

An Efficiency based account of Bilingualism

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Introduction

Regardless of the types of symbols used in different languages for communication, the primary role of a language is to transfer information in social context. Human language is shaped under a consistent demand for easy, robust and effective communication with minimum possible effort (Gibson et al., 2019). A likely influence of this demand can be observed on the structure of a language (Chao & Zipf, 1950). Formal linguistics theories in Chomsky tradition denies that language has been emerged for communication, because there exists ambiguities at multiple linguistic levels (Steinmann & Chomsky, 1978). However, recent studies following the information theory from Shannon tradition suggest that ambiguities do not pose a challenge for communication but it is resolved in a context (Piantadosi et al., 2012). Following on this theory, the efficiency based account of language processing has been influential for past few decades in scientific study of language. A number of cross-linguistic studies show that language exhibit a tendency to be structured for efficient use at different hierarchical linguistic levels e.g. word or syntax (Piantadosi et al., 2011). It has also been shown that the cross-linguistic universals are structured to facilitate the efficient communication. Meaning, the communication can be achieved with minimal effort at average in a given context. This effort can be quantified in terms of the length of the signal. An efficient signal will deliver the same amount of information in short signal by utilising context in an environment. This information can be explained following the information theory which links the notion of probability, information and communication theory (Shannon, 1948). According to which the information content of an event x is given by :

$$h(x) = \log_k \frac{1}{p(x)}$$

The average information content from X is given by the entropy of X .

$$H(X) = \sum_x p(x) \log \frac{1}{p(x)}$$

By utilising the concept from information theory the efficiency of any signal in terms of its information content can be approximated. The idea that language structure has been shaped for efficient communication is not new and has been found in one of the popular studies by George K. Zipf (Zipf, 1936), who found that the more frequent words are shorter in length. The Zipf's law also states that there is exist an inverse rank-frequency relation among the words in a language. Meaning, the most frequent word will appear twice as often as the second most frequent word and thrice as third most frequent word in any language. The distribution tells a lot about the relationship between the most frequent word and its length which is shaped by its regular use. Suggesting that when a word is used more frequently in communication its length is optimised accordingly in order to minimise the communication effort. A similar study refining this study (Piantadosi et al., 2011), established a relationship that the word length can be better ascertained by the context and predictability than the frequency of occurrence in a language. Together, these ideas can be utilised to study how predictability can influence the efficiency of a language in terms of its information content. The above-mentioned studies attempts to investigate the relationship within a language and suggest that language has been shaped to facilitate the efficient communication by minimising the structural redundancy in a language. However, there has been least effort in understanding these phenomena cross-linguistically, especially when most people around the globe are multilingual. Bilinguals having two lexicons each from different languages interact dynamically while communication (Green & Abutalebi, 2013). A large number of studies suggest that bilingual lexicon is integrated and there is co-activation when a lexical candidate from a single language is activated (Bialystok et al., 2009). Moreover, bilinguals are under consistent demand to select the appropriate language depending upon the context and inhibit the task a irrelevant language at the same time. This process of inhibition and selection incur cognitive cost when switching from one language to other, which intuitively goes against the idea of efficiency based account of communication. If there is a cost associated with the cross-linguistic switching during communication which requires one to select and inhibit alternate languages, why proficient bilinguals do that frequently in day to day communication? In other words, if an efficient communication can be achieved

by communicating in a single language why the language system dynamically shifts from one language to other? These questions can be addressed using the ideas from information theory.

Aims and objectives

The current study aims to investigate the following questions in the context of bilingualism and efficiency.

1. Cross-linguistic universals in two languages in bilinguals:

It is well known that there is a close relationship between linguistic context and frequency in a language. More specifically, the context in a language predicts the frequency of word occurrence. It has also been found that the context provides the information which reduces the need of imparting elaborated information in the upcoming word. And the signal length is depended on predictability; i.e, the more predictable a word, the shorter the signal length. Following on this idea, it can be investigated whether there exist a universal cross-linguistic pattern across different languages. And whether such universals have any consequences for bilingual processing and acquisition. The linguistic patterns found using computational methods can then be verified on bilingual participants to test its ecological validity. And the results from this study will be used to generate the predictions for the subsequent study.

2. Relationship between cross-linguistic universals and bilingual processes:

The aim here is to investigate whether the cross-linguistic features found in bilinguals two languages have any consequences for bilingual processing like code-switching and code-mixing. Proficient bilinguals frequently code-switch and code-mix to meet the conversational demands. It is still unknown why and under what conditions this happens. This study will take ideas from information theory to attempt to explain that the bilingual language system is dynamic, which shifts from one language to other based upon the efficiency of the signal. Meaning, if a certain language allows to communicate with less effort in a given context the language channel takes that route. The study will also try to investigate that the two languages are not

modular and operated in binary way rather there exist a fundamental goal to communicate where the actual structural difference does not constraint the language selection but it is guided by efficiency. In other words, a bilingual will switch to a language in which the communication will be achieved with less effort and regardless of the qualitative and structural differences in the two languages.

Method

Study 1 - Computational Model

Materials: Bilingual corpus will be trained on N-Gram model.

Procedure and Predictions: This study will use corpus linguistics and computational modelling to measure the cross-linguistic universals between two languages in a bilingual. The expected information conveyed by a word in from a randomly chosen word (w) from a large corpus in a context (c) can be calculated by.

$$P(C|W) = - \sum_c (C = c | W = w) \log P(W = w | C = c)$$

An N-Gram model will be trained on bilingual corpus and the information content as measured by two-gram, three-gram, and four-gram models will be used to predict the probability of the upcoming word either in L1 and L2. Following the Zipf's distribution words from different frequency ranges will be selected from both languages. It is expected that the context and predictability will guide the occurrence of a lexicon, regardless of the language membership of that word. Moreover, it is known that the higher the frequency of a word the less meaning conveyed by it in a context. Hence, it is predicted that the context will facilitate the choice of a language for which the word is frequent and conveys less meaning with minimum effort. This will also suggest that regardless of the membership of the language, the language choice is guided by the efficiency.

The results from this study will be used to curate stimulus for the behavioural study to administer whether bilingual language selection is also guided under same constraints as predicted by

the computational model. To test this hypothesis a behavioural study will be conducted with same corpus data by manipulating the predictability parameter in controlled manner from the computational model.

Study 2 - Behavioural Study

Participants:

30 high-proficient bilinguals. All participants will be screened for cognitive and neurological impairment before the experiment.

Materials:

Multiple sentences will be extracted from the above model based on different predictive weights of the final word. Crucially, the sets of sentences will have code-mixed sentences from high frequency region as predicted by the above N-Gram model. By this way sentences with 4 conditions will be constructed with different predictability values.

1. L1 with low and high predictable final word.
2. L2 with low and high predictable final word.
3. Code-mixed L1-L2 with low and high predictable final word.
3. Code-mixed L2-L1 with low and high predictable final word.

Procedure:

All participants will take language assessment on Language and Social Background Questionnaire (LSBQ; Luk & Bialystok, 2013), Ravens measure for fluid intelligence, and SES measure.

ERP Behavioural task:

The ERP N400 will be used as an index for prediction in cross-linguistic condition. The N400 amplitude has been shown to be sensitive to the context mediated prediction in a language (Kutas & Federmeier, 2011). However, there are no studies testing testing this effect in cross-linguistic condition. It is expected that when the final word in code-switched condition belongs to low-rank and high frequency region as predicted by the N-Gram model, the N400 amplitude will be attenuated as compared to the single language condition where the final word is predictable but not efficient in a given context. This result is expected in both condition

suggesting that the language selection is guided by the efficiency which is explained in terms of retrieval effort in a given condition not by the selected language itself. One crucial point here is that the predictability coefficient and cross-linguistic universal will be ascertained by the model which will be extracted across the two languages of a bilingual.

Conclusion and Discussion

The current study will attempt to investigate the question whether there exist any cross-linguistic universals across bilingual's two languages which affects the language choice, dynamic shifting and switching. So far in the bilingual literature, it is not well understood why and under what conditions bilingual shift to other language during communication. The current study will take forward the emerging ideas from information theory and linguistics to test whether the bilingual language control is guided by the efficiency. And whether the language system selects an element based on the effort required to retrieve that element regardless of the language L1 or L2 it belongs. The study will be helpful to understand the cross-linguistic universals and its consequences on bilingual processes and also opens the possibility to investigate the effect such universals on language learning in future.

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References

- [1] Bialystok, E., Craik, F. I. M., Green, D. W., Gollan, T. H.(2009). *Bilingual minds, Psychological Science in the Public Interest*, 10, 89129.
- [2] Chao, Y., & Zipf, G. (1950). *Human Behavior and the Principle of Least Effort: An Introduction to Human Ecology. Language*, 26(3), 394. doi: 10.2307/409735

- [3] Gibson, E., Futrell, R., Piantadosi, S., Dautriche, I., Mahowald, K., Bergen, L., Levy, R. (2019). *How Efficiency Shapes Human Language*. *Trends In Cognitive Sciences*, 23(12), 1087. doi: 10.1016/j.tics.2019.09.005.
- [4] Green, D. W., & Abutalebi, J. (2013). *Language control in bilinguals: The adaptive control hypothesis*, *Journal of Cognitive Psychology*, 25(5), pp. 515-530.
- [5] Kutas, M. & Federmeier, K. D. (2011). *Thirty years and counting: Finding meaning in the N400 component of the event-related brain potential (ERP)*. *Annu. Rev. Psychol.* 62, 621–647.
- [6] Luk, G., Bialystok, E., (2013). *Bilingualism is not a categorical variable: Interaction between language proficiency and usage*. *Journal of Cognitive Psychology*, 25, 605–621.
- [7] Piantadosi, S., Tily, H., & Gibson, E. (2012). *The communicative function of ambiguity in language*. *Cognition*, 122(3), 280-291. doi: 10.1016/j.cognition.2011.10.004.
- [8] Steinmann, M., & Chomsky, N. (1978). *Reflections on Language*. *Leonardo*, 11(2), 157. doi: 10.2307/1574029.
- [9] Shannon, C. (1948). *A Mathematical Theory of Communication*. *Bell System Technical Journal*, 27(4), 623-656. doi: 10.1002/j.1538-7305.1948.tb00917.x.