Discovering the Cognition behind Language: Financial Metaphor Analysis with MetaPro

Rui Mao
Continental-NTU Corporate Lab
Nanyang Technological University
Singapore
rui.mao@ntu.edu.sg

Kelvin Du
School of Computer Science and Engineering
Nanyang Technological University
Singapore
zidong001@e.ntu.edu.sg

Yu Ma
School of Economics and Management
Nanjing University of Science & Technology
China
mayu@njust.edu.cn

Luyao Zhu
School of Computer Science and Engineering
Nanyang Technological University
Singapore
luyao001@e.ntu.edu.sg

Erik Cambria
Continental-NTU Corporate Lab
Nanyang Technological University
Singapore
cambria@ntu.edu.sg

***Abstract*—Metaphors frequently appear in financial news headlines due to their ability to effectively convey complex financial concepts and market trends in a concise and memorable manner. Cognitive scientists have found that metaphors serve as the reflections of human cognition by means of concept mappings. In this work, we aim to analyze the metaphorical expressions and associated cognitive patterns employed by financial analysts in the headlines of financial analysis reports. Such an examination would enhance our comprehension of the cognitive state of financial analysts regarding various financial trends. We employ the latest computational metaphor processing tool, MetaPro to achieve this target by mining metaphors and cognitive patterns from 1,407,328 financial analyst report headlines, spanning the period from 14 February 2009 to 11 June 2020. We analyze the mined concept mappings by different time periods, and market movements, and deliver novel findings in these two dimensions.**

***Index Terms*—Finance, Computational Metaphor Processing, Cognitive Mining**

I. Introduction

Metaphors are a pervasive feature of our daily linguistic interactions. Conceptual Metaphor Theory [1] believed that metaphors also reflect human cognition, because a metaphor implies the concept projection from a target domain to a source domain, where the target and source domains are different. Target concepts refer to the concepts that are described or understood through the use of a metaphor. Normally, target concepts are abstract or complex. Metaphors provide a way to make them more understandable by projecting them to more concrete or familiar source concepts. Conversely, source concepts encompass the concrete or familiar concepts employed to represent the target concepts. Source concepts form the foundation for metaphorical analogies, thereby aiding in the illustration of abstract target concepts in a more accessible manner.

This study is supported under the RIE2020 Industry Alignment Fund – Industry Collaboration Projects (IAF-ICP) Funding Initiative, as well as cash and in-kind contribution from the industry partner(s).

For example, given "I *spent*[1] two days to read a book", we use a more concrete MONEY[2] (source) concept to describe an abstract TIME (target) concept. Then, conceptually, we believe TIME IS MONEY. The MONEY concept explains the preciousness of TIME. Metaphors help us understand abstract concepts. Without the metaphors of "magic, attraction, madness, union, nurturance, and so on", the concept of LOVE is not complete [1]. A famous psychological experiment [2] also confirmed that human cognition can be impacted by metaphors. In the experiments, participants were presented with two reports addressing crime in a city. One report depicted crime as a "wild beast preying on the city", while the other portrayed crime as a "virus infecting the city". It was observed that participants who metaphorically associated crime with a beast were inclined towards adopting punitive or restrictive approaches to combat crime.

On the other hand, participants who viewed crime as a virus tended to favor preventive measures. Notably, the participants in both groups were unaware of the influence exerted by the metaphorical expressions on their analyses and decision-making processes during the experiment. This study highlights the subtle impact of metaphorical language, which can operate at a subconscious level beyond human consciousness. However, the conventional methodologies employed in cognitive studies of metaphors face challenges when it comes to scaling up to larger populations. This limitation arises from their heavy reliance on human-centric analysis through case studies and interviews. Thus, it becomes intriguing to explore the potential of data mining techniques in analyzing cognition related to metaphors within extensive corpora. We focus on analyzing financial metaphors in this work by parsing and investigating concept mappings from financial news headlines.

[1]Italics denote metaphors.
[2]Small capitalized words denote concepts.

The motivation is that financial news headlines often employ metaphorical expressions because of their efficacy in succinctly and powerfully communicating intricate financial concepts and events. On the other hand, the concept mappings behind metaphors likely reflect the cognition patterns of analysts toward a certain market environment. Consequently, the cognition of analysts and their produced analytical reports possess a significant influence on public investment decisions at large. The data source utilized for this study consists of the stock analysts' report headlines pertaining to companies listed on the American Stock Exchange (AMEX), New York Stock Exchange (NYSE), and the National Association of Securities Dealers (NASDAQ) for the period spanning from 14 February 2009 to 11 June 2020.

MetaPro[3] [3] is employed to parse metaphorical expressions from the reports and obtain metaphor interpretation and concept mappings, because it is the most powerful metaphor processing tool that we can use to achieve our research targets from end to end, including state-of-the-art modules in the tasks of metaphor identification [4], interpretation [5] and concept mapping generation [6]. Then, we analyze the obtained concept mappings by different time periods and market volatility (e.g., up and down days). In this work, we aim to solve the following two research questions:

(1) To what extent have there been shifts in concept mappings within the US stock markets over the last decade (Investigated in Section V-A)?

(2) What characterizes the primary concept mappings within distinct market volatility, such as during index up and down days, relative to the index from the preceding trading day (Investigated in Section V-B)?

Accordingly, our main findings are summarized as follows: **a)** By observing the concept mappings over 10 years, we find the distinctive mapping patterns among different market environments, e.g., rising (14/02/2009-28/09/2018) and turbulent (29/08/2018-11/06/2020) markets. In the context of a thriving market, analysts' reports frequently placed emphasis on target concepts such as POSSESSION, DIRECTION, MOTION, ACT and ACTION through the use of metaphorical expressions. However, these concepts do not stand out as prominently in a volatile market. Conversely, during turbulent market conditions, metaphors were commonly employed to elucidate the nuances of new target concepts, including COMMERCE, FORCE, SOCIAL_GROUP, BELIEF, ENVIRONMENT, CONSISTENCY and ATTEMPT. These divergent conceptual choices between markets are indicative of the varied cognitive perspectives held by analysts. The source concepts were also gradually changing over different periods and market environments.
b) On up days, the headlines of analytical reports often exhibit a sense of cautious optimism, as both optimistic and cautionary source concepts are more commonly observed compared to down days. Conversely, during down days, the concept mappings within the reports tend to be more encouraging and persuading than the up days. This trend indicates a tendency among the report headlines to instill investor confidence in a pessimistic market environment, rather than exacerbating the downward trajectory of stock prices. The present study offers two primary contributions:

- We analyze the concept mappings of metaphors in the financial field at scale. To the best of our knowledge, this is the first analytical article that uncovers unlimited mappings between various source and target concept domains with the latest data mining technique.
- We deliver insights on the concept mappings of finance-related metaphorical expressions by different time periods and market movements. The findings from our data analysis serve as a valuable reference for understanding the cognitive patterns of financial analysts in different market periods and validity environments.

[3]https://metapro.ruimao.tech

II. Related Work

A. Text Mining-based Cognition Analysis

Text-based cognition computing has been studied for years. One of the most dynamic domains is affective computing, e.g., sentiment analysis [7] and emotion detection [8]. These works focused on understanding the sentimental (e.g., positive, neutral and negative sentiment polarities) and emotional status (e.g., joy, anger, fear, sadness, and more) of humans. Another significant trend is to detect mental health issues, such as depression [9], suicidal ideation detection [10], and more. By using these cognition- and psychology-oriented text-mining tools, researchers have gained insights based on big data analysis in many fields, such as analyzing public opinions about COVID-19 vaccines [11], presidential election [12], war [13] and metal health [14].

However, the aforementioned cognition analysis works heavily relied on classifiers with a restricted set of labels. As a result, the output of these classifiers and the corresponding analytical results were of low dimensionality, e.g., the statistics of a few labels, which limited their ability to provide deep insights into complex cognitive concepts. Topic modeling was used for analyzing public opinions about climate change [15], disaster [16], and cognition [17] changes, whereas the methods based on topic modeling failed to uncover the specific cognitive processes or mechanisms that underpin individual topics. This limitation arises from the fact that the identified topic words primarily serve as a summary of the overarching theme of a document and are heavily influenced by intended themes from various documents. Han et al. [18] used concept mappings as additional features to improve depression detection in accuracy and explainability. Nevertheless, the cognitive pattern analysis exhibited in a depressed group was primarily demonstrated via two case studies. A broad and systematic analysis of human concept mapping patterns from multiple perspectives is still lacking.

B. Financial Metaphor Analysis

Metaphors frequently appear in financial reports [19], reflecting the thought and practices of financial analysts and even becoming the outposts of the global economy [20]. Metaphors in news headlines can foreground a relevant or interesting aspect of the news story to attract potential readers [19]. Previous works explored and analyzed typical metaphor cases in the financial field [21], [22]. The most popular financial metaphors are bubble [23] and black swans [24], [25]. Arrese [23] analyzed the use of "bubble" as an economic metaphor from news in the case of the "real estate *bubble*" in Spain. Moreover, the "*black swans*" is a typical financial metaphor to reflect rare and surprising events with extreme impacts on financial markets [24]. Glette-Iversen and Aven [25] analyzed the black swan, grey swan and dragon-king metaphors, then discussed the implications for financial risk management. In addition, Forseth et al. [20] explored the metaphors used by the bankers to rationalize banking practices after the 2008 financial crisis, such as "*storm, tsunami and special year*" and "*cocktail party*". However, only very a few financial metaphor cases were analyzed in these studies, which can not provide more valuable insights from the current massive data.

Some financial metaphor analysis works used data mining methods to gain insights from large corpora [26], [27]. Sun et al. [28] studied LIQUID-related metaphorical chunks based on linguistic constituents, such as "cash flow". They explored how far LIQUID metaphorical chunks in business discourse are technical. Sun et al. [29] investigated metaphors to construct the cognitive portrayal of a company as perceived by stakeholders in Chinese and American reports on corporate social responsibility. Sun et al. [30] explored the relationship between the use of metaphorical hashtags, thematic orientations and audience engagement, based on the qualitative and quantitative approaches. Weibo posts from Chinese banks were used as a corpus. They showed that the posts with ANIMATE metaphor hashtags tend to be more engaging and can effectively enhance audience engagement. However, these studies primarily adopted word frequency statistics and word associations to analyze the utilization of metaphors.

Their research scope was confined to a small set of predefined concept domains, which restricts a comprehensive understanding of the cognitive processes involved. We aim to conduct an extensive analysis of financial metaphors using a large corpus and a broader author population, gaining insights derived from diverse concept mappings. By analyzing human concept mappings from metaphors, we can study cognitive patterns without disturbing subjects. This is a big advantage, compared to traditional interview-based [31] or human experiment-based [2] cognition studies.

III. METAPRO

MetaPro is employed to obtain concept mappings from financial news headlines. It is a computational metaphor processing system that can identify and interpret metaphors from the open domain and generate concept mappings. To our best knowledge, this is the only tool that is tailored

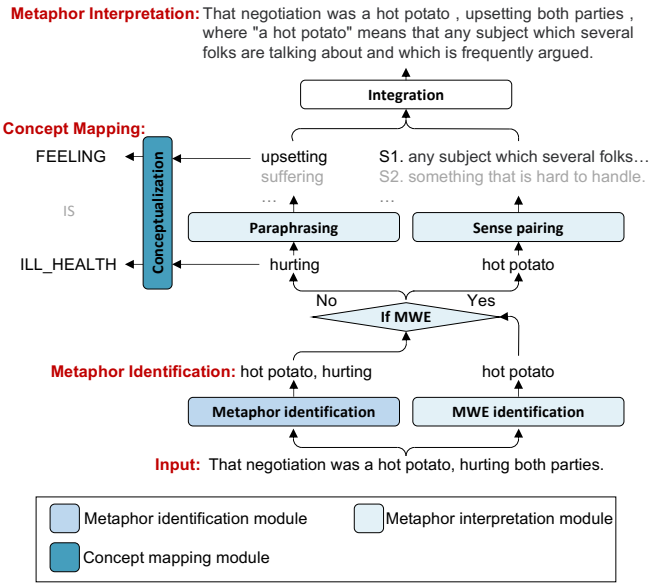

Fig. 1. The overall framework of MetaPro [3]. The colored boxes denote computational modules.

for metaphor processing and can generate concept mappings from end to end in an open domain. MetaPro consists of three technical modules, namely metaphor identification [4], metaphor interpretation [5], and concept mapping [6]. From Fig. 1, the general workflow of MetaPro can be explained with the following example: Given a metaphorical expression, "the negotiation was a *hot potato*, *hurting* both parties", MetaPro identifies "*hot potato*" and "*hurting*" are metaphoric. Then, "*hot potato*" is explained by its most appropriate gloss within the context. The single-word metaphor "*hurting*" is paraphrased into its literal counterpart "upsetting". The target concept "FEELING" is abstracted from the paraphrase "upsetting"; The source concept "ILL_HEALTH" is abstracted from the original metaphor "*hurting*". Finally, the concept mapping is given by the paired target and source concepts from the metaphor, yielding FEELING IS ILL_HEALTH. However, the current version of MetaPro cannot generate concept mappings for metaphoric multi-word expressions.

IV. DATA

The corpus used for our analysis originates from "Daily Financial News for 6000+ Stocks" on Kaggle[4] under the license of CC0 1.0 Universal (CC0 1.0)[5]. The data are publicly available and were gathered from Benzinga[6]. The corpus consists of the headlines of 1,407,328 public analytical articles about 6,204 stocks listed on American stock markets, e.g., NYSE, NASDAQ, and AMEX[7], spanning the period from 14 February 2009 to 11 June 2020.

[4]https://www.kaggle.com/datasets/miguelaenlle/massive-stock-news-analysis-db-for-nlpbacktests

[5]https://creativecommons.org/publicdomain/zero/1.0/

[6]https://www.benzinga.com/

[7]The stock-exchange mapping and its associated statistics in Table I is based on the list from https://github.com/miguelaenlle/Scraping-Tools-Benzinga

TABLE I
DATA STATISTICS.

		Statistics
Original Data	Time span	14/02/2009-11/06/2020
	Market	NYSE/NASDAQ/AMEX
	No. of headlines	1,407,328
	Avg. seq. len. of headlines	11
	Avg. no. of headlines per stock	227
	Avg. no. of headlines per year	124,176
	No. of analysts	1,034
	No. of stocks	6,204
	No. of stocks from NYSE	2325
	No. of stocks from NASDAQ	2519
	No. of stocks from AMEX	1360
MetaPro Output	No. of metaphoric sequences	262,741
	No. of metaphoric words/concept mappings	327,424
	No. of unique metaphors	3,024
	No. of unique paraphrases	2,929
	No. of unique concept mappings	6,929
	No. of unique source concepts	1,274
	No. of unique target concepts	1,156

The articles were written by 1,034 financial analysts. MetaPro detects 327,424 metaphors/concept mappings and 6,929 unique concept mappings from 262,741 (18.67% of overall sequences) metaphorical sequences. The 1,274 unique source concepts and 1,156 unique target concepts conceptualized from 3,024 unique metaphors and 2,929 unique paraphrases show the diversity of our analyzed concepts in this work. The detailed statistics can be viewed in Table I.

V. FINDINGS

A. Concept Mapping Analysis by Time

We generate a visualization depicting the most frequent concept mappings over a span of 10 years. The time period is segmented into four distinct stages, based on the morphological characteristics of the three exchange indices. The initial stage spans from 14 February 2009 to 3 October 2011, during which we observe a gradual increase in both the NYSE and NASDAQ exchanges. The slope of AMEX is relatively steeper at this stage, while it also shows an upward trend. The subsequent stage encompasses the period from 4 October 2011 to 11 February 2016, and similarly shows a gradual increase in the trends. The curves representing these two stages have moderately comparable shapes. The third stage spans from 12 February 2016 to 28 September 2018, characterized by a relatively steeper increase compared to the previous stages for NYSE and NASDAQ. The slope of AMEX is also higher than its slope at Stage 2 and is comparable to its slope at Stage 1. In general, there is a noticeable upward trend observed in the three exchange indices during Stage 3. The final stage covers the period from 29 September 2018 to 11 June 2020, where the three index trends exhibit significant volatility.

Target concepts reflect the fundamental cognition of analysts towards the financial market because they come from the real meanings of metaphorical expressions. An observable concept mapping trend is that target concepts, e.g., POSSESSION, DIRECTION, MOTION, ACT and ACTION were frequently used during the rising market (Stages 1-3), while these concepts did not appear within the most frequent concept mappings at Stage 4. These target concepts may suggest that analysts were trying to emphasize notions of guidance and proactive decision-making, perceiving the market as having a sense of predictability and opportunities for active investment strategies during such periods. On the other hand, 7 out of 15 frequent target concepts, e.g., COMMERCE, FORCE, SOCIAL_GROUP, BELIEF, CONSISTENCY, ENVIRONMENT and ATTEMPT from Stage 4 have never been top-ranked during former stages. These target concepts may suggest that analysts viewed the market as being strongly influenced by economic forces, social dynamics, collective beliefs, consistency in market behavior, environmental factors, and the need for attempts to navigate the challenging market conditions. The above observations show the differences in cognition between different market environments, e.g., rising and turbulent markets.

In contrast, the source concepts represent the concepts that analysts wanted to convey to the public beyond the target concepts (see the beast and virus example in Section I), because they originate from the literal meanings of metaphorical expressions rather than their contextual meanings. Then, we can observe how source concepts are gradually changed over time. During Stages 1 and 2, the common source concepts are SENSE_ORGAN, PERCEPTION, ACT, MOTION, FIGHT, ACTION, LOOK, CHANGE_OF_LOCATION and POSITION. Next, during Stages 2 and 3, the common source concepts are COMMUNICATION, PERCEPTION, DISPLAY, ACT, MOTION, FIGHT, CONFORMITY, ACTION, LOOK, PROPERTY, POSITION and EXTREMITY. During Stages 3 and 4, the common source concepts are COMMUNICATION, CHANGE_OF_STATE, DISPLAY, ACT, HAPPENING, REFERENCE_POINT, MOTION, FIGHT, ACTION, SIZE and LOOK. The common source concepts across all stages are ACT, MOTION, FIGHT, ACTION and LOOK, which are not distinguishable between different stages.

Here, we try to present speculative and hypothetical explanations about the message that the public may receive, based on these source concepts. During Stages 1 and 2, the unique source concepts, e.g., SENSE_ORGAN, PERCEPTION, CHANGE_OF_LOCATION and POSITION may suggest that investors should perceive market dynamics and mind the stock position. During Stages 2 and 3, new concepts such as COMMUNICATION, DISPLAY, CONFORMITY, PROPERTY and EXTREMITY emerge, which may signify the importance of paying attention to market and corporate information, and aligning property profit expectations. The concept of EXTREMITY may lead to a consideration of whether the market price has reached the peak. Finally, the distinctive concepts observed in Stages 3 and 4, such as CHANGE_OF_STATE, HAPPENING, REFERENCE_POINT and SIZE at Stages 3 and 4 potentially increase the recognition of market state changes, the happening big shift, and the establishment of reference points for managing capital sizes. The above points of view are just hypotheses because different message receivers may have different perceptions about the projected concepts in their minds. The interpretation of metaphors and the associated source concepts is inherently subjective and heavily influenced

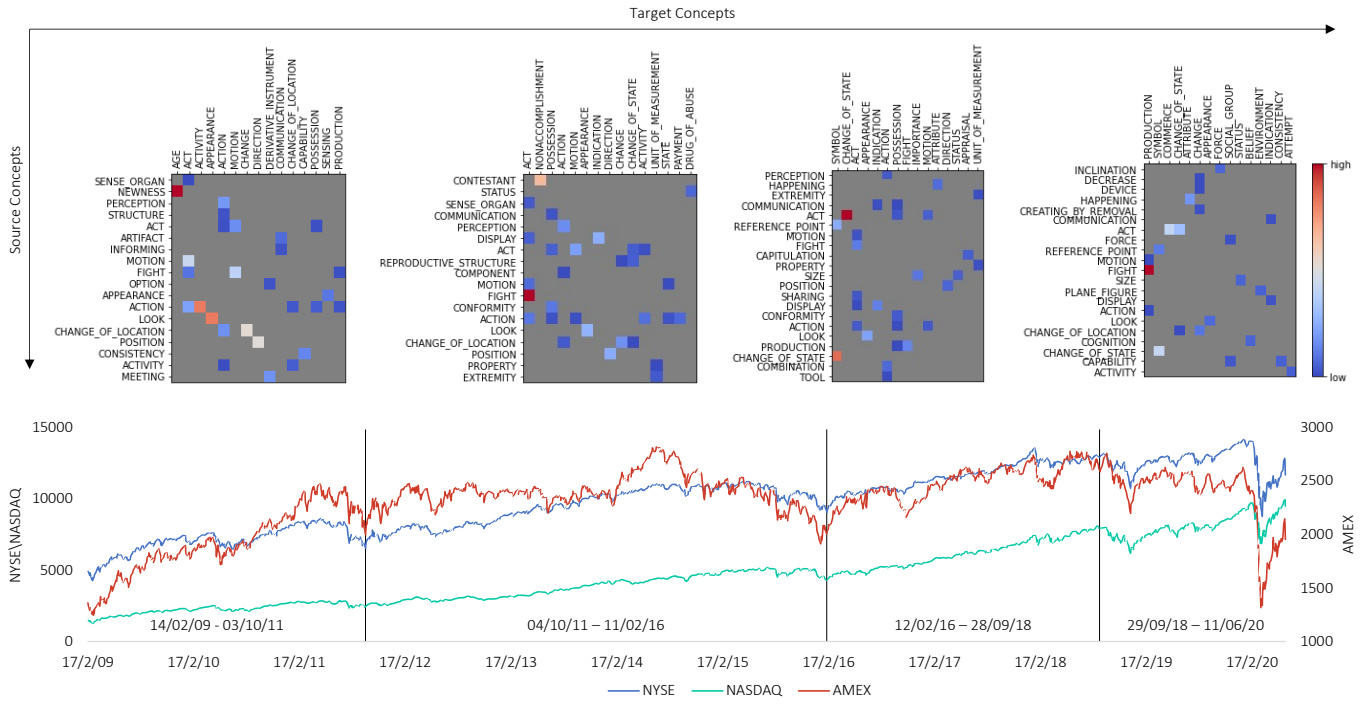

Fig. 2. The temporal evolution of concept mappings. The grey on the heatmaps denotes the absence of concept mappings between target (horizontal axis) and source (vertical axis) concepts. The frequencies of target and source concept mappings are represented by different colors, with gradual changes from blue (low frequency) to red (high frequency). The line chart is plotted according to adjusted closing prices from NYSE, NASDAQ and AMEX.

by shared experiences and cultural backgrounds[8]. However, these concepts can indeed convey information beyond the literal expressions to the public to a certain extent, thereby affecting investment decisions by information recipients.

B. Concept Mapping Analysis by Market Volatility

We list the most distinguishable concept mappings according to the up and down days of markets in Fig. 3. We define an "up day" as a day when the exchange index on a given day exceeds the index observed on the preceding trading day; A "down day" refers to a day when the index value is lower than the previous trading day. The up or down day of a stock is defined by the exchange index movement on that day. We did not use the prices of individual stocks as the measure because the majority of headlines in our corpus do not just reflect the rise and fall of individual stocks. They are information that is directly or indirectly related to a specific stock released on a certain day, including general and industrial information, market analysis, and stock-related analysis. In Fig. 3, we can observe many optimistic source concepts, e.g., MEDICINE IS FEAT, SOUND IS MOVEMENT, SOCIAL_CONTROL IS SOUND and MUSICAL PERFORMANCE IS COMMUNICATION frequently appeared on up days, while they rarely appeared on down days. However, analysts were not blindfolded on up days.

[8]In Thibodeau and Boroditsky's psychological experiment [2], test subjects within the same group who read the same crime report expressed similar opinions on crime control measures.

We can also observe cautionary concept mappings, e.g., CHANGE_OF_INTEGRITY IS ACCIDENT, CONDITION IS DANGER, NONACCOMPLISHMENT IS FORCE, NONACCOMPLISHMENT IS CHANGE_OF_INTEGRITY and MOTION IS STRUGGLE. This complex mix reflects both the complexity of financial market information (e.g., up days are not all good news) and the cautious optimism of analysts on up days. For down days, there are more encouraging and persuading concept mappings than up days, such as ACT IS GATHERING, ACTION IS BEGINNING, OBSTRUCTION IS PHYSICAL_CONDITION, PROPERTY IS COMMUNICATION, RUNNING_AWAY IS ACTION

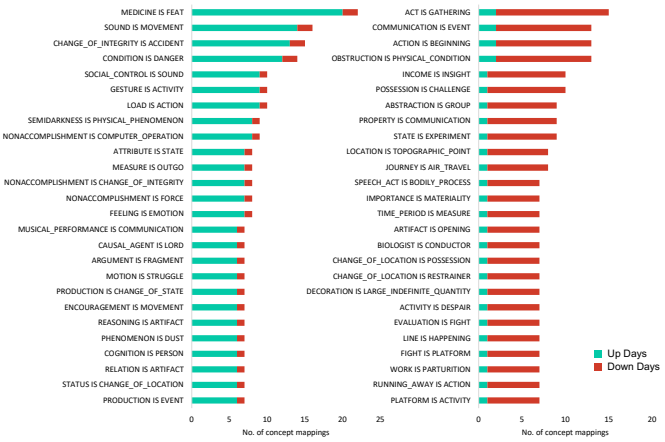

Fig. 3. The distinguishable concept mapping statistics by up and down days.

and WORK IS PARTURITION. These concept mappings indicate a tendency among the analytical report headlines to foster investor confidence in a pessimistic market environment, rather than exacerbating the decline of stock prices. However, there is one hopeless exception that also frequently appeared during downward market trends, e.g., ACTIVITY IS DESPAIR. This particular mapping may signify the pessimistic sentiment conveyed in certain reports under such market conditions.

VI. Conclusion

This study employs MetaPro, a computational metaphor processing tool, to conduct cognitive research in the financial domain. The cognitive analysis is based on metaphorical concept mappings that are parsed from the headlines of 1,407,328 financial analysis reports over 10 years. Previous psychological experiments and cognitive studies have posited that metaphor analysis can offer insights into human cognition. Expanding on this groundwork, our data-driven study represents a pioneering effort in the field, as it utilizes extensive data and computational approaches to investigate cognitive processes through the analysis of metaphors and the unlimited mappings between various concept domains. We present significant findings pertaining to the temporal evolution of concept mappings, and the concept mapping variations during up and down days.

Our research demonstrates that we can use concept mappings to analyze human cognition from multiple aspects. Our uninterrupted analysis method provides several advantages over human-involved experiments on cognitive research. First, gathering sufficient data for quantitative analysis is challenging in human experiments, making it difficult to explore research questions from multiple perspectives during stratified analysis. However, by leveraging the widespread presence of metaphorical expressions in everyday text, and adhering to ethical guidelines and privacy protection, we can access a large number of research samples. Next, traditional human-involved cognitive research heavily relies on participant cooperation. Obtaining natural cognitive feedback is crucial for the success of experiments. In contrast, with permission or using publicly available data, our method can analyze the everyday expressions of the research subjects without interference, which more truly reflects the cognitive situation of the subjects. Finally, recruiting qualified participants and experts may be costly. Conversely, the employed automated data mining tool enables us to analyze large samples at a very low cost.

References

[1] G. Lakoff and M. Johnson, *Metaphors We Live by*. University of Chicago press, 1980.

[2] P. H. Thibodeau and L. Boroditsky, "Metaphors we think with: The role of metaphor in reasoning," *PLOS One*, vol. 6, no. 2, p. e16782, 2011.

[3] R. Mao, X. Li, K. He, M. Ge, and E. Cambria, "MetaPro Online: A computational metaphor processing online system," in *Proceedings of ACL: System Demonstrations*, 2023, pp. 127–135.

[4] R. Mao and X. Li, "Bridging towers of multi-task learning with a gating mechanism for aspect-based sentiment analysis and sequential metaphor identification," *AAAI*, vol. 35, no. 15, pp. 13 534–13 542, 2021.

[5] R. Mao, X. Li, M. Ge, and E. Cambria, "MetaPro: A computational metaphor processing model for text pre-processing," *Information Fusion*, vol. 86-87, pp. 30–43, 2022.

[6] M. Ge, R. Mao, and E. Cambria, "Explainable metaphor identification inspired by conceptual metaphor theory," *AAAI*, vol. 36, no. 10, pp. 10 681–10 689, 2022.

[7] E. Cambria, Q. Liu, S. Decherchi, F. Xing, and K. Kwok, "SenticNet 7: A commonsense-based neurosymbolic AI framework for explainable sentiment analysis," in *Proceedings of LREC*, 2022, pp. 3829–3839.

[8] W. Li, L. Zhu, R. Mao, and E. Cambria, "SKIER: A symbolic knowledge integrated model for conversational emotion recognition," *AAAI*, pp. 13 121–13 129, 2023.

[9] D. William and D. Suhartono, "Text-based depression detection on social media posts: A systematic literature review," *Procedia Computer Science*, vol. 179, pp. 582–589, 2021.

[10] S. Ji, S. Pan, X. Li, E. Cambria, G. Long, and Z. Huang, "Suicidal ideation detection: A review of machine learning methods and applications," *IEEE Trans. Comput. Soc. Syst.*, vol. 8, pp. 214–226, 2020.

[11] A. Karami, M. Zhu, B. Goldschmidt, H. R. Boyajieff, and M. M. Najafabadi, "COVID-19 vaccine and social media in the US: Exploring emotions and discussions on Twitter," *Vaccines*, vol. 9, p. 1059, 2021.

[12] E. Xia, H. Yue, and H. Liu, "Tweet sentiment analysis of the 2020 US presidential election," in *Companion proceedings of the Web Conference*, 2021, pp. 367–371.

[13] M. B. Garcia and A. Cunanan-Yabut, "Public sentiment and emotion analyses of Twitter data on the 2022 Russian invasion of Ukraine," in *proceedings of ICITACEE*, 2022, pp. 242–247.

[14] S. C. Guntuku, D. Preotiuc-Pietro, J. C. Eichstaedt, and L. H. Ungar, "What twitter profile and posted images reveal about depression and anxiety," in *AAAI*, vol. 13, 2019, pp. 236–246.

[15] C. Duong, Q. Liu, R. Mao, and E. Cambria, "Saving earth one tweet at a time through the lens of artificial intelligence," in *IJCNN*, 2022.

[16] C. Duong, V. C. Raghuram, A. Lee, R. Mao, G. Mengaldo, and E. Cambria, "Neurosymbolic ai for mining public opinions about wildfires," *Cognitive Computation*, 2023.

[17] U. C. Priva and J. L. Austerweil, "Analyzing the history of cognition using topic models," *Cognition*, vol. 135, pp. 4–9, 2015.

[18] S. Han, R. Mao, and E. Cambria, "Hierarchical attention network for explainable depression detection on Twitter aided by metaphor concept mappings," in *COLING*, 2022, pp. 94–104.

[19] J.-S. Shie, "Metaphors and metonymies in New York Times and Times Supplement news headlines," *J. Pragmat.*, vol. 43, pp. 1318–1334, 2011.

[20] U. Forseth, E. A. Røyrvik, and S. Clegg, "Naturalizing, normalizing and neutralizing: metaphors framing the global financial crisis in nordic banks," *Culture and Organization*, vol. 29, no. 2, pp. 157–174, 2023.

[21] J. Ho, "An earthquake or a category 4 financial storm? a corpus study of disaster metaphors in the media framing of the 2008 financial crisis," *Text & Talk*, vol. 39, no. 2, pp. 191–212, 2019.

[22] T. Oberlechner, T. Slunecko, and N. Kronberger, "Surfing the money tides: Understanding the foreign exchange market through metaphors," *Br. J. Soc. Psychol*, vol. 43, no. 1, pp. 133–156, 2004.

[23] Á. Arrese, "The use of 'bubble' as an economic metaphor in the news: The case of the 'real estate bubble' in Spain," *Language & Communication*, vol. 78, pp. 100–108, 2021.

[24] N. N. Taleb, *The black swan: The impact of the highly improbable*. Random House, 2007, vol. 2.

[25] I. Glette-Iversen and T. Aven, "On the meaning of and relationship between dragon-kings, black swans and related concepts," *Reliab. Eng. Syst. Saf.*, vol. 211, p. 107625, 2021.

[26] J. Ho and W. Cheng, "Metaphors in financial analysis reports: How are emotions expressed?" *English Specif. Purp.*, vol. 43, pp. 37–48, 2016.

[27] W. H. Zeng, C. Burgers, and K. Ahrens, "Framing metaphor use over time: 'Free Economy' metaphors in Hong Kong political discourse (1997–2017)," *Lingua*, vol. 252, p. 102955, 2021.

[28] Y. Sun, Z. Cui, Y. Hu, and Q. Wang, "Exploring the technicality of LIQUID metaphorical chunks in business discourse," *J. Engl. Acad*, vol. 57, p. 101113, 2022.

[29] Y. Sun, G. Jin, Y. Yang, and J. Zhao, "Metaphor use in Chinese and American CSR reports," *IEEE Trans. Prof. Comm.*, vol. 61, p. 295, 2018.

[30] Y. Sun, Y. Hu, D. Gou, and Q. Wang, "To orient and to engage: Metaphorical hashtags in Weibo posts of Chinese banks," *J. Pragmat.*, vol. 194, pp. 87–100, 2022.

[31] R. S. Keefe, M. Poe, T. M. Walker, J. W. Kang, and P. D. Harvey, "The Schizophrenia cognition rating scale: an interview-based assessment and its relationship to cognition, real-world functioning, and functional capacity," *Am. J. Psychiatry*, vol. 163, no. 3, pp. 426–432, 2006.