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Political Communication as Epistemic Consumption: A Neuroeconomic Perspective

Political Science

Keywords: non-semantic type of communication, communication theory, verbal and non-verbal communications, semantic analysis, Barack Obama, etc.

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Abstract

The aim of this paper is to contextualize and unify existing interdisciplinary literature by introducing the concepts of a non-semantic type of communication, namely pragmatic communication. Despite the utility of cognitively deducing the connotative and denotative meaning of the message we also propose that communication without semantics contains a so called expectancy violation utility which causes neurophysiological changes that help the receiver to reduce the uncertainty (or prediction errors) about its environment. Increasing the uncertainty of the environment where the public lives, would create the tendency for the publics to prefer the more surprising messages, that is, more information rich political messages. This uncertainty reduction with uncertainty seeking behavior illustrates the shift from exploitative into explorative behavior of the audience which indirectly impacts the value of the political message, by making the political message obsolete.

1. Introduction

Defining communication has been a debate for decades in communication science. Communication is found to be related with wide spectrum of activities and concepts. Some of the communication theorists focused on epistemology of communication (Foerester, 1980), others on the ontology of communication (Jensen, 1995) a third group on pragmatics of communication (Chowdhury, 2003). Even nowadays there is no unique definition of communication. Despite the lack of determining a unified definition of the communication phenomena, academics agree that the paradigm of communication science relies upon the communication phenomenon which represents a relational process where a message is created and interpreted with the aim to elicit a response (Allyn & Festinger, 1961). Purpose of communication is to deliver meaning. The fact that meaning is created by perception, communication ends to be perceptual activity (Broadbent, 2013). Crafting the semantic content of the messages in such a way that it would elicit a response based on the receiver's denotative and connotative interpretation, leads to the traditional thought that communication is only about exchanging meaning. Meaning on the other side, is thought to stimulate cognitive, behavioral, emotional and physiological responses (Pulvermüller, Shtyrov, & Ilmoniemi, 2005). Traditional research on communication theory tried to condemn the view that semantic characteristics of the source of the message and the context of the message are the cornerstone of communication and influence. In this paper we address to communication as a reflection of intentionality.

Intentionality represents a purposive action of active receipt of information from the world by directing sense organs to sample the input from the external environment (Freeman, 1999). The

concept of intentionality has been introduced by St. Thomas Aquinas in the 13th century with the aim to describe the motivation behind the phenomenon where living beings push themselves in a specified direction into the world ("intendere", Latin for "to stretch forth") and making use of the consequences of this action by learning and adapting to these consequences.

The aim of this adaptation is to decrease the surprising and thus negative impact of these consequences. Communication activities represent exploitation efforts, or the action of making use of currently available informational resources. On the other hand, the subject's second intentionality of optimizing and principle of least action (Hanc & Taylor, 2004) was trying to decide whether she should continue exploiting current resources, that is the available sensory information, or should she shift to exploration which is leading to new sensory information. This tradeoff between exploitation and exploration is well known in the field of neuroscience and artificial intelligence (Schlosshauer, 2005). What is of additional interest in this paper is to study the shift of the intentionality from exploitation into exploration activity, because it is this shift of intention that defines the relevance of a political message for the publics after a political communication through media has been occurred. Semantic properties of the message alone are useful to reduce the general uncertainty about the configuration of the environment, and it is the relative frequency of semantic properties of the message which measures the expectancy violation impact of the message during exploitation. This expectancy violation or prediction error serves the receiver to "learn by making mistakes" thus become better predictor (Schultz & Dickinson, 2000). However, expectancy violation is not infinite. There is a point when the message becomes functionally obsolete in terms of reducing the uncertainty of the receiver about the hidden states of the world. Therefore, despite the exploitation role of the intentionality for denotative and connotative meaning, the very act of deciding to shift to exploratory role in order choose other sensory information leads to the intentionality of optimizing and principle of least action. This leaves open the question: **is intentionality of political communication also non-semantically oriented epistemic consumption?** The key principle of self-organizing behavior is survival (Barton, 1994). Self-organization property represents the inner ability and intentionality to cope with a particular uncertainty in the configuration of the environment through selective sampling of external sensory inputs, that is, external sampling of environment's salient patterns (Itti, Koch, & Niebur, 1998). Then after, these samples are being used by the system to make inferences about future potential configurations of the environment, also known named as hidden states (Friston, 2010). Self-organizing behavior in mathematical terms can be described as the minimization of the Shannon entropy or the uncertainty that would endanger the system's existence in the world (Friston, Kilner, & Harrison, 2006). Both biological and non-biological systems are self-organized systems. They both have phase boundaries or thresholds which act as criteria for behavior optimization and they both can perform phase shifts. However, biological systems are in advantage compared to non-biological systems because of intentional action selection on which phase they will shift. Intentional action is followed by learning and gaining knowledge about the hidden states of the world. It of huge importance in external environment sampling process for the reason that biological systems would be more effective in sampling the particular environment configuration states that would lead to inference of those hidden states.

Communication can be categorized in different types based on what categorization criteria is used. Based on communication channels there are verbal and non-verbal communications, based on style and purpose there are formal and informal communications, internal and external, written or oral, vertical and horizontal. In this paper we want to underline the role that communication plays in self-organization of biological systems.The interest for denotative and connotative meaning is related to the relative frequency which is the probability of encountering a particular semantic property of the message. If semantic properties of the message are predictable for the receiver, the interest for these semantic properties drops significantly.

In other words, manipulating the probability of semantic properties of the message impacts the utility of the denotative and connotative meaning. In biological systems there is a tendency to shift from exploitation to exploration as long as current denotative and connotative meaning become obsolete (Cohen, McClure, & Angela, 2007). This indicator that a shift to exploration is required has a meaning in itself which is not semantical but yet it informs the biological system. As long as communication purpose is to elicit a response, this can be done by semantics, but also can be done without semantics by manipulating the probability of the properties of the message. The role of statistical, which is probabilistic properties of the object leads to quantum theory, where the research suggests that meaning is created by perception and perception is probabilistic (Rao, Olshausen, & Lewicki, 2002). According to Niels Bohr (Honner, 1987) everything is probabilities and possibilities unless observer observes and creates meaning. Similarly, according to Copenhagen interpretation (Stapp, 1972), physical systems generally do not have definite properties prior to being measured, and quantum mechanics can only predict the probabilities that measurements will produce certain results. The act of measurement affects the system, causing the set of probabilities to reduce to only one of the possible values immediately after the measurement (Schlosshauer, 2005). This reduces the Shannon's entropy (Shannon, 2001), respectively the information quantity the system offers to the observer. Under the same logic, after the act of measurement of the political message's statistical properties, the set of the messages' possible probabilities are to be reduced to only one and thus the information quantity the political message provides to the audience drops nearly to zero, thus the political message becomes functionally obsolete. To illustrate this, in the next subsection we make use of a hypothetical experiment.

2. Hypothetical experiment

Imagine that couple of hours after the United States of America president Election Day of year 2008, audience is uncertain thus very curious to see who has won the elections. When they search for an online portal, there they read the following news report statement:

"The 44th president of the United States of America is Barack Obama."

A semantic analysis of this news report in terms of denotation provides information that the president of United States of America was chosen and he is Barack Obama. In addition, the audience concludes that the winner of the elections where many other politicians were competing, it turned out the winner to be Barack Obama. But this leads to a big surprise, because according to

audience's beliefs or expectations, the chances that Barack Obama could win were very low (not to say impossible), taking into account the audience's previous knowledge that during the history of the USA there has been a considerable number of presidents (in total 43) and up till the "current" elections none of them was black. The audience is surprised and thus reduced the uncertainty about who will be the winner, but they start wondering about the accuracy and reliability of the news report. So, they encounter a new uncertainty: **How accurate are the news that are reporting the election results?** Depending on what the audience finds out, they again will be highly surprised (if the news report is true positive) or lowly surprised (if the news report are false negative). This hypothetic experiment reveals a set of uncertainties the receiver of the message faces with when receiving a political message through news.To further formalize our uncertainty reduction, respectively to measure the scope of the surprise, we can further apply the laws probability theory. In the hypothetic experiment, the scope of how big the surprise is, depends on our expectations and beliefs formed by knowing the fact that from previously 43 presidents of USA none of them was black and by the fact that from our previous experience of reading news reports, we do know that news not always report the truth. Therefore, we have to answer two questions:

- With what prior beliefs does the audience read the news that the new president of USA will be black?
- What is the audience's posterior beliefs after they read the news that the new president of USA will be black?

The "pure" prior which we consider it to be the prior which has not been combined with any evidence is formed by the frequentist logic, or quantifying the uncertainty by the relative frequency of events occurring (Neyman, 1977). However, in the case when there has been no black USA president elected before, this "pure" prior would not make any sense, because it would be zero, which means that the audience would have no expectation at all that the president of USA can be black and this does not represents the real tendency (or even hope for Barack Obama fans) of the audience to believe that the president of USA can be black. To measure the level of surprise when reading the message **"The 44th president of the United States of America is Barack Obama."**we have to measure the expectations of the audience for reading a news report with such statement. In addition, we frame the audience's belief formation into two main stages:

- Belief formation BEFORE reading the news reports about the results of 2008's USA presidential elections and

- Belief formation AFTER reading the news reports about the results of 2008's USA presidential elections.

2.1 Belief formation BEFORE reading the news report

We can formally illustrate this non-zero prior belief updated with the element of evidence. The audience is often reading news, which according to their experience (or by consulting the official statistics of news report sincerity) they are aware that the news reports are not true positive

all the time. For simplicity, we assume that the truth of news reported is 88%. In other words, in 88% of the time news report true positive and in 12% of the time news report false positive. In our hypothetic example, this quantified uncertainty about the validity of the news reports as source of information, is assumed to state that if the newly elected USA president would be black, there is a chance of 88% that the news would report that the newly selected USA president is black, and 12% chance that the news would report that the newly selected USA president is black if indeed the newly elected president is white. This evidence is proven that is being taken under consideration by the message receiver(Knill & Pouget, 2004). Let Θ be a set of two mutually exclusive events A=**"2008 presidential elections' winner will be black**" and X= "**News will report that the winner is black**", and let $\Theta = \{A, X\}$. Both of these events have the opposite events: $\bar{A}$= **"2008 presidential elections' winner of 2008 will be white"** and$\bar{X}$=**"News will report that the winner is white".**Let N be the total number of presidents USA has had in history including the newly chosen, which is $N = 44$ presidents. Assuming a uniform distribution among all the 44 candidates, the relative frequency of the person who is president of USA being black is very low $P(A) = \frac{1}{N} = \frac{1}{44} = 0{,}022$ or 2.2%, whereas the relative frequency that the president of USA is white is very high $(\bar{A}) = \frac{43}{N} = \frac{43}{44} = 0{,}977$. $P(A)$ represents our prior belief or expectation that we had about whether the winner of 2008 elections will be black skinned before we receive any evidence. Prior beliefs usually are formed from past experiences. However, there is not a must to have prior past experiences in order to have prior beliefs. For example, a prior belief in our case where there was no black president for 43 times in a row, does not mean that the prior beliefs of the receiver of the political message regarding the issue of whether the 44th president will be black or not can be very little (as we hypothesize 0.022), but not zero. It is in human nature to have belief for things that have never happened or never seen before. Prior beliefs can be considered as a sort of intuitive intelligence.

For further illustration, if there would be in total only 3 presidents in the history of USA, all white skinned, then probability that the fourth president would be black skinned is approximately ten times higher $P(A) = \frac{1}{4} = 0{,}25$ relative to(Knill & Pouget, 2004) the probability $P(A) = 0.022.$ If this was the case, our beliefs that the winner of the 2008 election will be black is considerably higher, thus both the curiosity to find out whether the new USA president is black and the surprise of the news that this hypothesis of ours turns out to be true, would be way lower. In summary, the probability that the person is president of USA and he is black, can be represented by joint probability(Durrett, 2010) as $\mathrm{P}(A, X) = P(\mathrm{A}|X) \cdot P(X) = P(\mathrm{X}|A) \cdot P(\mathrm{A})$

Probability of the newly selected president being black given that the news report the same can be formalized as conditional probability $P(\mathrm{X}|A)$ which from the above equation can be computed as$P(A \mid X) = \frac{P(\mathrm{X}|A) \cdot P(\mathrm{A})}{P(X)}$, given that $P(X) > 0$.This formula represents the Bayes Theorem. This answers the question "how likely is the winner to be black when news report says he is black?". This formula is consisted of four elements:

- **The posterior** $P(A \mid X)$: Probability that newly selected USA president is black (A) given that news report so (X). This is what we want to know: How likely is it the newly elected president of USA to be black given that news report so?

- **The prior** $P(A)$: Probability of USA president elected being black.

- **The likelihood** $P(X|A)$: Probability that news report says that newly elected president is black (X) given that he really was black (A).

- **The normalizing constant** $P(X)$: is nothing but a normalizing constant, that is, a constant that makes the posterior density add up to one. It is also known as the marginal probability of data and it is calculated as: $P(X) = P[(X \cap A) \cup (X \cap \bar{A})] = P(X \mid A) \cdot P(A) + P(X \mid \bar{A}) \cdot P(\bar{A})$.

The normalizing constant for year 2008 in our hypothetical experiment is calculated to be: $P(X) = 0.88 \cdot 0.022 + 0.12 \cdot 0.977 = 0.136$. Whereas the posterior belief that the newly selected USA president in elections of 2008 is black, is calculated to be: $P(A \mid X) = \frac{P(X \mid A) \cdot P(A)}{P(X \mid A) \cdot P(A) + P(X \mid \bar{A}) \cdot P(\bar{A})} = \frac{0.019}{0.136} = 0.141$. At the moment that the message receiver takes into consideration this evidence he updates the first prior of 2% with the evidence of 88%, and this update results into a posterior of 14.1% belief that the newly elected president in 2008 will be black (Table 1). So, before reading the news, the audience has expectation of 14.1% that the newly elected president in 2008 will be black given that they will receive such information from the news. Therefore, the posterior of 14.1%, at the moment of reading news acts as prior.

Table 1. Matrix table illustrating the publics' belief formation in terms of subjective probability before reading the news for presidential elections results of 2008. We hypothesized the values of the prior to be $P(A) = \frac{1}{44} = 0.022$ and not zero, because in reality humans not always form prior beliefs based on frequency of an event happening. They tend to form prior beliefs even for events that they have never seen or events that never occurred. Whereas the values for the likelihoods are hypothesized to represent the bias of news reports, namely the probability that news report the newly elected president to be black given that in reality he is black (the true positive), respectively the probability that news report the newly elected president to be black given that in reality he is white (the false negative).

Color of the USA president	PRIORS as % of total USA presidents (N=44)	LIKELIHOODS as the sincerity of the news (USA statistics)
BLACK	$P(A) = \frac{1}{44} = 0.022$	$P(X \mid A) = 0.88$
WHITE	$P(\bar{A}) = \frac{43}{44} = 0.977$	$P(X \mid \bar{A}) = 0.12$

Respectively, the posterior belief that the newly selected USA president in elections of 2008 is white, is calculated to be: $P(\bar{A}\,|\,X) = \frac{P(X\,|\,\bar{A})\cdot P(\bar{A})}{P(X\,|\,A)\cdot P(A)+P(X\,|\,\bar{A})\cdot P(\bar{A})} = \frac{0.117}{0.136} = 0.858$. The posterior belief that the newly selected USA president in elections of 2008 is black turns out to be considerably lower than the newly selected USA president in elections of 2008 is white. However, the probability of the 44th president of USA to be white is not 0.977 as we would logically think, instead it is 0.873 after taking into consideration the prior and our experience with the sincerity of the news reports as evidence. This is an illustration of how the public, which is the receiver of the political message, through active inference creates expectations about the outcomes of events toward which the intentionality is focused. The fact that the audience has an expectation (a prior) of 14.1% for reading a news report that the newly elected president in 2008 will be black determines the surprise of reading such message from the news in year 2008. This surprise also known as information gain(Lee & Lee, 2006), can be measured with the Kullback-Leibler divergence (Kullback, 1997) which measures the distance between two probability distributions, in our case it is the distance between the prior of 14.1% and the posterior formed after updating our prior with the evidence that only 88% of time news report are true positive. This can be calculated as: $KL = [P(A\,|\,X)\|P(A)] = \sum P(A\,|\,X)\ log\frac{P(A\,|\,X)}{P(A)} = 0.114$. At this point we conclude that audience starts reading the news reports for the 2008's USA presidential election results with a prior of 0.141 that the new president of USA will be black. In the next subsection we formalize the belief formation after reading the news report and we calculate the level of surprise when reading the news report that the newly elected president of USA in 2008 is black.

2.3 Belief formation AFTER reading the news report

To measure our surprise of reading the news which states that the 44th elected president of USA is black, we have to formalize the audience' belief formation after reading the news reports. The posterior belief calculated previously $P(A\,|\,X) = 0.141$ becomes the prior belief before reading the news report that the 44th elected president of USA is black (Table 2). So, in 2008 we will have this normalizing constant, $P(X)_{2008} = 0.88\cdot 0.139 + 0.12\cdot 0.861 = 0.227$ and $P(A\,|\,X)_{2008} = \frac{P(X\,|\,A)\cdot P(A)}{P(X\,|\,A)\cdot P(A)+P(X\,|\,\bar{A})\cdot P(\bar{A})} = \frac{0.122}{0.227} = 0.547$. Respectively, belief that the newly selected USA president in elections of 2008 is white, is: $P(\bar{A}\,|\,X)_{2008} = \frac{P(X\,|\,\bar{A})\cdot P(\bar{A})}{P(X\,|\,A)\cdot P(A)+P(X\,|\,\bar{A})\cdot P(\bar{A})} = \frac{0.103}{0.227} = 0.453$.

Table 2. Matrix table illustrating the publics' belief formation in terms of subjective probability in presidential elections of 2008. We hypothesized the values of the prior to be $P(A) = P(A\,|\,X)_{2008} = 0.139$, because the `public in already have a previous experience for the elected president of USA to be black. The values for the likelihoods are assumed to remain the same for the validity of news reporting in year 2008 as in year 2008.

Color of the USA president	PRIORS as % of total USA presidents	LIKELIHOODS as the sincerity of the news (USA statistics)
BLACK	$P(A)_{2008} = P(A \mid X) = 0.141$	$P(X \mid A) = 0.88$
WHITE	$P(\bar{A}) = 1 - P(A \mid X)_{2008} = 0.858$	$P(X \mid \bar{A}) = 0.12$

Knowing the audience's posterior belief, by using the Kullback-Leibler divergence we can calculate the surprise the audience experiences when they read the news report in year 2008 that the44th elected president of USA is Barack Obama

as$KL_{2008} = \left[P(A \mid X)_{2008} \| P(A)\right] = \sum P(A \mid X)_{2008}\, log \frac{P(A \mid X)_{2008}}{P(A)} = 0.321.$

2.4 Surprise of reading news report that the elected USA president in 2012 is again black

In USA presidential elections of 2012, Barack Obama was re-elected as president of USA. The belief formation of the audience reading the news that the 45th president of USA is again black can be formalized as follows (Table 3)

$P(X)_{2012} = P(X \mid A) \cdot P(A)_{2012} + P(X \mid \bar{A}) \cdot P(\bar{A})_{2012} = 0.536$ and

$P(A \mid X)_{2012} = \frac{P(X \mid A) \cdot P(A)}{P(X \mid A) \cdot P(A) + P(X \mid \bar{A}) \cdot P(\bar{A})} = 0.898$. Respectively, belief that the newly selected USA president in elections of 2012 is white, is$P(\bar{A} \mid X)_{2008} = \frac{P(X \mid \bar{A}) \cdot P(\bar{A})}{P(X \mid A) \cdot P(A) + P(X \mid \bar{A}) \cdot P(\bar{A})} = 0.101.$

Table 3. Matrix table illustrating the publics' belief formation in terms of subjective probability in presidential elections of 2012. We hypothesized the values of the prior to be $P(A)_{2012} = P(A \mid X)_{2008} = 0.547$, because the `public in already have a previous experience for the elected president of USA to be black. The values for the likelihoods are assumed to remain the same for the validity of news reporting in year 2012 as in year 2008.

Color of the USA president	PRIORS as % of total USA presidents (N=45)	LIKELIHOODS as the sincerity of the news (USA statistics)
BLACK	$P(A)_{2012} = P(A \mid X)_{2008} = 0.547$	$P(X \mid A) = 0.88$
WHITE	$P(\bar{A})_{2012} = 1 - P(A \mid X)_{2008} = 0.452$	$P(X \mid \bar{A}) = 0.12$

However, the surprise, in 2012 elections would not be as big as in 2008, because our prior for 2012 is the posterior of 2008, and the posterior of 2008 will be adjusted with our new new evidence, thus the distance in between the prior belief and posterior belief in 2012 decreases. As we can see, the surprise of the political message that the newly selected president of USA in 2008

is black, is higher than the surprise of the same political message received in 2008 ($KL_{2008} > KL_{2012}$)for$r = \frac{KL_{2008}[P(A|X)\|P(A)]}{KL_{2012}[P(A|X)\|P(A)]} = \frac{0.321}{0.193} = 1.66\ times.$

3. Bringing all together: pragmatic communication as instrument for political communication

Politics main instrument is communication. It is communication that allows to strategically control when, how and where the information is spread to the public. There are two main types of communication: verbal and non-verbal. The basic constitutive element of both of these types of communication is the semantics or the "meaning".

Traditional research on communication theory tried to condemn the view that semantics or the meaning is the cornerstone of communication and influence. In this study we propose an additional perspective. Non-semantic political messages are measured by the absolute entropy of message.

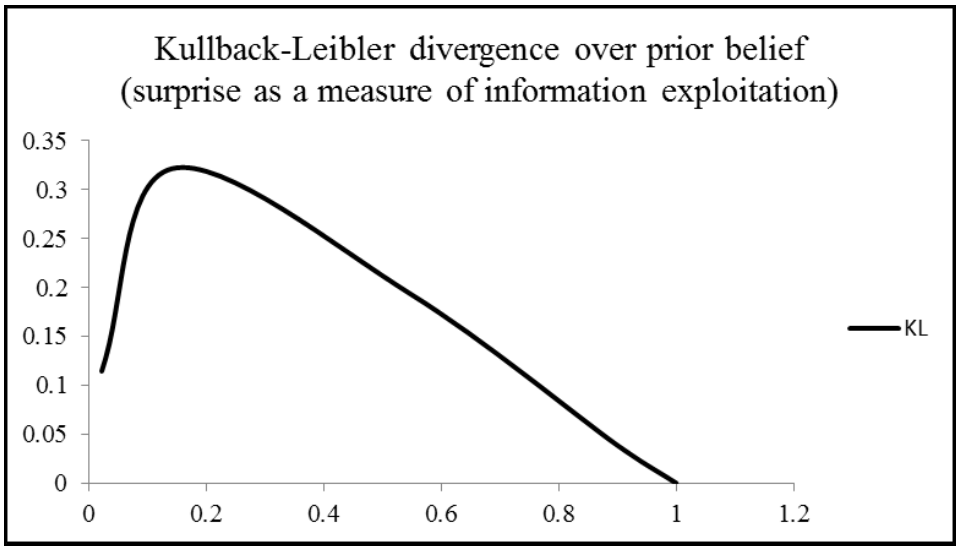
The relative entropy of the message represents the entropy of the message for each individual of the public (entropy of the message differs among the individuals in the public). Together with the semantic or meaning of the news report who serves a purpose, and that is the purpose to reduce uncertainty about our curiosity of who is the election winner, we do receive another element which somehow "informs" or creates a change in our physiology (arousal) and that is the element of surprise. Exchanging information without meaning or communicating by surprising the receiver represents pragmatic communication.

The very role of pragmatic communication is to feed the epistemic curiosity of the audience by providing political messages high in relative entropy (surprise) and delaying as much as it is possible the decision of the audience to shift from information exploitation into information exploration activity.

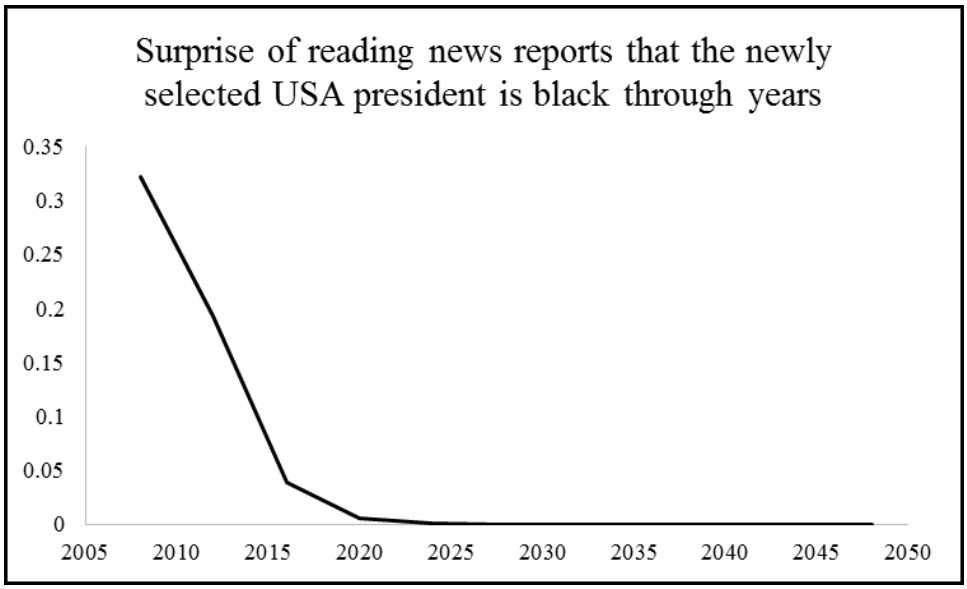
In Graph 1, we have illustrated how the political message of the news report **"The 44th president of the United States of America is Barack Obama."**loses its capability to surprise the audience, that is to satisfy their epistemic consumption appetite where at the point that the difference between the prior and posterior beliefs of the audience are almost equal, the audience decides to shift into reading (exploring) new more interesting political messages. In

Graph 2, we use the same simulation data to predict the surprise of the same political message from the hypothetical experiment in a temporal basis.

Graph 1. The point when the audience decides to shift from information exploitation to information exploration is when the surprise or information content of the political message measured by Kullback-Leibler divergence becomes zero, $KL[P(A \mid X) \| P(A)] = 0$.



Graph 2. A hypothesized temporal scenario of the "surprise" of reading in the news that the newly selected president of USA is black.



4. Conclusion

In this paper we have applied probability theory in order to quantify the uncertainty of the public when receiving a political message. It turned out that the statistical properties of the political message play an important role in defining the audience's decision to shift their intentionality from information exploitation to information exploration, or epistemic consumption, a decision which directly causes the political message to become functionally obsolete.

By functionally obsolete we address to the function that the political message has on eliciting neurophysiological response to the receiver of the message through surprise. We conclude that as long as political communication role is on eliciting response to the audience, this response can be elicited not only through syntactic and semantic communication, but also through manipulating the statistical properties of the message. The latter elicitation of neurophysiological responses by manipulating the relative entropy of the message is called political pragmatic communication.

References

Allyn, J., & Festinger, L. (1961). The effectiveness of unanticipated persuasive communications. The Journal of Abnormal and Social Psychology, 62(1), 35.

Barton, S. (1994). Chaos, self-organization, and psychology. American Psychologist, 49(1), 5.

Broadbent, D. E. (2013). Perception and communication. Elsevier.

Chowdhury, G. G. (2003). Natural language processing. Annual Review of Information Science and Technology, 37(1), 51–89.

Cohen, J. D., McClure, S. M., & Angela, J. Y. (2007). Should I stay or should I go? How the human brain manages the trade-off between exploitation and exploration. Philosophical Transactions of the Royal Society B: Biological Sciences, 362(1481), 933–942.

Durrett, R. (2010). Probability: theory and examples. Cambridge university press.

Foerster, H. von. (1980). Epistemology of communication. The Myths of Information: Technology and Postindustrial Culture, 18–27.

Freeman, W. J. (1999). Consciousness, intentionality and causality. Journal of Consciousness Studies, 6(11–12), 143–172.

Friston, K. (2010). The free-energy principle: a unified brain theory? Nature Reviews Neuroscience, 11(2), 127.

Friston, K., Kilner, J., & Harrison, L. (2006). A free energy principle for the brain. Journal of Physiology-Paris, 100(1–3), 70–87.

Hanc, J., & Taylor, E. F. (2004). From conservation of energy to the principle of least action: A story line. American Journal of Physics, 72(4), 514–521.

Honner, J. (1987). The description of nature: Niels Bohr and the philosophy of quantum physics.

Itti, L., Koch, C., & Niebur, E. (1998). A model of saliency-based visual attention for rapid scene analysis. IEEE Transactions on Pattern Analysis and Machine Intelligence, 20(11), 1254–1259.

Jensen, K. (1995). The social semiotics of mass communication.

Knill, D. C., & Pouget, A. (2004). The Bayesian brain: the role of uncertainty in neural coding and computation. TRENDS in Neurosciences, 27(12), 712–719.

Kullback, S. (1997). Information theory and statistics. Courier Corporation.

Lee, C., & Lee, G. G. (2006). Information gain and divergence-based feature selection for machine learning-based text categorization. Information Processing & Management, 42(1), 155–165.

Neyman, J. (1977). Frequentist probability and frequentist statistics. Synthese, 36(1), 97–131.

Pulvermüller, F., Shtyrov, Y., & Ilmoniemi, R. (2005). Brain signatures of meaning access in action word recognition. Journal of Cognitive Neuroscience, 17(6), 884–892.

Rao, R. P. N., Olshausen, B. A., & Lewicki, M. S. (2002). Probabilistic models of the brain: Perception and neural function. MIT press.

Schlosshauer, M. (2005). Decoherence, the measurement problem, and interpretations of quantum mechanics. Reviews of Modern Physics, 76(4), 1267.

Schultz, W., & Dickinson, A. (2000). Neuronal coding of prediction errors. Annual Review of Neuroscience, 23(1), 473–500.

Shannon, C. E. (2001). A mathematical theory of communication. ACM SIGMOBILE Mobile Computing and Communications Review, 5(1), 3–55.

Stapp, H. P. (1972). The copenhagen interpretation. American Journal of Physics, 40(8), 1098–1116.