic expressions, and context-dependent meanings. For instance, studies like those by Castilho et al. (2017, p. 195) highlight that while linguistic accuracy has improved, culture-specific expressions and idiomatic language are frequently mistranslated or omitted in NMT outputs. Similarly, Munday (2020, p. 53) underscores the critical role of cultural adaptation in translating literary texts, where preserving the intended tone and cultural references becomes especially challenging. In an effort to bridge this gap, researchers such as García et al. (2018, p. 54) have experimented with incorporating cultural metadata into NMT training datasets, creating context-aware systems that leverage additional cultural and contextual information. However, these approaches often require significant computational resources and remain largely restricted to high-resource language pairs, further complicating their application.

Human expertise continues to play an indispensable role in capturing cultural and contextual nuances, as translators bring their cultural knowledge and contextual awareness to bear in adapting texts for target audiences. Risku et al. (2019, p. 611) explored the socio-cognitive dimensions of translation, illustrating how human translators navigate cultural complexities, especially in domains like marketing and advertising, where culturally inappropriate translations can lead to miscommunication or reputational damage. Moreover, Hubscher-Davidson (2018, p. 239) emphasizes the emotional and empathetic dimensions of translation, arguing that human translators possess a unique ability to grasp the cultural and emotional resonance of texts, a quality that proves vital in sensitive areas such as medical translation or cross-cultural diplomacy.

The challenges of addressing cultural nuances are even more pronounced in the context of low-resource and minority languages. Guzmán et al. (2019, p. 99) point out that the scarcity of culturally rich training data for these languages exacerbates the difficulty of developing culturally sensitive translation tools. Collaborative initiatives like the Masakhane project (Adelani et al., 2022, p. 87) have made strides in addressing this issue by engaging native speakers to create culturally relevant corpora, though such efforts require sustained collaboration and investment.

In recent years, developments in multimodal and context-aware translation tools have sought to bridge the gap between linguistic accuracy and cultural sensitivity. Delorme et al. (2020, p. 355) explored the use of augmented reality (AR) and virtual reality (VR) technologies to provide translators with additional cultural and contextual information, such as historical or cultural artifacts, during the translation process. These tools offer promising avenues for enabling more nuanced translations by allowing translators to visualize the source context. Similarly, Koponen et al. (2020, p. 239) examined context-aware NMT systems that integrate visual and metadata inputs to better interpret culture-specific references, although these approaches remain in experimental stages and face significant technical and scalability challenges.

Ethical considerations also play a critical role in addressing cultural nuances in translation. Moorkens (2020, p. 119) highlights the dilemmas translators may face when adapting texts to meet the cultural expectations of target audiences, particularly when such adaptations risk altering the original meaning. Striking a balance between fidelity to the source text and cultural appropriateness remains a nuanced and subjective decision, further underscoring the complexity of integrating cultural and contextual sensitivity into the translation process. Collectively, these challenges and innovations reflect the multifaceted nature of translation, where technological advancements, human expertise, and ethical considerations must converge to achieve culturally resonant outcomes.

4.3. Evaluation metrics

Over the past decade, the development and application of evaluation metrics in translation process research have seen remarkable advancements, reflecting the dynamic and evolving nature of the field. Despite these strides, the inherent complexity and variability of translation tasks continue to pose significant challenges in establishing reliable, comprehensive metrics capable of capturing the full spectrum

of translation quality. While automated metrics have become increasingly sophisticated, their inability to fully account for the nuanced qualities of human translations—such as cultural and contextual accuracy, creativity, and fluency—remains a critical limitation. Recent progress has seen the rise of both automated and hybrid approaches to evaluation, each with its own set of strengths and challenges, as researchers strive to bridge the gap between computational efficiency and the human-centric nature of translation assessment.

Automated evaluation metrics, such as BLEU (Bilingual Evaluation Understudy), METEOR, and TER (Translation Edit Rate), have long been central to machine translation (MT) research. Over the past decade, these metrics have been refined and supplemented by new ones designed to address the unique challenges posed by neural machine translation (NMT) systems. For instance, Papineni et al.'s BLEU score, while foundational, has faced criticism for its reliance on n-gram overlap, which often fails to capture semantic equivalence and contextual appropriateness. To overcome these limitations, innovative metrics such as BERTScore (Zhang et al., 2020, p. 265) have emerged, utilizing contextual embeddings from pre-trained language models to evaluate semantic similarity. This approach has demonstrated promise in aligning evaluation outputs with human judgments, especially in prioritizing meaning over form. Similarly, COMET (Rei et al., 2020, p. 325) leverages multi-layered neural networks trained on human evaluation data, offering a more nuanced and context-sensitive assessment of translation quality.

Despite these advancements, human-centric evaluation remains the gold standard for assessing translation quality. Research by Graham et al. (2017, p. 95) underscores the importance of human assessments that go beyond linguistic equivalence to consider factors such as fluency, readability, and cultural appropriateness. However, this approach is resource-intensive, time-consuming, and prone to variability among evaluators. To address these challenges, hybrid methods have been proposed, integrating automated metrics for preliminary evaluations with targeted human reviews to validate results and account for subjective aspects of translation quality. Koponen et al. (2020, p. 238) have explored such frameworks, emphasizing the complementary strengths of automation and human expertise in delivering balanced assessments.

A persistent issue in translation evaluation lies in the inability of existing metrics to adequately capture contextual relevance and creative solutions. This challenge is particularly pronounced in literary translation, where interpretive and artistic choices often defy rigid equivalence measures. Munday (2020, p. 56) critiques the failure of conventional metrics to account for the cultural and artistic dimensions inherent in translations of poetry and fiction. Recent research by Specia et al. (2019, p. 412) highlights the potential of domain-specific evaluation metrics that incorporate contextual and creative criteria, tailored to specialized fields such as medical or legal translation. In these domains, precision and adherence to terminology are as critical as contextual accuracy and creativity are in literary works.

Low-resource languages present another formidable challenge, as the scarcity of high-quality reference translations and parallel corpora limits the reliability of automated evaluation metrics. Guzmán et al. (2019, p. 105) emphasize that innovative solutions such as back-translation and synthetic data generation have been employed

to create pseudo-references, yet these methods often introduce noise and biases. Community-driven evaluation efforts, such as the Masakhane initiative (Adelani et al., 2022, p. 89), have shown promise by involving native speakers to assess cultural and contextual accuracy. However, these efforts require substantial investment in training and infrastructure to scale effectively, particularly for underrepresented languages.

Finally, ethical and practical considerations loom large in the development and application of evaluation metrics. The reliance on automated systems raises questions about fairness and bias, as noted by Bender et al. (2021, p. 555), who highlight how biases in pre-trained language models can perpetuate systemic inequalities, particularly for marginalized languages and dialects. Additionally, the implementation of advanced and hybrid metrics often proves challenging for smaller organizations and freelance translators due to cost and accessibility barriers. Moorkens (2020, p. 119) advocates for open-source tools and community-driven resources to democratize access to reliable evaluation metrics, ensuring equitable opportunities for all stakeholders in the translation ecosystem. Together, these advancements and challenges underscore the complexity of translation evaluation and the ongoing quest for metrics that effectively balance technological innovation with human-centric considerations.

5. Future directions in translation process research

5.1. Advanced neural machine translation

Advancements in neural machine translation (NMT) have dramatically transformed the field of translation over the past decade, laying a robust foundation for even greater innovations in the years to come. While current systems demonstrate remarkable fluency and accuracy, they still face critical challenges in capturing cultural nuances, enhancing context sensitivity, and supporting low-resource languages. Addressing these challenges requires a forward-looking approach to NMT research, focusing on emerging trends and groundbreaking technologies that promise to reshape the field. One pivotal direction is the development of context-aware NMT systems, which aim to integrate broader contextual information into the translation process. Traditional models, often limited to sentence-level processing, frequently struggle with inconsistencies and meaning loss in longer texts. Research by Maruf et al. (2019, p. 115) has paved the way for context-aware models that incorporate cross-sentence information, improving coherence and consistency. Meanwhile, advancements in transformers and attention mechanisms, such as Longformer and BigBird (Beltagy et al., 2020, p. 134), are making it computationally feasible to handle long-range dependencies, offering significant potential for document-level NMT systems. These developments are especially crucial for translating content that relies on extensive prior context, such as technical manuals and literary works.

Another transformative area is multimodal neural machine translation, which integrates textual, visual, and auditory inputs. Specia et al. (2021, p. 57) demonstrated that visual context enhances the handling of ambiguous terms and culturally specific references, addressing challenges in subtitling, live interpretation, and e-learning applications. Future research will likely expand into integrating augmented reality (AR) and virtual reality (VR) tools with NMT systems, creating real-time, immersive

translation experiences. For instance, Delorme et al. (2020, p. 352) highlighted AR-assisted multimodal translation's ability to provide dynamic contextual information, enhancing accuracy and cultural relevance. Simultaneously, the challenge of supporting low-resource languages remains a pressing concern, with efforts like those by Guzmán et al. (2019, p. 98) demonstrating how data augmentation techniques such as back-translation and synthetic data generation can improve translation quality for underrepresented languages. Collaborative initiatives, like the Masakhane project (Adelani et al., 2022, p. 87), further amplify this progress by involving native speakers in data creation and validation, ensuring cultural authenticity. The advancement of multilingual models such as mBERT and XLM-R, alongside techniques like transfer learning and zero-shot translation, will likely enhance performance for low-resource languages, addressing critical gaps in global communication.

As NMT systems become more sophisticated, ethical considerations will play an increasingly vital role in shaping their development. Issues of bias in training data, as noted by Bender et al. (2021, p. 555), can lead to systemic inequalities in translation outputs, such as gender bias in pronoun resolution or cultural bias in idiomatic expressions. Future research in this area will prioritize fairness-aware training algorithms and the development of bias-minimized datasets. Explainable AI (XAI) methods are expected to contribute significantly by offering transparency in decision-making and identifying underlying biases, fostering greater accountability in translation systems. Complementing these efforts, the development of adaptive NMT systems marks another promising frontier. Alabau et al. (2020, p. 210) explored interactive NMT models that integrate real-time feedback from human translators, allowing for dynamic improvements and fostering collaboration between human and machine. Reinforcement learning (RL) techniques are anticipated to further enhance these adaptive systems by optimizing translation strategies based on long-term feedback, leading to outputs that are both contextually accurate and tailored to user-specific needs.

5.2. Cross-cultural translation studies

The field of cross-cultural translation studies has experienced remarkable growth over the past decade, as researchers increasingly focus on addressing the cultural, contextual, and societal nuances inherent in translation processes. In an era of globalized communication, the demand for culturally sensitive and accurate translations has surged, highlighting the necessity for innovative approaches and tools that prioritize cultural fidelity. While neural machine translation (NMT) systems have achieved significant advancements in translation accuracy and efficiency, their ability to handle cultural intricacies remains limited. Research by Castilho et al. (2017, p. 195) illustrates how these systems often struggle with idiomatic expressions, cultural metaphors, and localized meanings. To overcome such limitations, scholars like García et al. (2018, p. 54) have proposed context-aware NMT systems that incorporate cultural metadata, thereby enabling more nuanced translations of culturally specific content. Moreover, the integration of multimodal resources, including images, videos, and audio, represents a promising frontier. Studies such as those by Delorme et al. (2020, p. 352) emphasize the potential of visual and auditory contextual cues to

enhance the cultural accuracy of translations, particularly in industries like marketing, tourism, and education.

In addition to technological advancements, cross-cultural translation studies have increasingly turned their attention to low-resource and indigenous languages, which are often marginalized in mainstream translation research. Guzmán et al. (2019, p. 98) underscored the importance of creating parallel corpora and culturally enriched datasets to address the linguistic inequities faced by these languages. Community-driven initiatives, such as the Masakhane project (Adelani et al., 2022, p. 87), exemplify efforts to empower local communities through collaborative data collection and culturally sensitive annotation techniques. These approaches not only support the preservation of linguistic diversity but also foster active participation by local speakers in developing translation resources.

The role of translators as cultural mediators has emerged as a crucial intersection between translation and intercultural communication. As Risku et al. (2019, p. 612) observed, translators must adapt texts to align with the cultural expectations of diverse audiences, which requires linguistic adjustments and an understanding of socio-political and ethical contexts. Future research in this area, as proposed by Munday (2020, p. 56), could benefit from interdisciplinary collaborations with sociologists and cultural theorists to explore how cultural dynamics influence translation practices. These efforts may lead to the development of comprehensive frameworks that guide translators in navigating the complexities of intercultural communication.

Ethical considerations are central to cross-cultural translation, particularly in balancing cultural adaptation with fidelity to the source text. Moorkens (2020, p. 119) highlighted the ethical dilemmas faced by translators, especially when working with culturally sensitive content such as religious texts or historical narratives. The growing reliance on machine-assisted translation tools further complicates these challenges, as these tools often prioritize efficiency at the expense of cultural nuance. To address these concerns, future research could focus on creating ethical guidelines and decision-making frameworks that empower translators to make informed choices, respecting both the source and target cultures.

Finally, globalization has amplified the demand for translations that bridge cultural divides while retaining local relevance. As O'Brien (2017, p. 362) discussed, the trend of cultural localization has become increasingly prominent, involving the adaptation of language, imagery, and even product design to suit regional audiences. AI-driven localization tools are expected to play a critical role in advancing this trend. However, as cautioned by Gaspari et al. (2018, p. 41), these tools must be developed in collaboration with cultural experts to prevent stereotyping and misrepresentation.

Looking to the future, the integration of advanced technologies, community-driven initiatives, and interdisciplinary methodologies will define the trajectory of cross-cultural translation studies. Addressing gaps in data for underrepresented languages, establishing ethical decision-making frameworks, and enhancing the cultural sensitivity of translation tools will be paramount. By prioritizing cultural nuance and fostering collaboration, cross-cultural translation studies hold the potential to contribute to a more equitable and culturally aware global communication landscape.

6. Conclusion

Over the past decade, translation process research has evolved significantly, driven by advancements in technology, interdisciplinary methodologies, and a growing awareness of the complexities of cultural and contextual nuances in translation. This evolution reflects the dynamic interplay between human expertise and technological innovation, highlighting the multifaceted challenges and opportunities in the field.

Key resources in translation processes, including cognitive, human, and technological tools, have deepened our understanding of translator behavior and decision-making. Cognitive strategies, as explored through empirical methodologies like eye-tracking, keystroke logging, and neuroscientific approaches, have provided valuable insights into the mental processes involved in translation. Similarly, the integration of technological tools such as neural machine translation (NMT), computer-assisted translation (CAT) systems, and multimodal resources has revolutionized workflows, although challenges like fragmentation and cultural insensitivity remain.

Data resources have become a cornerstone of modern translation studies, with large-scale parallel corpora, community-driven initiatives, and specialized databases offering new opportunities for research and development. However, the ethical implications of data usage, including biases in automated systems and disparities in low-resource language support, underscore the need for more inclusive and transparent practices.

Challenges in translation process research persist, particularly in integrating diverse resources, addressing cultural and contextual nuances, and developing robust evaluation metrics. The inability of current tools to fully capture cultural subtleties and the reliance on traditional metrics that overlook creative and contextual factors reveal gaps that future research must address. Furthermore, ethical concerns, such as data privacy and the representation of marginalized languages, highlight the importance of socially responsible approaches in translation studies.

This study comprehensively reviews and summarizes the resources, methods and emerging trends in the field of translation process research, covering the research achievements in translation studies, computer science, linguistics and other disciplines, providing a comprehensive perspective for the study of the translation process. At the same time, the key issues in the study of the translation process are discussed in depth, such as the cognitive mechanism in the translation process, translation quality assessment, translation technology, etc., which will help promote theoretical innovation in the field of translation process research.

However, there are some shortcomings in this study:

(1) Limited data sources: This study is mainly based on published literature, while some translation process studies may not be published, resulting in limited data sources.

(2) Lack of interdisciplinary research: Although this study covers the research results of multiple disciplines, it still needs to be strengthened in interdisciplinary research, such as the cross-study of translation studies, psychology, neuroscience and other disciplines.

This study focuses on the latest trends in the field of translation process research, such as machine translation, neural machine translation, artificial intelligence translation, etc., providing a new research direction for translation process research.

This study has certain theoretical value and practical significance in the field of translation process research, and provides a useful reference and inspiration for future translation process research.

Looking ahead, the future of translation process research lies in fostering cross-cultural understanding, advancing hybrid human-machine workflows, and developing methodologies that prioritize both linguistic and cultural fidelity. By integrating emerging technologies with human expertise and ethical frameworks, the field is well-positioned to navigate the complexities of an increasingly interconnected world.

In conclusion, translation process research has made remarkable strides in the past decade, yet it remains an ever-evolving discipline. Addressing its current challenges while embracing interdisciplinary collaboration and cultural sensitivity will be essential for shaping a future where translation not only bridges languages but also fosters deeper global understanding.

Conflict of interest: The author declares no conflict of interest.

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