Metaphoric coherence in popular science webtoons

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Abstract

With the advent of digital media, science dissemination genres have changed into multimodal ones, enhancing research accessibility and popularizing scientific knowledge among the general public. This paper examines popular science webtoons (PSWs) designed specifically for mobile devices, with verbal and visual semiotic resources interplaying to make scientific knowledge easily understandable for lay readers. This study presents a cognitive and multimodal analysis of 40 PSWs to explore the construction mechanism of multimodal metaphoric coherence. Our findings reveal that metaphors are recurrently used to establish a deep link between different semiotic modes and systematic scientific comprehension, which assists the science audience's cognitive processes of conceptualizing science. Importantly, the study identifies two metaphoric text-image relations and five metaphoric coherence types within the analyzed PSWs, which offers valuable insights into the necessity for diverse communication modes in creating resonant multimodal narratives. This underscores the transformative effect of metaphors in bridging the gap between scientific concepts and non-expert readers. Our analysis lays the foundations for understanding how metaphors function in similar multimodal contexts, paving the way for further research to refine discursive techniques and semiotic modes for future science communication. This paper also has implications for academics attempting to convey their scientific findings to lay readers.

Keywords: science popularization, popular science webtoons, multimodal metaphor, metaphoric coherence.

Resumen

La coherencia metafórica en los "webtoons" de divulgación científica

Los medios digitales han transformado los géneros de divulgación científica y los han convertido en multimodales, lo cual supone una mejora para el acceso a la

investigación y facilita la popularización del conocimiento científico entre el público general. Este artículo examina los webtoons de divulgación científica (PSWs, por sus siglas en inglés), diseñados específicamente para dispositivos móviles, donde los recursos semióticos verbales y visuales interactúan para hacer que el conocimiento científico sea fácilmente comprensible para los lectores no especializados. Este estudio presenta un análisis cognitivo y multimodal de 40 PSWs con el fin de explorar los mecanismos de construcción de la coherencia metafórica multimodal. Los hallazgos revelan que las metáforas se utilizan de manera recurrente para establecer un vínculo profundo entre los diferentes modos semióticos y una comprensión científica sistemática, lo que facilita los procesos cognitivos del público para conceptualizar la ciencia. Este estudio identifica dos tipos de relaciones metafóricas entre texto e imagen y cinco tipos de coherencia metafórica dentro de los PSWs analizados. Estos resultados proporcionan datos valiosos sobre la necesidad de combinar modos diversos de comunicación para crear narrativas multimodales significativas. Estas narrativas subrayan el efecto transformador de las metáforas, ya que facilitan la comprensión de los conceptos científicos por parte de los lectores no expertos. Nuestro análisis sienta las bases para comprender cómo funcionan las metáforas en contextos multimodales similares y allana el camino para futuras investigaciones que perfeccionen las técnicas discursivas y los modos semióticos en la comunicación científica. Asimismo, tiene implicaciones para los académicos que tratan de transmitir sus hallazgos científicos al público general.

Palabras clave: divulgación científica, webtoons de divulgación científica, metáfora multimodal, coherencia metafórica.

1. Introduction

Science popularization has long been a crucial driving force in improving public science literacy, making scientific knowledge accessible and engaging for non-experts (Parkinson & Adendorff, 2004; Rosenthal, 2020; Sapp, 1992). In the era of traditional media, science popularization was primarily realized through printed publications like newspapers and magazines, which was followed by radio and television broadcasts, and further expanded to online formats via mobile devices in today's digital era. Science now reaches out to a wider audience through various multimodal genres, such as online videos (Bernad-Mechó & Valeiras-Jurado, 2023; Jiang & Lim, 2022; Jiang & Qiu, 2022; Xia, 2023a; Xia & Hafner, 2021), science magazines (Molek-Kozakowska, 2018), podcasts (Ye, 2021), and blogs (Freddi, 2020; Luzón, 2013). The rise of mobile devices, especially mobile phones, has also

transformed the traditional format of cartoons and comic strips, leading to the emergence of a novel and intriguing multimodal genre for science popularization: the webtoon, which is "the most pervasive and powerful form of digital serial production" (Cho, 2021, p. 73), known for its accessibility and innovative storytelling techniques.

Originating in South Korea in the early 2000s, webtoon is defined as "a digital form of comic" (Ko et al., 2022, p. 1) that combines texts and images in a format of serial, scrolling strip displayed in an infinite canvas to make a coherent narration optimized for mobile devices (Cohn, 2013). Webtoons initially gained popularity for entertainment purposes, and their usage in science popularization was limited until the emergence of the popular science webtoon (henceforth PSW) in 2015 when PSWs began to be published on Chinese WeChat[1] Official Accounts managed by media organizations, educational institutions, or independent creators. PSWs typically possess three key features. First, PSWs are displayed in a vertical and sequential scrolling format adapted for mobile devices. Second, PSWs integrate original visual creation with verbal elements under the guidance of experts from various fields. Third, each PSW employs a logical and coherent progression of narrative enhanced by the sequential combination of texts and images (Cohn, 2013). While these features highlight the potential of the PSW as an effective medium for science communication, little research has been conducted on its specific strategies to merge artistic visuals with intricate scientific concepts. This study therefore aims to explore how PSWs manage to transform complex ideas into accessible and engaging narratives.

Central to PSWs, narrative is seen as "a dominant form of science communication to non-expert audience" (Dahlstrom, 2014, p. 13616). It is used to shape and interpret reality, and structure events into a meaningful sequence, but it is storytelling that plays the pivotal role in making narratives accessible, understood, and interpreted within cultural and social contexts (Bruner, 1991). Thus, storytelling is vital for conveying scientific knowledge effectively because integrating science into a narrative helps readers grasp complex subjects with less cognitive effort (Fisch, 2000) and also taps into their imaginations and emotions (Martinez-Conde & Macknik, 2017; Riedlinger et al., 2019). The elements of storytelling can be divided into structural elements and expressive elements, as summarized in Table 1. Structural elements refer to the fundamental building blocks that provide the skeleton of a story (Campbell, 1949; Forster, 1927; Morrow, 1986), whereas expressive elements pertain to how the story is told, which influences the

emotional engagement of the story (Bruner, 1991; Genette, 1980). These elements are integrated into PSWs to create an innovative form of mobile multimodal storytelling, covering a wide range of scientific and technological subjects of public interest to attract digital-centric audience across different ages and professional groups. Despite the growing interest in mobile storytelling (Alexander, 2011; Dunford & Jenkins, 2017; Schleser & Xu, 2021), PSWs produced mainly in Chinese with some English throughout are little known. Their novelty, coupled with language and cultural barriers, has likely contributed to the scarcity of international scholarly attention. However, their utilization of multimodal interaction to create meanings for narrative-driven science popularization calls for in-depth research.

Structural elements	Explanations
Plot	The sequence of events in a story (introduction, rising action, climax, falling action, and resolution)
Setting	Where and when the story takes place.
Characters	The individuals involved in the story.
Conflict	The main problem or challenge.
Theme	The underlying message or central idea the story conveys.
Expressive elements	**Explanations**
Point of view	The perspective from which the story is told.
Tone	The attitude or feeling conveyed.
Mood	The emotional atmosphere experienced by readers.
Style	The author's unique way of delivering information.

Table 1. Structural elements and expressive elements of storytelling.

PSWs "bridge" (MacArthur et al., 2020, p. 64) the gap between the scientific knowledge in institutional discourse and the existing knowledge of lay viewers (Luzón, 2019), in a way that largely relies on metaphor as a "potentially valuable tool for knowledge mediation" (Beger, 2016, p. 57) and a key mechanism in storytelling (Turner, 1996). Metaphors "render theoretical concepts intelligible" (Smedinga et al., 2023, p. 263) by allowing people to "understand one domain of experience in terms of another" (Lakoff & Johnson, 1980, p. 117), to guide lay readers through complex and abstract scientific concepts and theories (Phipps, 2020). While previous research focused solely on verbal metaphors in science popularization (Brown, 2003; Pramling & Säljö, 2007; Williams, 2009), visual and

multimodal metaphors in scientific popularization discourse have been rarely analyzed. In particular, little attention has been paid to the interaction between verbal and visual metaphors, as well as the text-image interplay within multimodal metaphors in science popularization.

Maintaining coherence in science popularization discourse is crucial for readers to follow the flow of information and keep engaging with discourse development (López Orellana, 2012). Conceptually, "the structural logic provided by metaphors" (White, 1997, p. 242) can construct coherent narratives that make the reading experience fluid, immersive, and dynamic (Ponterotto, 2000); hence, "metaphors can ensure the coherence of discourse" (Kövecses, 2009, p. 91), achieving what is called "metaphoric coherence" (Zhang, 2008, p. 7). Previous studies have been carried out on metaphoric coherence in verbal texts (Liao, 1999; Kimmerl, 2009; Ponterotto, 2000; Rezanova & Shilyaev, 2015; Wee, 2005), without giving any attention to metaphoric coherence in multimodal discourse, where verbal, visual, and multimodal metaphors form cross-modal cohesive ties (Górska, 2017) to build discourse coherence (Halliday & Hasan, 1976). Thus, it is worth conducting an in-depth investigation to highlight implications for multimodal science popularization.

1.1. Conceptual metaphor theory

Conceptual metaphor theory (CMT) is valuable for uncovering the metaphors that influence popular perceptions of abstract scientific concepts (Beger & Smith, 2020). "Many conceptual metaphors are based on image schemas" (Kövecses, 2020, p. 9) as "recurring dynamic patterns of our perceptual interactions and motor programs that give coherence and structure to our experience" (Johnson, 1987, p. xiv), including UP-DOWN, SOURCE-PATH-GOAL, CONTAINER, LINK, and PART-WHOLE (Lakoff, 1987, p. 267). For example, the conceptual metaphor BAD IS DOWN allows people to understand and discuss the abstract concept of BAD in terms of orientational bodily experience. This "mapping" across source and target domains (Figure 1) enables us to "conceptualize one mental domain in terms of another" (Lakoff, 1993, p. 203).

Succeeding CMT, Conceptual Blending Theory (CBT) creates new meanings and scenes by projecting structures and contents from two or more source domains to a blended target domain with emergent properties that are not presented in the input domains (Fauconnier & Turner, 2002) (Figure 2),

which is often employed to analyze "meaning emergence in specific complex expressions/visuals" (Zibin & Altakhaineh, 2023, p. 380). For example, the classic sentence "They dug their own financial grave" owns a generic space that hosts "pre-conceptual topologies" (Fauconnier & Turner, 1998, p. 135) which provide a shared framework that allows for the integration of different mental spaces. There are two input spaces: the first input space encapsulates the physical action of digging a grave associated with creating a final resting place, which symbolizes death and finality. In the second input space, making poor decisions leads to financial ruin or bankruptcy. The generic space in this case captures commonalities between physical actions and causal consequences, encompassing abstract structures like agents causing negative results in both physical and metaphorical contexts. The blended space inherits the physical construction of graves and digging from the first input, and derives causal and intentional event structure from the second.

Overall, CMT examines how existing conceptual metaphors shape our understanding, whereas CBT facilitates the creation of new concepts through blending. They complement each other, as CMT provides foundational mappings for CBT to manipulate. Therefore, CMT and CBT can collectively explain how humans comprehend scientific concepts conveyed through metaphors across sensory modalities (Beger & Smith, 2020).

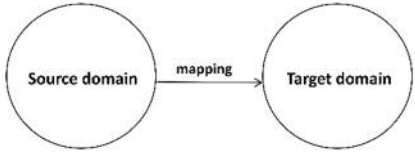


Figure 1. Cross-domain mapping.

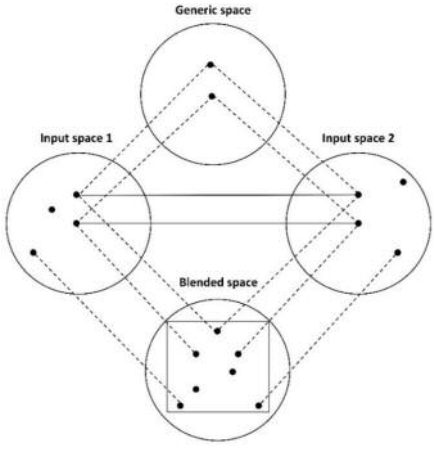


Figure 2. Conceptual blending model.

1.2. Metaphors and text-image relations

As multimodal discourse, PSWs are replete with both monomodal metaphors which are verbal metaphors in texts or visual metaphors in images, and multimodal metaphors in which source domains and target domains are represented by at least two different modes (Forceville, 2002, 2008, 2009) that provide "different potentials for making meaning" (Kress, 2010, p. 79). As meanings are not the simple sum of the meanings of each mode, but are produced by the interaction of different modes in communication (Barthes, 1977), the interplay between verbal metaphors and visual metaphors, as well as that of verbal and visual representations in cross-modal mapping process between source domains (verbal/visual) and target domains (verbal/visual) within multimodal metaphors (Figure 3), are pivotal for structuring and explaining scientific knowledge to lay readers.

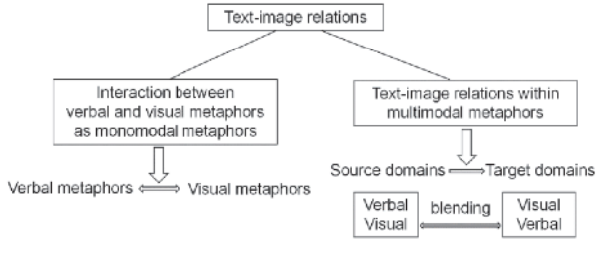


Figure 3. Text-image relations among metaphors

As is summarized in Table 2, Van Leeuwen (2005, p. 230) classified two key text-image relations, namely "elaboration" and "extension". Elaboration involves, on the one hand, "specification", where the image makes the text more specific ("illustration"), or the text makes the image more specific ("anchorage"); on the other hand, "explanation", where the text paraphrases the image or vice versa. Under the umbrella of extension, terms including "similarity", "contrast", "complement" and "relay", respectively, describe whether text is similar to image, contrasts with it, or adds further information to the image and vice versa. Hart and Marmol Queralto (2021) distinguished two types of text-image relations in online news from the perspective of metaphors. One is "anchorage", in which "language serves to highlight or downplay the potential metaphoricity of images" and the metaphor presented by images cannot be realized without "verbal instantiations" (p. 554). The other is "convergence", in which "images have a potential metaphoric reading that is consistent with a verbal metaphoric framing" (p. 554). While both classifications help to improve the connection between text and image, elaboration and extension emphasize clarity and depth, and anchorage and convergence focus on establishing unified metaphorical meanings. Diversity of genres may imply different conventions for text-image interrelations, thus underscoring the necessity for thorough elucidation of the text-image relations among metaphors in PSWs.

Text-image relations	Subtypes	Explanations
Elaboration	-Specification	- Illustration: the image makes the text more specific
		- Anchorage: the text makes the image more specific
	-Explanation	The text paraphrases the image or vice versa
Extension	-Similarity	The content of the text is similar to that of the image
	-Contrast	The content of the text contrasts with that of the image
	-Complement	The content of the image adds further information to that of the text
	-Relay	The content of the text adds further information to that of the image
Metaphorical text-image relations	**Explanations**	
Convergence	Images have a potential metaphoric reading that is consistent with a verbal metaphoric framing	
Anchorage	Language serves to highlight or downplay the potential metaphoricity of images	

Table 2. Text-image relations and metaphorical text-image relations.

1.2. Metaphoric coherence

Coherence is the unifying force that integrates different semiotic resources to form an overall meaningful presentation in multimodal discourse (Bandyopadhyay, 1990; Kress & Bezemer, 2023). As "fundamental parts in human meaning-making" (Danesi, 2018), metaphors can structure discourse development (Goatly, 1997) by connecting different discourse sections (Lakoff & Johnson, 1980) to ensure discourse coherence (Kövecses, 2010). Within PSWs, cohesive ties can be constructed solely by verbal metaphors or visual metaphors, and they can also be supplemented or reinforced by the text-image relations among metaphors, which lays the foundations for discourse coherence (Bateman, 2014). However, there is a paucity of systemic studies investigating metaphoric coherence in multimodal science popularization discourse.

Among the few studies on metaphoric coherence (Liao, 1999; Ponterotto, 2000; Rezanova & Shilyaev, 2015), mega-metaphor and cognitive network are two notable theories to explain its mechanism. Mega-metaphor manifested through micro-metaphors ("metaphorically used lexemes in the text") is "a conceptual metaphor that gives coherence to metaphorical expressions of a particular discourse, at the same time organizing the discourse into a coherent whole" (Rezanova & Shilyaev, 2015, p. 33; see Figure 4). For example, the mega-metaphor DOG IS MAN can be portrayed through several interconnected micro-metaphors with mappings from human experiences as source domain onto the life of a dog as target domain, which grants the discourse coherence.

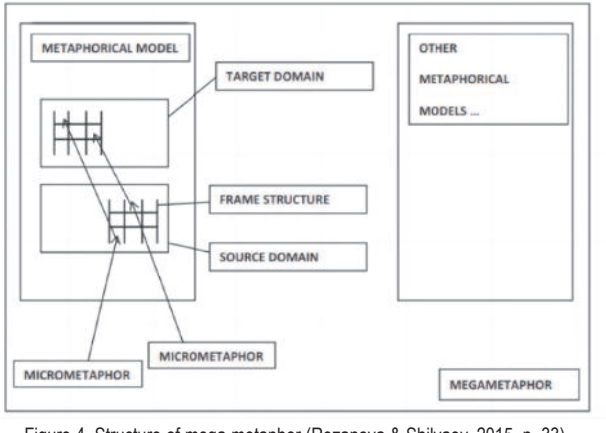


Figure 4. Structure of mega-metaphor (Rezanova & Shilyaev, 2015, p. 33).

Metaphors can also be extended to construct cognitive metaphor networks by linking lexical units (Ponterotto, 2000), as Langacker (1987) observed that related metaphors can create a network organization. For example, the cognitive metaphor network (Figure 5) is based on a textual conversation on intimate relationships, introduced by the conceptual metaphor UNDERSTANDING IS SEEING and further structured by LOVE and LIFE metaphors, making the conversation a coherent whole. However, this metaphor network is only an illustrative example of how metaphors function to construct coherence within textual discourse rather than multimodal discourse.

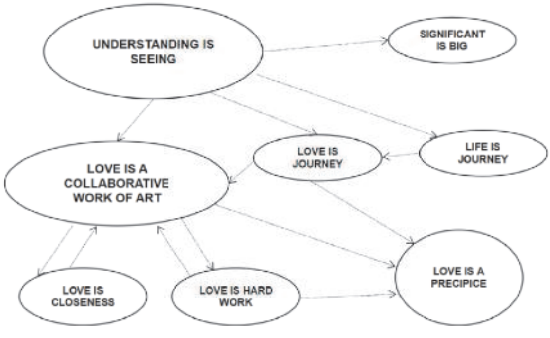


Figure 5. Cognitive metaphor network (Ponterotto, 2000, p. 293).

While the aforementioned studies provide valuable insights, they are limited to text-based analysis and do not account for the multimodal nature of communication, where text and image work in tandem. Our study highlights the importance of considering text-image relations among metaphors, as they play a crucial role in the overall metaphoric coherence within multimodal discourse manifested in the form of storytelling. The present paper can provide help for scientists who are keen on "building their identities as lay-friendly popularizers" (Xia, 2023b, p. 83) and for designers to create compelling and coherent multimodal narratives by raising their awareness of semiotic and metaphoric decisions in the construction of PSWs that cater to non-specialists. Investigating metaphors and the construction of metaphoric coherence in PSWs, this paper attempts to answer the following research questions:

(i) What are the recurrent metaphors used in PSWs?

(ii) How can verbal metaphors and visual metaphors interplay with

each other and what are the text-image relations within multimodal metaphors in PSWs?

(iii) How do metaphors contribute to the construction of metaphoric coherence in PSWs?

2. Methodology

2.1. PSW corpus

The corpus of this study contains 40 PSWs randomly selected from the 177 PSWs issued on the WeChat Official Account *TuTuShiTao* from 2018 to 2021. *TuTuShiTao* is affiliated with *China Daily*, an authoritative national comprehensive media website and China's most significant English website. It took the first place in the 31st China News Award 2021 and over a hundred of its original PSWs were promoted by various central media outlets. The 40 PSWs cover natural sciences (biology, chemistry, physics, medicine, geography, and environment), and social sciences (history, culture, economics, and psychology).

2.2. Data analysis

This study merged both qualitative and quantitative methods. 40 PSWs selected were loaded into NVivo20 software for data annotation, quantitative analysis, and the classification of data generated from metaphor identification.

The analytical procedure of this research mainly followed four steps (see Figure 6).

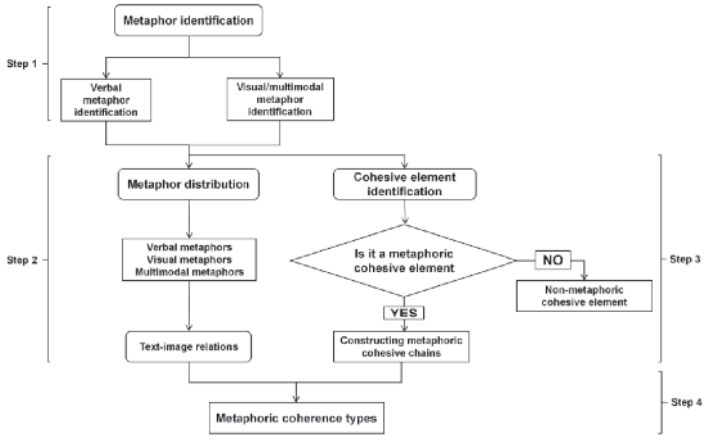


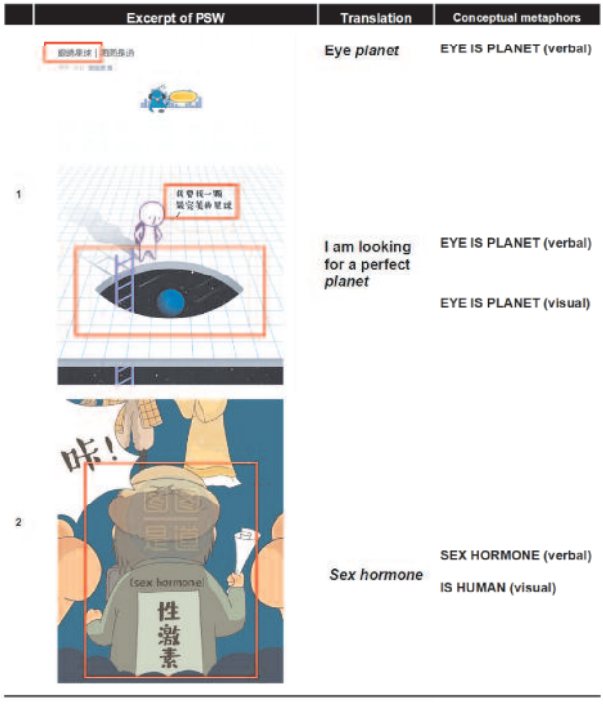
Figure 6. Research procedures.

First, verbal metaphors were pinpointed following the MIPVU (Metaphor Identification Procedure VU) (Steen et al., 2010). For instance, in Excerpt 1 (Figure 7), "EYE" and "PLANET" in verbal mode are metaphorical expressions abstracted into the conceptual metaphor EYE IS PLANET, where parts of the characteristics of "PLANET," such as its shape and environment, are mapped onto "EYE" as the target domain. Visual and multimodal metaphors were identified based on Forceville's criteria (1996, 2002, 2008). For instance, at the bottom of Excerpt 1 (Figure 7), "EYE" as the target domain and "PLANET" as the source domain in visual mode are blended, indicating the conceptual metaphor EYE (eyeball) IS PLANET. In Excerpt 2 (Figure 7), an image of a film director marked by the text "SEX HORMONE" composes a multimodal metaphor representing the conceptual metaphor SEX HORMONE IS DIRECTOR (HUMAN), where "SEX HORMONE" is the target domain in verbal mode and "DIRECTOR (HUMAN)" is the source domain in visual mode. The powerful influence owned by the "DIRECTOR" when orchestrating the elements of a film, is mapped onto "SEX HORMONE" which controls various bodily functions and processes.

Forty PSWs were coded independently by two authors, with discrepancies resolved through discussions until a consensus was reached. Recurrent metaphors were calculated in this step as well. It should be noted that the same conceptual metaphor can be presented in verbal form and repeated in visual form or vice versa within one PSW. This complicates the calculation

of recurrent conceptual metaphors because we treat metaphor as a conceptual unit and define recurrent conceptual metaphors as those repeated across 40 PSWs rather than within one PSW. In this study, a conceptual metaphor that appears in the same PSW is counted once, no matter how many times it is repeated and whether it is visual or verbal.

Second, after metaphor identification, the distribution of monomodal and multimodal metaphors was presented to determine their respective frequencies within the corpus. The text-image relations between verbal and visual metaphors and the relations within multimodal metaphors were then identified, based on the classification provided by Van Leeuwen (2005) and Hart and Marmol Queralto (2021).



[Excerpt 1 is selected from the PSWs: Eye planet. (https://mp.weixin.qq.com/s/1or_oy2ui7dzKVBLgoyBEA) Excerpt 2 is selected from the PSWs: There is a "fast forward button" in your body. Don't press it. (https://mp.weixin.qq.com/s/hV9pYdeO28qXi74KA0LU_w) The red frames are added by Author 1. The translation in excerpts is provided by the designers of PSWs, while those in the translation column as in Excerpt 1 are provided and cross-checked by Author 1 and Author 2].

Figure 7. Metaphor identification.

Third, the corpus was re-examined for coding source domains, target domains, or conceptual metaphors as metaphoric cohesive elements that connect different parts of the discourse through repetition, substitution, or structural logic of information, to form metaphoric cohesive chains. Cohesive elements that are not metaphorical were excluded from the metaphoric cohesive chains. A metaphoric cohesive chain should be created by repeating the same metaphoric cohesive element more than four times (Somasundaran et al., 2014), whereas a metaphoric cohesive element that appears less than or is equal to four times was regarded as an independent metaphor. Though independent metaphors are not able to form metaphoric cohesive chains, they are still treated as metaphoric cohesive elements once they are parts of the narration in PSWs. During the chain construction process, text-image relations also play an indispensable role in connecting verbal and visual metaphoric cohesive elements. In Figure 7, the conceptual metaphor EYE IS PLANET, presented in either verbal or visual mode, emerges across the whole PSWs more than four times, forming a metaphoric cohesive chain. Apart from being the components of conceptual metaphor, "EYE" and "PLANET" can respectively form two cohesive chains bonding to the metaphoric cohesive chain constructed by EYE IS PLANET, which increases the intensity of coherence. Metaphoric cohesive chains of 40 PSWs were compiled by both authors. A minimum threshold of 80% inter-coder agreement was set (Artstein & Poesio, 2008), with Cohen's Kappa used to evaluate the agreement's reliability. The Cohen's Kappa in this study reached 82.5%, which indicates substantial inter-coder reliability (Steen et al., 2010). Disagreements were discussed and resolved to ensure consistency.

Fourth, the metaphoric cohesive chains constructed in Step 3 were visualized in the form shown in Figure 8, from which different types of metaphoric coherence achieved through metaphors in PSWs were clarified to illustrate the role of metaphors in enhancing discourse coherence.

Eye planet

Page	Target domain	Source domain
1	Eye	Planet
	Eye	Planet
	(Eye)	(Planet)
	(Ladder)	Link
	Eye	Planet
2	(Rocket riding)	Journey
	(Rocket track)	Link
3	(Eye)	(Planet)
	xerophthalmia	"Desert" planet [荒漠星]
	Eye	Planet
4	(Rocket track)	Link
	(Eye)	(Planet)
	Eye with parasite	"Parasite" planet [虫星]
	Eye	Planet
	Disease	Invasion-War
5	(Rocket riding)	Journey
	(Rocket track)	Link
	(Eye)	(Planet)
	Eye with conjunctivitis	"Fire" planet [火炎星]
	Eye	Planet
	Disease	Invasion-War
	Disease	Invasion-War
6	(Rocket track)	Link
	(Eye)	(Planet)
	Eye with uveitis	"Grape" planet [葡萄星]
	Eye	Planet
	Tears	magma
	Disease	Invasion-War
	Disease	Invasion-War
7	(Rocket riding)	Journey
	(Rocket track)	Link
	(Eye)	(Planet)
	Eye with colobooma of choroid	"Sinkhole" planet [天坑星]
	Eye	Planet
	Disease	Invasion-War
	Eye	Planet
	Disease	Invasion-War
8	(Rocket riding)	Journey
	(Rocket track)	Link
	(Eye)	(Planet)
	Eye with myopia	"Short" planet [近星]
	Eye	Planet
	Glasses	Umbrella
9	(Rocket track)	Link
	(Eye)	(Planet)
	Eye with hyperopia	"Long" planet [远星]
	Eye	Planet
	Glasses	Umbrella
10	(Rocket track)	Link
	(Eye)	(Planet)
	Eye with presbyopia	"Old and vague" planet [老花星]
	Eye	Planet
	Eye	Planet
	Glasses	Umbrella
11	(Rocket riding)	Journey
	(Rocket track)	Link
	(Eye)	(Planet)
	Eye with cataract	"White turbid" planet [白浊星]
	Eye	Planet
12	(Rocket track)	Link
	(Eye)	(Planet)
	Eye with glaucoma	"Cyan" planet [青光星]
	Eye	Planet
	Optic nerve	Conduit
13	(Rocket track)	Link
	(Eye)	(Planet)
	Eye with retinal detachment	"Waning" planet [没落星]
	Eye	Planet
14	(Rocket riding)	Journey
	(Rocket track)	Link
	(Eye)	(Planet)
	Eye with color blindness	"Sc Mang" planet [色芒星]
	Eye	Planet
15	(Rocket track)	Link
	(Eye)	(Planet)
	Lazy Eye	"Lazy" planet [懒星]
	Eye	Planet
	Eye	Human

["()" refers to visual mode. "[]" refers to the original text in Chinese. The target domains and source domains were translated by Author 1 and cross-checked by Author 2].

Figure 8. Metaphoric cohesive chains in PSWs.

Results

3.1. Recurrent conceptual metaphors in 40 PSWs

Recurrent conceptual metaphors offer systematic and coherent pictures of metaphors used in popularizing science, connecting abstract scientific concepts for coherent human understanding. For instance, the MACHINE metaphor, like BODY IS MACHINE and its subcategory CELL IS MACHINE, have been used across time since the Industrial Revolution (Williams, 2009) to depict bodies and cells through machines with specific functions and mechanisms that people are familiar with (Reynolds, 2018). MACHINE metaphors, like HEART IS MACHINE and BODY IS MACHINE, which not only echo the MACHINE metaphors generally used in science popularization, also recur in our corpus. To have a general idea of recurrent metaphors in the 40 PSWs, a conceptual metaphor list was compiled to generate a word cloud (Figure 9) and the top ten source domains recurring in 40 PSWs were presented in Table 3.

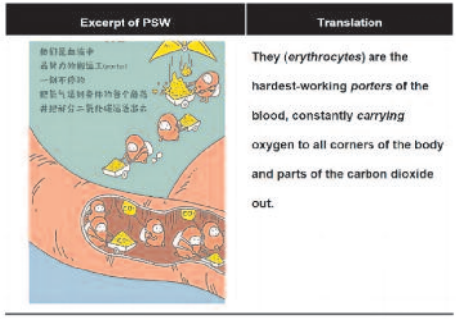
Figure 9. Word cloud of target domains and source domains.

Source domain	Total	Weighted percentage (%)
HUMAN	232	20.24
WAR	24	2.09
JOURNEY	13	1.13
LINK	9	0.79
CONTAINER	6	0.52
MONSTER	5	0.44
ARROW	3	0.26
FACTORY	3	0.26
HEADQUARTERS	3	0.26
MACHINE	3	0.26

Table 3. Top ten recurrent conceptual metaphors in PSWs.

In this word cloud, HUMAN metaphor in the color green is the most central conceptual metaphor in our corpus. When depicted as human, the target domain demonstrates human abilities and traits (Lakoff & Johnson, 1980), which is pivotal and useful in facilitating readers' clear and direct understanding since the target domain is perceived in terms of human experiences, motivations, emotions, and behaviors. In addition, HUMAN metaphor in the 40 PSWs serves not only to make complex scientific concepts accessible and engaging to a wider audience but also to evoke emotional responses and connections. For instance, in the conceptual metaphor ERYTHROCYTE IS PORTER (Figure 10), the main feature of a "porter" as the story character whose job is to carry things from one place to another is mapped onto "erythrocyte" which transmits oxygen and carbon dioxide in the blood. Coherent with this HUMAN metaphor in

verbal mode, erythrocytes are then visually depicted as human beings wearing red clothes and busy carrying things through blood vessels. The metaphor simplifies the complex biological process of the human body by creating a cognitive bridge between the familiar concept of porters and the less familiar role of erythrocytes. It evokes readers' emotional responses, as it draws upon their existing knowledge of porters, sparking readers' curiosity and engagement while aiding understanding of erythrocytes' function. Besides, HUMAN metaphor can also be realized by attributing verbal behaviors of human beings to non-human entities (see further discussion in section 3.2.2).



[The excerpt is selected from the PSWs: Do the toxins and waste products result in dark blood? (https://mp.weixin.qq.com/s/qxMRICghp1UpJBqdCDaF1Q)].

Figure 10. Illustration of HUMAN metaphor.

Other non-recurrent metaphors that appear relatively less frequently are related to and vary with the topics of each PSW. As is in Table 3, in addition to the HUMAN metaphor mentioned above, the commonly used WAR, JOURNEY, CONTAINER, and MONSTER metaphors in everyday life (Lakoff & Johnson, 1980) also frequently appear in PSWs, and other less frequent source domains in PSWs are ARROW, FACTORY, HEADQUARTERS, and MACHINE, which suggests that science popularization texts tend to use metaphors that draw on human experiences and activities. It should be noted that the LINK metaphor, a genre-specific metaphor utilized in PSWs, has not been observed in other science popularization genres (see sections 3.2 and 3.3).

Table 4 presents the top ten recurring target domains, denoting the popularized scientific topics in PSWs, with the most frequent target domain being TAO. TAO (道) (Figure 11), a traditional wisdom deeply embedded in

various aspects of Chinese culture and philosophy, means "way," "path," or "principle," and symbolizes the natural order and harmony of the universe, serving as the origin and essence of all existence. It emphasizes the cultivation of inner wisdom, equilibrium, and harmony through practices such as meditation, martial arts, and medicine (Kirkland, 2004), and also promotes the exploration of the unknown and the pursuit of truth which are essential for scientific inquiry and innovation.

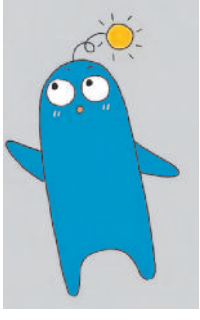


Figure 11. Illustration of personified Tao.

Tao functions as the intellectual property (hereafter IP) of *TuTuShiTao* for patent protection, consistently personified in PSWs to lead the topic; develop narration; increase reader engagement; enhance reader acceptance and memorability; and contribute to the discourse coherence. In the context of contemporary science communication, the utilization of traditional wisdom like TAO in PSWs that reflects traditional values and beliefs not only enriches the narrative but also makes science approachable to readers. Other frequently used target domains in Table 4 are BRAIN, CELL, HEART, LIVER, VIRUS, DISEASE, TOOTH, LUNG, SPECIES, and IMMUNITY, related to biology and medicine; EARTH and TREE, related to environment and geography, and MONEY and BITCOIN, related to the economy. Ultimately, these target domains used in PSWs reflect the prevailing trend in science popularization which focuses more on natural science than social science or interdisciplinary subjects.

Target domain	Total	Weighted percentage (%)
TAO	25	2.18
BRAIN	11	0.96
CELL	11	0.96
HEART	11	0.96
LIVER	9	0.79
VIRUS	9	0.79
EARTH	8	0.70
CO2/DISEASE/TOOTH	7	0.61
BITCOIN/LUNG	6	0.52
IMMUNITY/MONEY/SPECIES/TREE	5	0.44

Table 4. Top ten recurrent target domains in PSWs.

3.2. Text-image relations among metaphors

Table 5 displays the distribution of different types of metaphors in 40 PSWs. Multimodal metaphor accounts for the largest proportion followed by visual metaphor which is slightly higher than verbal metaphor. Text-image relations among metaphors in PSWs fall into two categories: "convergence" and "complementation."

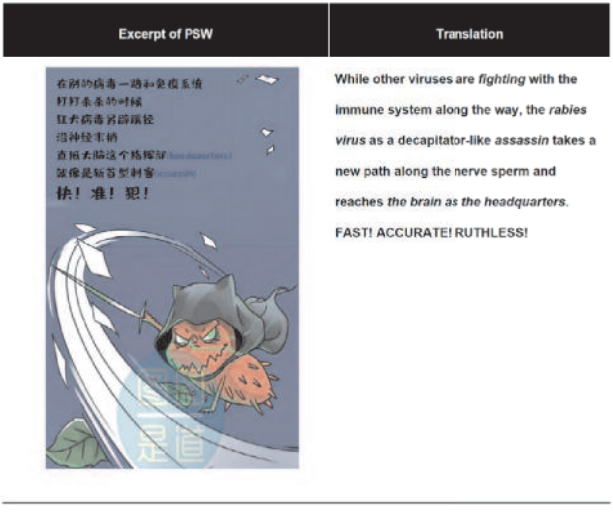
Metaphor	Target domain mode	Source domain mode	Number	Total (%)
Visual metaphor	visual	visual	397	440 (29.3%)
	-	visual	43	
Verbal metaphor	verbal	verbal	363	437 (29.2%)
	-	verbal	74	
Multimodal metaphor	verbal	visual	326	
	visual	verbal	281	622 (41.5%)
	verbal	visual+verbal	15	

Table 5. Distribution of multimodal, visual, and verbal metaphors in PSWs.

3.2.1. Text-image relation between verbal metaphor and visual metaphor

In PSWs, the text-image relation between verbal metaphor and visual metaphor is "convergence", which means the underlying conceptual metaphor

can be extracted from each mode separately (Hart & Marmol Queralto, 2021). The excerpt (see Figure 12) features the verbal metaphor RABIES VIRUS IS ASSASSIN (HUMAN), followed by the visual metaphor RABIES VIRUS IS ASSASSIN, in which target domain RABIES VIRUS blended with source domain ASSASSIN is draped in an assassin's cloak and holding a sword, not only mirroring the verbal metaphor but also amplifying its impact by providing a concrete and evocative representation without conveying additional information. Compared with conceptual metaphors delivered solely in verbal mode, the convergence between the verbal and visual metaphors results in a coherent and impactful expression that "resonates with the audience" (Ritchie, 2013, p. 17), which improves science communication effectiveness and leads to both cognitive and emotional responses.



[The excerpt is selected from the PSWs: The rabies virus has a 100% fatality rate and has never failed. (https://mp.weixin.qq.com/s/5HvNZXpE8jiSLi4mHVkpbA)].

Figure 12. Convergence between verbal metaphor and visual metaphor .

3.2.2. Text-image relation within multimodal metaphor

Different from the non-metaphoric text-image relations, the texts and images within multimodal metaphors complement each other and form three sub-types in PSWs: "relay", "personification" and "blending."

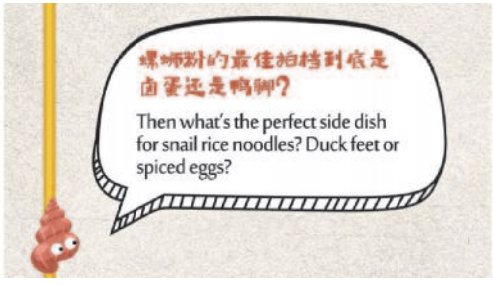
When it comes to "relay", "text and image stand in a complementary relationship" (Barthes, 1977), with each providing distinctive information on

its own rather than duplicating each other's meaning. Figure 13 draws an image of Death holding a sickle with the text "COVID-19" on it, which represents the metaphor COVID-19 IS THE SICKLE OF DEATH, with the target domain COVID-19 in verbal mode, and the source domain THE SICKLE OF DEATH in visual mode, indicating that the image of Death wielding a sickle symbolizes the destructive power of the virus that cuts down lives indiscriminately. The feature of Death's sickle is mapped to COVID-19, which reveals the deadly nature of the virus and emphasizes the urgency of taking precautions to prevent its spread to evoke readers' own experience during the pandemic.

[The excerpt is selected from the PSWs: Reliable but unreliable "herd immunity". (https://mp.weixin.qq.com/s/fvwsMoMlu3VhWAcgZC3tEQ)].

Figure 13. Illustration of text-image relation: relay.

In the case of "personification," the characteristic of source domain HUMAN in verbal mode is mapped to non-human entities in visual mode to create a sense of familiarity or empathy. In this situation, text and image are complementary to each other to form a multimodal metaphor that permits the description of specific physical qualities (Alahmadi, 2022). In Figure 14, a snail is asking questions, illustrating the multimodal metaphor SNAIL IS HUMAN, in which the target domain SNAIL is in visual mode and the source domain HUMAN is conveyed through one of the human traits: speaking, which reveals that the snail is treated as a human by endowing it the ability to speak. Living organisms and microorganisms are frequently depicted as human beings in PSWs, and this explains why the HUMAN metaphor takes the first place among metaphors used in PSWs.



[The excerpt is selected from the PSWs: Are there snails in the snail rice noodle? (https://mp.weixin.qq.com/s/khTBMz-IrwiMYgLDZ7DzBQ)].

Figure 14. Complementation between visual target domain and verbal source domain.

The "blending" relation in PSWs occurs when text and image are seamlessly integrated as source or target domains, which blurs the lines between the two and creates a unified, cohesive message that is greater than the sum of its parts. Figure 15 depicts a girl falling surrounded by negative feelings and symptoms of depression arranged in a downward orientation. It denotes the conceptual metaphor BAD (DISEASE) IS DOWN, in which the orientational trait of DOWN is mapped onto the girl as a patient and disease symptoms. In this example, texts are endowed with spatial and orientational sense to convey the pernicious nature of depression and prompt reflection on the broader cultural and societal factors tied to this mental illness. This unique type of complementation named as blending relation emerges when "the writer blends the conceptual and the narrative" (Kress & Van Leeuwen, 2021, p. 112), which leads readers to engage with the PSWs and challenges the conventional modes of interpretation. In traditional conceptual blending theory, blending involves combining input spaces within a single mode, usually language. Here, however, the model extends blending by integrating visual elements, adding layers of meaning that monomodal approach would not capture. Details are shown in the text-image blending model (Figure 16). The generic space integrates attributes like subject, orientation, movement, color, and emotion, which bridge verbal and visual representations, to facilitate the blending process and create a cohesive understanding of the metaphorical relationship between the girl and the environment around her. Different from the monomodal blending, in our case, input space 1 presents the verbal mode subject of disease symptoms with grey color and negative tone, and input space 2 visually portrays a girl falling against a black background, which embodies vulnerability and the impact of negative

feelings. The blended space merges the downward orientation, assigning to the disease symptoms in verbal form to increase emotional engagement through both multimodal interactions.

[The excerpt is selected from the PSWs: I am not unhappy, but depressed... (https://mp.weixin.qq.com/s/wT5397GgzV0qOoFVTAbKUQ) The translation in this excerpt is provided by Author 1 and cross-checked by Author 2].

Figure 15. Text-image blending.

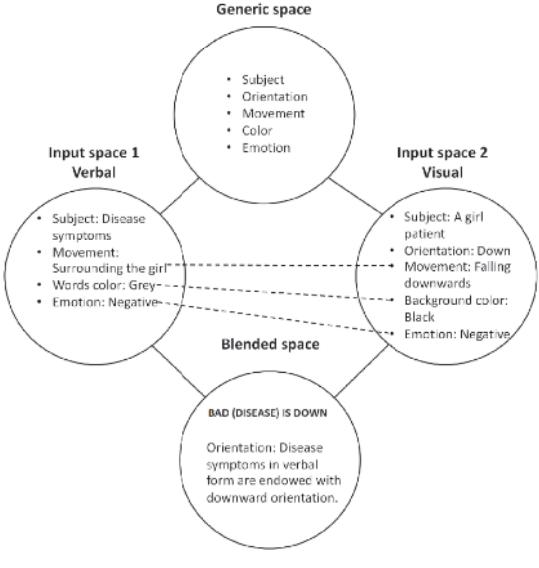


Figure 16. Text-image blending model: BAD (DISEASE) IS DOWN.

3.3. Metaphoric coherence in PSWs

Table 6 shows five metaphoric coherence types identified based on the cohesive chains constructed from the 40 PSWs, which extends the previous studies on metaphoric coherence (Liao, 1999; Ponterotto, 2000; Rezanova & Shilyaev, 2015), by adding three new metaphoric coherence types in PSWs. The distribution of the metaphoric coherence types presents a diverse usage of metaphors and reflects the varied strategies in conveying meaning through metaphor. The potential coexistence of different metaphoric coherence types within the same PSW underscores the dynamic nature of metaphors to enhance discourse coherence. Furthermore, the narrative structure of PSWs complements metaphoric coherence, reinforcing the overall discourse coherence by aligning metaphoric chains with storytelling techniques.

Metaphoric coherence types	Total (%)
Single-chained metaphoric coherence	16 (40%)
Network metaphoric coherence	7 (17.5%)
Link metaphoric coherence	6 (15%)
Topic-based metaphoric coherence	6 (15%)
Mega-metaphoric coherence	5 (12.5%)

Table 6. Metaphoric coherence types in PSWs.

3.3.1. Single-chained metaphoric coherence

"Single-chained metaphoric coherence" (Figure 17) relies on one single recurrent metaphor that is reiterated throughout the whole PSW to form a single cohesive chain, accompanied by several other independent metaphors. In Figure 18, the visually depicted "black balloon" anchored by the text "depression" indicates the conceptual metaphor DEPRESSION IS BLACK BALLOON forms a "coherent scenario" (Gibbs, 2006, p. 435) that set in a dark somber tone. It reflects the conflict between the two characters—the patient and the black balloon (depression), which showcases the dark nature of depression that shadows the life of the patient struggling with it. With careful and deliberate repetition throughout the PSW, the conceptual metaphor builds a single metaphoric cohesive chain strengthened by two cohesive chains constructed by the source domain or target domain respectively, which weaves a thread of coherence that ties together seemingly disparate elements of the discourse, thus creating a unified and compelling narrative that resonates with the reader while maintaining scientific clarity.

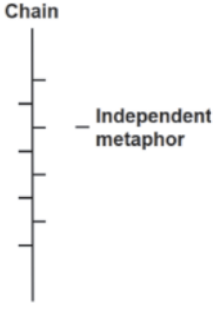
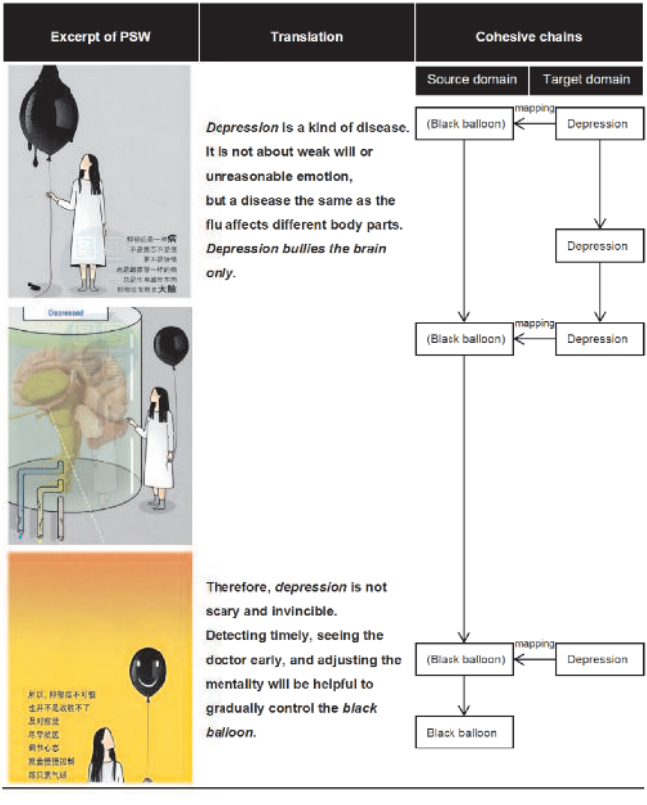


Figure 17. Pattern of single-chained metaphoric coherence.

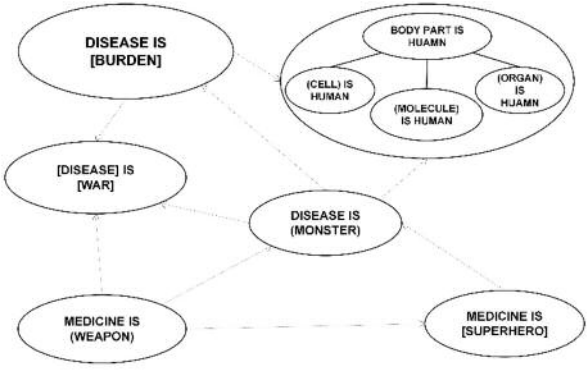


["()" refers to visual mode, the same hereafter. The excerpt is selected from the PSWs: I am not unhappy, but depressed... (https://mp.weixin.qq.com/s/wT5397GgzV0qOoFVTAbKUQ)].

Figure 18. Illustration of single-chained metaphoric coherence.

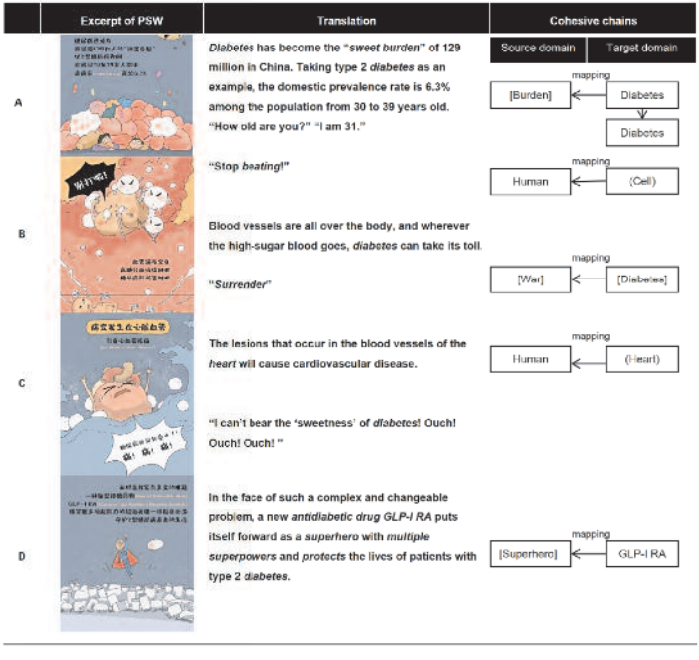
3.3.2. Network metaphoric coherence

Aligning with the cognitive metaphor network (Ponterotto, 2000) mentioned in section 1.3, "network metaphoric coherence" is constructed by metaphors that can be connected into a network to achieve discourse coherence in a PSW (Figure 19). In Excerpts A and B (Figure 20), the conceptual metaphor DISEASE IS BURDEN/WAR leads in conflicts between individuals and diabetes, which unwraps a cohesive and compelling narrative for readers to follow. The story characters, human body components in Excerpts B and C (Figure 20), including organs, cells, and molecules attacked by diabetes are referred to as human beings, which presents the conceptual metaphor BODY PART IS HUMAN. As members of society rely on one another to thrive, the various components of the body must work together harmoniously to ensure well-being and vitality. Through this lens, the impact of diabetes on these vital elements serves as a stark reminder of the interconnectedness and interdependence of human body's intricate systems that help form a part of the metaphor network. Excerpt D (Figure 20) shows that MEDICINE is treated as SUPERHERO getting involved in the conflicts to protect patients from the WAR launched by diabetes, which is again related to the metaphor DISEASE IS WAR. In this story constructed by an intricate network of metaphors, the battlefield within the human body rages on, with diabetes launching its relentless attacks on the unsuspecting cells and organs. The medicine, like a valiant superhero, steps in to battle the forces of disease and restore the balance and harmony of the fragile body ecosystem. Thus, the underlying logic of those metaphors is the confrontation between disease and medicine within the human body, shaping the entire network-like metaphoric coherence that enhances the storytelling process in the PSW. Distinct from the monomodal-based cognitive metaphor network, network metaphoric coherence in PSWs integrates multimodal elements, including verbal and visual modes. Among those source and target domains in Figure 20, four of them are presented in visual-verbal mode. The visual representations of metaphors, such as medicine as a superhero or human body parts as human beings are depicted to create a more immersive and compelling narrative. This multimodal aspect of network metaphoric coherence thus represents a significant advancement over the traditional cognitive metaphor network, which offers a more dynamic and holistic approach to discourse coherence in PSWs.



("[]" refers to visual-verbal mode, the same hereafter).

Figure 19. Pattern of network metaphoric coherence.

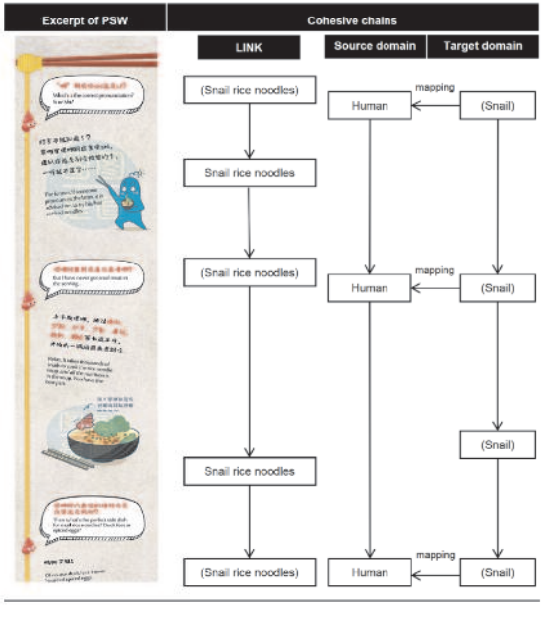


[The excerpt is selected from the PSWs: Affected by the sweet couples on the Chinese Valentine's Day? Be careful with this "sweet" disease! (https://mp.weixin.qq.com/s/zkTmg0dtDnLunoqGtt_U4w)].

Figure 20. Illustration of network metaphoric coherence.

3.3.3. Link metaphoric coherence

"Link metaphoric coherence" is a way of building coherence unique in PSWs, and it is based on the LINK schema, a cognitive structure to create a metaphorical bridge between different statements or arguments. This helps the readers follow the logic and structure of PSWs and understand the inter-relatedness of each statement. Link metaphoric coherence also makes PSWs interesting and memorable for readers exposed to novel and creative ways of presenting scientific information. The repeated visual presence of the snail rice noodles creates a vertical, continuous and visible thread that embodies the journey of storytelling in the PSW (Figure 21). Strung on the noodles, the snail character narrates knowledge through soliloquizing and dialogue with Tao. Thus, besides the cohesive chain guided by the Link schema, the multimodal metaphor SNAIL IS HUMAN forms a secondary metaphoric cohesive chain through repetition, which strengthens the discourse coherence. This novel method improves the coherence of the PSWs and also enriches science communication by making it captivating for readers who are not merely passive recipients but active participants in the unfolding exploration of ideas.



[The excerpt is selected from the PSWs: Are there snails in the snail rice noodle? (https://mp.weixin.qq.com/s/khTBMz-IrwiMYgLDZ7DzBQ)].

Figure 21. Illustration of link metaphoric coherence.

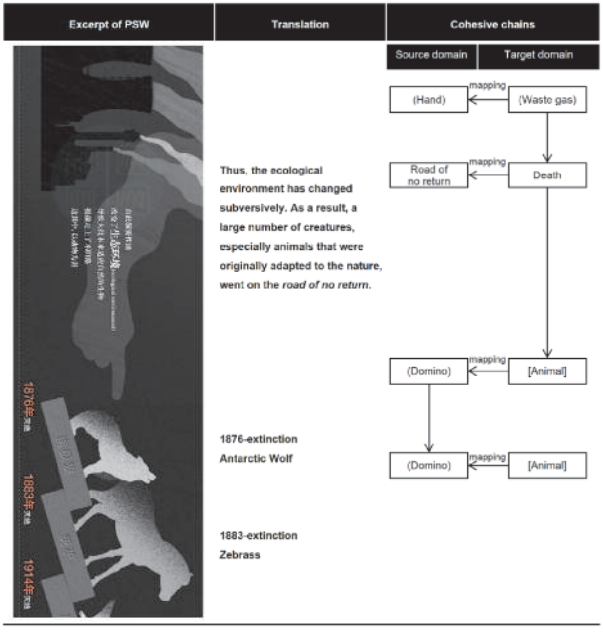
3.3.4. Topic-based metaphoric coherence

"Topic-based metaphoric coherence" is achieved when metaphors are arranged according to the shifts in the topics narrated in PSWs, without forming cohesive chains. Figure 22 showcases all the metaphoric cohesive elements in one PSW, chronologically and logically narrating statements related to different facets of extinction as the main theme of the story, including extinction in ancient or modern times as well as the reasons for extinction. As is portrayed in Figure 23, waste gas emitted by a factory transforms into a human hand, which topples the dominoes that suppress the animals, incorporating the visual metaphor WASTE GAS IS HUMAN HAND and multimodal metaphor EXTINCTION IS COLLAPSE OF DOMINOES. The transformation of waste gas into a human hand effectively demonstrates how human action causes destruction. Dominoes serve as a striking symbol of the inter-connectedness of different species and ecosystems, which suggests that the collapse of one element inevitably leads to the demise of others within the intricate network of life. The conflict between human actions and the natural world is essential for creating narrative tension and keeping readers emotionally engaged as they witness visual and multimodal metaphors presented in a reflective and negative tone delivered under the black frame. These different metaphors are skillfully woven together to highlight the intricate relationships between diverse metaphoric cohesive elements and underscore the complexity of the rich and overarching theme of extinction to prompt readers' reflection on the fragility of ecosystems and the impact of human activities on the natural world.

Human may go extinct next

Page	Target domain	Source domain	
2	Extinction	(Meteorite fall)	Extinction in ancient times
3	Dinosaur extinction Mammoth extinction Smilodon extinction	(Dinosaur skeleton) (Mammoth skeleton) (Smilodon skeleton)	
7	Bad Extinction Industrial pollution	(Black) Road of No Return-Journey metaphor (Hand)	
8	Species Extinction	(Dominoes fall)	Extinction in modern times
9	Species Extinction Species Extinction	(Dominoes fall) (Dominoes fall)	
10	Zoo captivity Zoo captivity	(Handrail) (Handrail)	
11	Extinction edge Extinction edge	(Dominoes crack) (Dominoes crack)	
12	Extinction Human prevent Extinction	Carriage wheel (Hands stop dominoes fall)	
13	Ecological chain Disintegrate	(Link) [Bad]	Reasons of extinction in modern times
14	Species Extinction	(Human-made extinction)	
15	Human's influence	(Man's hand)	
16	Species replacement Species Extinction	Shuffle Get knocked out	

Figure 22. Illustration of cohesive chains.



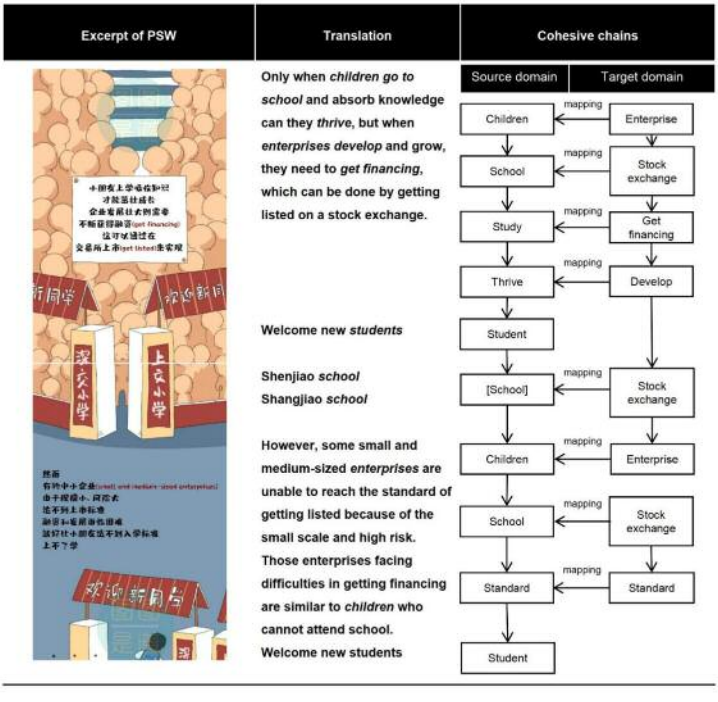
[The excerpt is selected from the PSWs: Humans may go extinct next... (https://mp.weixin.qq.com/s/qhRVVl5SoFzwmNltTEd3rQ)].

Figure 23. Illustration of topic-based metaphoric coherence.

3.3.5. Mega-metaphoric coherence

"Mega-metaphoric coherence" refers to the presence of one dominant conceptual metaphor that is introduced at the beginning of the discourse that unifies the structure of all the micro-metaphors together throughout the whole PSW. Setting up a mega-metaphor and consistently incorporating it into science communication can efficiently engage readers by providing a coherent framework for understanding complex scientific information. Excerpts (see Figure 24) denote one mega-metaphor: ENTERPRISE IS CHILD and several micro-metaphors combined under the mega-metaphor, entailing STOCK EXCHANGE IS SCHOOL, GETTING LISTED ON STOCK EXCHANGE IS ATTENDING SCHOOL, and GETTING FINANCING IS STUDYING. Under this scheme, the nurturing and growth of a child are mapped onto the expansion and evolution of an enterprise, which frames the storytelling setting of the PSW and the story plot of an enterprise's "growth" journey. The narrative likens the stock exchange to a school, highlighting its role as an educational and competitive

environment where enterprises gain development and recognition. Getting listed on the stock exchange is compared to attending school represents, symbolizing a formal process of acknowledgment, with studying parallels the process of obtaining financing acquisition of knowledge and resources necessary for success in the business world. Overall, these metaphors as storytelling elements united by the mega-metaphor offer a unique, structured and immersive narrative about the dynamics and challenges of entrepreneurship and finance, ensuring the coherence of PSW on both conceptual and discursive levels.



[The excerpt is selected from the PSWs: Why should we build a Beijing Stock Exchange even if there are Shanghai Stock Exchange and Shenzhen Stock Exchange? (https://mp.weixin.qq.com/s/iYNfeBIlmFEM9RQZcjTy0w)].

Figure 24. Illustration of mega-metaphoric coherence

4. Discussion

This study has elaborated on the use of metaphors in PSWs in a bid to demystify complex scientific concepts and to enhance the accessibility and coherence of science narratives. The findings contribute to the existing

literature by revealing the synergistic interplay of verbal, visual, and multimodal metaphors, as well as the expansion of metaphoric coherence from verbal discourse into multimodal discourse. The extension is essential and potent in meaning-making and rendering abstract scientific knowledge intelligible to lay readers.

Metaphor choices in PSWs: cognitive foundations

Addressing our first research question, the present study unveiled several recurrent metaphorical domains in PSWs, including HUMAN, WAR, JOURNEY, LINK, and CONTAINER, which are common metaphors we live by and reflect human cognitive preference (Fauconnier & Turner, 2002; Lakoff & Johnson, 1980). In essence, the prevalence of such metaphors in PSWs not only reflects the fundamental workings of human cognition (Gibbs, 1994), but also underlines the inherent connection among linguistic expressions, metaphors, and the construction of systematic scientific understanding (Carrillo & Martínez, 2023). Among these conceptual metaphors, the HUMAN metaphor emerges as particularly prominent. For instance, the intellectual property of PSWs—TAO, animals, plants, cells and human organs—all hinges on HUMAN metaphors to narrow the distance between the science concepts and human bodies as "conduits for re-presentation of the world through the five major senses" (Gibbs, 2006, p. 16), thus allowing readers to relate to abstract concepts through anthropomorphic features and to grasp "a greater chance of identification and empathy" (Dahlstrom, 2014, p. 13616). Our study's analysis of recurrent metaphors offers a fresh perspective on spotlighting the metaphorical choices that conform to human cognition in science popularization.

Multimodal metaphors and text-image relations

In response to our second research question, compared to purely verbal manifestations, PSWs provide multimodal realizations of "abstract concepts and the dynamic activation of metaphoricity" (Górska, 2019, p. 279). Since the visual components in PSWs are created in direct relation to verbal scripts, as noted by the editors of *TuTuShiTao*, the visual elements are either consistent with or supplement verbal ones. This study investigated the text-image relations between verbal metaphors and visual metaphors, as well as text-image relations within multimodal metaphors. Convergence and complementation are two main types of metaphoric text-image relations in

PSWs, among which convergence chimes with the previous study (Hart & Marmol Queralto, 2021), which indicates that it plays a significant role in the construction and interpretation of both verbal texts and multimodal texts. Moreover, with relay designated as a sub-type of complementation based on the classification of Van Leeuwen (2005), our study goes beyond by offering an exploration of two novel sub-types of complementation in PSWs: personification and blending. First, personification is typically represented in monologue or dialogue that marks the point of view in storytelling as a form of science popularization; second, blending steps out of the conventional boundaries and suggests dense interactions and close relations among metaphors in different semiotic modes. Our analysis of these novel types demonstrates how the synthesis of language and imagery in PSWs creates layered meanings and underscores the complexity and richness of metaphoric text-image relations in scientific popularization. Likewise, the findings highlight the innovative strategies that enhance the overall creativity and communication effectiveness to engage readers in an immersive narrative experience.

Metaphoric coherence in the multimodal storytelling of PSWs

For the third research question, our study emphasizes discourse coherence constructed by metaphors in PSWs, which aligns with previous research (Ponterotto, 2000; Rezanova & Shilyaev, 2015) on metaphoric coherence in verbal discourse in terms of network metaphoric coherence and mega-metaphoric coherence. However, our research takes a significant step forward by expanding the boundaries of metaphoric coherence from verbal discourse to multimodal discourse. Three new metaphoric coherence types are discovered in PSWs, including single-chained metaphoric coherence, link metaphoric coherence and topic-based metaphoric coherence. Single-chained metaphoric coherence involves a single constant recurrent metaphor that functions similarly to symbols in storytelling, reinforcing and making key ideas coherent in a narrative arc. Link metaphoric coherence, predominantly in visual mode, substantiates the abstract coherence into "noodles", "strings", or "tracks". This visual metaphorical approach not only enriches the cognitive experience, but also provides a dynamic platform for readers to navigate complex scientific concepts with ease. In nature, the link schema that forms link metaphoric coherence in multimodal discourse acts as a bridge between the abstract and the concrete, weaving a cohesive visual science narrative that transcends traditional verbal discourse

boundaries (Kress & Van Leeuwen, 2021). The third type, topic-based metaphoric coherence structures metaphors according to shifts in the narrative, akin to changing themes in a story, which enhances the plot progression, thematic depth, and the memorability of scientific information. As discussed, the present study indicates the underlying connections among metaphoric coherence, storytelling, and science popularization. Through metaphoric coherence, PSWs ensure that scientific information is not presented as fragmented or isolated ideas, but rather as part of a unified narrative that maintains the reader's engagement (Bateman et al., 2017). Moreover, key storytelling elements such as character, conflict, plot, and theme work synergistically with metaphoric coherence, reinforcing the emotional and cognitive impact of the narrative in PSWs.

Moreover, the current research progresses beyond prior studies in exploring metaphoric coherence by emphasizing that multimodal cohesive chains not only maintain the narrative flow (Markhabayeva & Tseng, 2024) but also increase the intensity of coherence in PSWs (Zhang & Rushan, 2021). Within one metaphoric cohesive chain, source domains and target domains are bonded together through mappings, which strengthens the inner cohesion of the chains. In addition, the convergence between verbal metaphors and visual metaphors compactly weaves the inner structure of a cohesive chain into a compact unity. Furthermore, the intensity of metaphoric coherence can be reinforced because of the compatibility among different metaphoric coherence types within one PSWs, for example, the coexistence of link metaphoric coherence that functions like a plot thread (the rocket track), and mega-metaphoric coherence (the mega-metaphor EYE IS PLANET) that holds the big-picture of the whole story. Intense metaphoric coherence aids in crafting coherent multimodal narratives that resonate with the readers guides them to navigate complex scientific information, enhances their engagement with PSWs, and facilitates comprehension and retention of science knowledge. Additionally, metaphoric coherence serves as an invaluable analytical tool to unpack how metaphors are consistent within themselves and construct discourse coherence, to reveal the cognitive processes and communicative aspects involved in using metaphors, as well as to offer practical insights for science communicators to craft coherent and resonant multimodal narratives.

5. Conclusions

This research has delved into the intricate realm of multimodal science popularization, which sheds light on the paramount role of metaphors in demystifying complex scientific concepts and enhancing the coherence of science narration. Nonetheless, it should be admitted that the scale of the corpus used in this research is relatively small, which may affect the generalizability of the findings. Additionally, feedback from readers was not incorporated, limiting the ability to assess how well metaphor strategies resonate with or are understood by the target audience. Future studies may explore larger-scale datasets and incorporate reader perspectives to refine our understanding of how multimodal metaphors might be employed more successfully to boost scientific literacy and broaden public involvement with science.

Despite the limitations, the present study gains a comprehensive understanding of how scientific knowledge is modified for non-expert readers and digital media by looking at the cognitive and multimodal features of PSWs, which can help to increase public awareness of scientific literacy and research accessibility. To maintain coherence and effective usage of metaphors in multimodal ensembles, it becomes crucial for science communicators to understand the relationship between metaphors and coherence. For science readers, the cohesive presentation paired with metaphoric coherence makes PSWs easier to read and allows scientific knowledge accessible. The current target readers of PSWs are mainly Chinese citizens, but our findings offer both theoretical and practical insights for global science communicators who seek to craft coherent and resonant multimodal narratives. This study contributes to the evolving landscape of science popularization by illuminating the transformative power of metaphors in constructing cohesive and engaging narratives that bridge the gap between abstract scientific concepts and lay readers. In the long run, the present study has the potential to lead to comprehensive research to build effective discursive methods and semiotic modes for future multimodal science dissemination genres.

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NOTES

[1] WeChat is one of the most popular social media platforms in China, with over 1.37 billion monthly active users (Statista, 2024).