A Review of Memory, Translation, and Bilingualism

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Abstract:

The human capacity for linguistic expression has inspired vast amounts of research in cognitive psychology. This is especially true for those capable of linguistic expression in multiple languages. This brief overview of bilingualism and its relationship with memory and translation found that consensus in the research community does not exist on the nature of these phenomena. Predominant models for translation and bilingual semantic memory did not correspond with one another. This review thus suggested that these models, especially those being used in artificial intelligence, should be revised with the findings of cognitive psychology researchers in mind. Future research in bilingual semantic memory and translation should also aim to unite findings present in each other's literature. Despite this controversy, general consensus was found regarding the positive and negative impacts of bilingualism, with the positive far outweighing the negative. This motivates greater integration of L2 learning in academia as the literature demonstrated the benefits of bilingualism extend beyond translation and language-related tasks.

Introduction:

Language is one of humankind's unifying characteristics. However, the wide variety of human languages often makes any sort of unification seem very difficult. Fortunately, bridging these gaps has been made possible by the capability for humans to speak multiple languages, and use them in parallel. Translation between two languages requires a multitude of cognitive resources to be properly accomplished. In his seminal essay on the woes of translation, author and trilingual Vladimir Nabokov (1941) enumerates many of the shortcomings of translators. Nabokov notes that a translator must have just as much talent as the author one is translating, and

concludes that perfection in translation is not “attainable by merely following a few perfect rules” (Nabokov, 1941). Nabokov’s first-hand insights on translation highlight the difficulties in deducing the cognitive science behind this herculean task. Translators must move beyond simple, literal translations, encoding cultural tidbits and often times fitting prosody to words across different languages. Thus, it is clear that proper translation engages parts of the mind involved with everything from one’s long-term memories, to notions of musicality.

Of particular interest to cognitive science research is the role of memory more broadly in bilingualism and translation. The act of translation itself involves components of episodic, working and semantic memory working in tandem to transmit an expression from one language into another (Płońska, 2014). The cognitive demands of translation have led researchers to propose various theories and models of translation that account for the complex encoding and decoding of language. These models integrate and attempt to answer the question of how bilinguals store memory. Of course, those learning a second language, L2 learners, are capable of translation as well, especially of shorter words or phrases. Because there is evidence of differences in localization patterns between these L2 learners and native bilinguals (Kim, Relkin, Lee, & Hirsch, 1997), this review will specifically focus on native bilinguals and their storage of semantic memories. These individuals are also the most effective translators, meaning they make for good models of study. Capabilities that arise from bilingualism and bilingual translation also have impacts beyond just translation. There’s evidence that bilinguals are both positively and negatively impacted by their ability to think and speak in multiple languages. This is of particular interest as it motivates the continued study of languages despite the ever present linguistic divides we face in the world today. Beyond the realm of humanity, this review’s conclusions

about bilingual memory also lend suggestions to ways in which to improve machine translation architectures which have yet to reach human parity.

Brief Outline:

- Memory in Translation
    - Memory and Machine Translation Models
    - Memory and Human Translation Models
- Bilingual Semantic Memory
    - The Revised Hierarchical Model
    - Discontents of the Revised Hierarchical Model
- Effects of Bilingualism
    - Positive Consequences
    - Negative Consequences

Memory in Translation

As it stands, the current research on memory in translation has revealed more questions than conclusions. Given that the nature of language still remains a matter of debate, it's unsurprising the relationship between translation and memory is controversial. The task of translation itself though remains fairly agreed upon: an expression from one language is encoded into some sort of representation that is then decoded into the target language (Bajo et al., 2001). The nature of this intermediate representation is not entirely clear; research involving artificial neural networks and machine translation has demonstrated these intermediate representations equate to universal representations of phrases in translation (España-Bonet, Varga,

Barrón-Cedeño, & van Genabith, 2017). McCann et al. (2017) demonstrated the power of these representations by extracting intermediate sentence embeddings from a state-of-the-art encoder-decoder machine translation architecture. This encoder-decoder machine translation architecture is realized using a deep artificial neural network that leverages predictive, probabilistically-generated word embeddings like Word2Vec (Mikolov et al., 2013), or co-occurrence-produced vectors like GloVe (Pennington, Socher & Manning, 2014). The intermediate sentence embeddings exist as vector representations with equivalent amounts of information from the source and target language vectors. Concatenating these embeddings to other, monolingual word vectors and using these concatenations as word vectors in downstream tasks like sentiment analysis and question-answering tasks significantly improved performance. More pertinent to conceptualizing the role of memory in translation is the integration of memory into machine translation systems. Neural network architectures that integrate memory models have shown significant improvements over their memoryless counterparts (Bahdanau et al., 2015; Sukhbaatar et al., 2015). These more recent in silico findings are paralleled by conclusions drawn from human translation (Gile, 2009).

The translator is tasked with efficiently distributing their working memory to carry out multiple tasks at once, including suppressing any information that may not actually be relevant to the translation. Research has shown that this process involves devoting approximately 80% of a translator's cognitive load to listening and comprehension, but only 20% to speech or L2 production (Gile, 2009). These findings demonstrate the emphasis on encoding the source expression into an intermediate representation. The nature of this encoding scheme however is hotly debated in the research community. Humans performing translations demonstrate

distributed brain signals that include areas typically involved in language tasks like Broca and Wernicke's area and the caudate nucleus, a region involved in executive decision-making (Hervais-Adelman, Moser-Mercer, Michel, & Golestani, 2015). The primary schools of thought on how humans perform translate initially fell into two categories: those who believe there to be minimal decoding and encoding between languages and those who believe translation to involve a complex mapping from an L1 representation to an L2 representation (Bajo et al., 2001). Those in the former school of thought, known as the Interpretive Theory of Translation argue that a bilingual lexicon is accessed by working memory during translation and speech in both languages (Choi, 2003). One such model to arise from these early theories of translation is the bilingual interactive activation + (BIA+) model (Dijkstra & van Heuven, 2002). In this model, word recognition is performed via a "task schema" that specifies particular operations to be performed to successfully translate the sentence. This schema is retrieved from memory during translation; its activation is weighted such that different schemas may be activated. Van Heuven and Dijkstra (2010) found support for this bilingual lexicon model using brain imaging techniques like ERP and fMRI.

In conclusion, the incongruencies between translation models for artificial intelligence and human intelligence highlight the need for greater integration of experimental psychology results into artificial intelligence research. With that being said, there remain many unanswered questions about the nature of translation. However, insights from more general bilingual memory research prove useful for better understanding translation.

Bilingual Semantic Memory

Chief among these areas is semantic memory, or general world knowledge. Given that language is inevitably rooted in our experiences of the world, studying semantic memory in bilinguals provides valuable insights into how we come to encode our experiences in language. A seminal paper in the field of bilingual semantic memory by Kroll and Stewart (1994) showed that bilinguals use conceptual representations of words and pictures to retrieve lexical representations in picture naming, concept naming and translations. This process is affected by interference if there exist multiple representations of that concept, a possibility in picture naming and translation. The authors initially proposed bilingual semantic memory as part of the Hierarchical Model of Semantic Memory, which was later revised in Kroll et al. (2010) as the Revised Hierarchical Model (RHM). This model merges models of word association and concept mediation into a single, dynamic model. The RHM effectively accounts for the phenomenon observed in Kroll and Stewart (1994) such as the linkage of the L2 and L1 lexicons through shared conceptual representations in bilinguals. However, the RHM is not without its critics.

Brysbaert and Duyck (2010) note that the authors fail to specify the architectures that bring about semantic and conceptual representations. The authors also note that L1 and L2 lexicons may not actually be separate as proposed by Kroll et al. (2002). Bilingual participants in an experiment conducted by Spivey and Marian (1999) were asked to perform actions on familiar objects. When these objects had similar sounding names, even across languages, the participants experienced lexical interference. These findings suggest that the RHM may require further revisions, especially with respect to its integration of semantic and conceptual representations. The validity of the RHM is further complicated by its incompatibility with the integrated lexicon proposed by the BIA+ model of translation. Understanding the nature of

bilingual semantic memory will ultimately positively contribute to better models of related tasks like translation. However, bilingualism confers other benefits beyond the realm of translation.

Memory Benefits of Bilingualism

Because translation and other bilingual activities require incredible memory capabilities, it is unsurprising that these individuals' memory capabilities exist in other domains. Padilla et al. (2005) showed that translators have higher working memory capacity. This is beneficial for any number of non-linguistic tasks. However, Padilla et al. (2005) also showed that these individuals are susceptible to interference imposed by the demands of simultaneous comprehension and production. This suggests that long-term knowledge from other, longer-term memory systems may provide support to the storage capacity of the phonological loop, a process facilitated by the episodic buffer. Those learning languages are also affected by interference of L2 words, but are more susceptible to interference than their bilingual counterparts. Bilinguals are faster at naming words in L1 than other high span memory individuals who are learning a second language (Kroll et al., 2002). This suggests that long-term knowledge potentially in the form of semantic memory possessed only by bilinguals is particularly useful in preventing this interference, although unable to completely prevent interference. Other studies have also shown that controlled processing is negatively correlated with working memory capacity for language usage. Gutiérrez-Clellen et al. (2004) showed that susceptibility to word interference was positively correlated with high word recall. Taken into consideration with Padilla et al., this would suggest all bilinguals have worse controlled processing capabilities.

These negative effects primarily relating to interference are negligible in relation to the advantages of bilingualism. Bialystok et al. (2012) found that those who are bilingual exhibit

better executive control than those who only speak one language across all ages and backgrounds. This positively impacts all aspects of an individual's life, from general planning capabilities to academic performance. Beyond these general benefits, those who are bilingual also demonstrate slower development of Alzheimer's disease symptoms (Schweizer et al., 2012). These external benefits, albethey loosely related to memory, likely stem from the usage and integration of areas of the brain like the caudate nucleus into bilingual tasks. These areas' capabilities thus have enhanced performance in external, non-linguistic tasks. As such, the benefits of bilingualism far outweigh the risks. Further imaging research would likely highlight other areas of the brain valuable for bilingual tasks. These findings could motivate correlative studies between other functions of these regions and bilingualism.

Conclusions

This review highlighted many of the conflicts currently present in the research community surrounding bilingualism and translation. Of particular note were absolutely incompatible models of human translation and semantic memory. These models differ primarily in their treatment of lexicon access between L1 and L2, suggesting the need for further research in this area to benefit and hopefully unite these areas of research. Machine translation research further complicates matters by demonstrating results close to human parity using models almost entirely independent of human translation models. Common to these models however is the integration of memory in some form or another to account for the cognitive demands imposed by bilingualism. These cognitive demands are not without their rewards; bilinguals, despite being acutely affected by interference, are conferred a number of other benefits beyond language. Given the benefits of bilingualism, these capabilities should continue to be fostered in the

academic world. The findings of this review provide insights for those building and testing models across computational linguistics, psycholinguistics, and translation studies in the hopes that a unified model can eventually be constructed to explain humanity's incredible and mysterious capability for language.

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