Metaphoric Transfer Effect in Information Visualization Using Glyphs

Yi-Na Li
Business School,
Nankai University
+86 15850657820
yina@nankai.edu.cn

Dong-Jin Li
Business School,
Nankai University
+86 13752249929
djli1280@163.com

Kang Zhang
Department of Computer Science
University of Texas at Dallas
+1-972-883 6351
kzhang@utdallas.edu

ABSTRACT
Metaphor is the underlying mechanism of information communication. Although metaphors are ubiquitous in information visualization designs, different connotations influence users' information processing dissimilarly. However, visual metaphors imply interfering attributes caused by the source concepts, and lead to backfire effects on users' inferences. Understanding the pros and cons of metaphoric transfer effect in information visualization would help optimizing visualization designs, and improve efficiency and accuracy of information processing. This study empirically examines how metaphors influence different activities of information processing, including comprehension, inference and judgment in information visualization. Metaphors illustrating strongly implying semantic meanings in source domain can improve both the user's conceptual fluency in information comprehension, and the rate of correctness in information searching.

Categories and Subject Descriptors
H.1.2 [**User/Machine Systems**]: Human information processing-*visual information communication, cognitive bias, cognitive fluency, inference and judgment*

General Terms
Experimentation, Human Factors, Theory

Keywords
Metaphoric transfer effect, information visualization, persuasion, processing fluency

1. INTRODUCTION
Conceptual Metaphor Theory (CMT) indicates that metaphor is the fundamental mechanism to shape the way we think and act [26]. People interpret unfamiliar concepts by transferring correlated attributes from familiar objects. To interpret a design of information visualization, users have to remember the mapping relationships between data variables and attributes of visual stimuli. With increasing number of variables, the complicated mapping relationships make the memory task challenging, and exacerbate confusion in understanding data. Users are forced to use their limited working memory to the mapping relationships, and decrease available cognitive resources for further information processing. To optimize users' experiences, designers introduce principles of structural metaphor to guild their designs. According to those principles, they design icons highly representational, and organize visual stimuli structurally consistent with familiar schemas. Psychologists suggest that information consistent with their schemas is easier to attend and recall [1][9][14] [27]. Using metaphors, information visualization can evoke schema. Schema is the accumulated knowledge of social groups, personalities, events and abstract concepts [27] stored in users' long-term memory. The evoked schema can help to integrate variables structurally, save the resources of working memory, avoid users' information overload during interpretation, and therefore decrease the perceived difficulty. Scholars call the perceived ease in information processing "cognitive fluency", which is a generally preferred mind states in information processing [6] [41].

In previous research, information visualization tends to aim at fast analysis and communication. Although scholars have studied the persuasive power in information informing [34], scarce research has discussed users' other various cognitive activities in the entire process, particularly the effect of information interpretation, persuasion, logical inferences and judgment making. Ambiguous understandings of various intended metaphors on different activities impeded the development of a good user-centered design. Additionally, most previous research takes a metaphor-focused approach, in which a metaphor is assigned or identified to symbolize particular concepts, without further discussion on the influences of metaphors. Such approaches are built on a presumption that visual stimuli in information visualization can objectively represent information. Having created many important designs, previous approaches are in need of objective evaluation. It is imperative to explore the consequences of different metaphors. i.e. the *metaphoric transfer effect* on information processing.

Our study executes empirical experiments to examine how users process a target concept when manipulating a corresponding source concept, particularly the cognitive fluency in information processing, the rate of correct answers in information search, inferences and judgment. We analyze the pros and cons of the metaphor transfer effect on different cognitive activities during information processing, and provide guidelines for both visualization designers and users to improve their communication and the quality of decision-making. Our research makes the following contributions:

- Theoretically, it challenges the long assumed benefit of metaphor application, explores the influence of metaphoric transfer effect in various scenarios, and therefore paves the way to in-depth understanding of the underlying mechanism in visual information communication.
- It also provides a case study and evaluation on the interaction between visual information and literal information. We prove that metaphors, usually illustrated literally, can make the visually complex stimuli absorbed with high processing fluency.

2. RELATED WORK

2.1 Metaphor-Based Designs

A growing body of research has proposed applications of diversified metaphors in user interface design and information visualization. For example, scholars have adopted spatial metaphors to realize higher levels of usability of mobile interfaces [18], assigned semantically resonant colors to represent data (for example, blue for data about *ocean*, green for *plants*, and pink for *love*) [29], designed firewall warnings in software using metaphor of a brick wall, a locked door, and a bandit [35]. Others have classified and summarize primary metaphors in interfaces [4] and visual analytics [13], and assessed the effectiveness of alternative metaphors for groups of different cultures and ages [17].

Metaphor has been used as a universal guideline to improve quick learning and interpretation [42] in both user interface design and information visualization. Nevertheless, the roles of metaphor are different in those two types of design. In interface icon designs, metaphors indicate particular functions, showing right pages or warning on users' wrong operations. In contrast, in information visualization, the metaphors are meant for logical reasoning, involving complicated information processing activities, such as identifying certain patterns, comparing the attributes of objects, and making judgment. Furthermore, information visualization do not lead to an established conclusion, and nor respond to users' inferences and judgments. Thus, it is highly necessary to explore the role of metaphors in different types of processing activities in information visualization. A great number of studies have confirmed the benefits of metaphors in user's information processing, e.g. establishing user expectation and encouraging prediction about a dynamic system [11]. Current research, however, lacks discussion on the validity of metaphors as the bases of reasoning and possible backfire effects on judgments and inferences.

2.2 The Metaphoric Nature of Glyphs in Information Visualization

In the era of big data, glyph based encoding has become an important method for information visualization [7]. Glyphs are a type of pictorial visual signs expressing conventional meanings. As early as in Paleolithic Age around 18,000 B.C., ancients started using pictograph symbols in cave paintings to record important events [7]. The writing system of Chinese language also evolved from glyphs. A glyph is visually associated with the attributes of its referent, evoking the learnt information about the referent in one's long term memory for further information processing. Comparing with general visual tokens, which are in nature semantically indeterminate [5][16][30], glyphs can carry schema information, and evoke the accumulated knowledge about similar stimuli in social cognition. Therefore, designers take advantages of the built-up meanings of glyphs to facilitate efficient communication.

In the practice of information visualization, scholars created patterns of galaxy using Fermat's spirals to illustrate financial time serials [28], visualized spatial multivariate medical data using 3D glyphs to differ pre-attentive and attentive information [37], and introduced glyphs to encode connectivity information in topology tasks [12]. Obviously, the glyphs are not used to express the original meanings. For example, designers attached the concept of time to the pattern of galaxy, which initially may not cause association to the concept of time, and the connectivity is not physically visible. One can infer that, information visualization assigns particular mental association when using glyphs to generate and convey meanings. The entailment of meanings in such assignments is conceptual mapping essentially. The metaphor theory provides an insightful view for exploring the underlying mechanism in glyph-based information visualization, and explaining the validity and consequences of feature mappings between variables and visual stimuli.

2.3 Conceptual Metaphoric Transfer Effect

Information visualization helps users to analyze and comprehend information efficiently by mapping relationships between visual stimuli and sematic meanings metaphorically. We usually do not realize that a metaphor is acting [20]. For example, we say "the foot of a mountain" without realizing the personalization of the mountain, and call an important person as "big man" using a concept of size to imply statues. Visually, we tend to see a bold solid line as strongly correlated, and comparatively a line of dots as weakly correlated. Metaphors rely on the analogy between the source and target concepts. The target concept represents commonplace knowledge about something concrete, familiar, tangible and simple. In contrast, the source domain represents referents which are abstract, unfamiliar, intangible or complicated. The link between the elements of those two dissimilar concepts typically operates asymmetrically from a concrete concept to an abstract one [27]. Lakoff and his colleagues have concluded conventional metaphors ubiquitous in our language, proving that metaphors are not merely decorative linguistic devices [24]. Instead, they are a unique underlying mechanism through which we comprehend abstract concepts and perform abstract reasoning. Metaphors are fundamentally conceptual, not limited to linguistic rhetoric figures, but widely used to shape meanings [27]. Using conceptual metaphors, information visualization designers define the meanings of visual tokens, while viewers detect information, recognize meaningful patterns, infer conclusions and make judgments.

Cognitive psychologists developed the metaphoric transfer strategy to empirically examine the metaphor influence in information processing [27]. This strategy manipulates the concept of source domain, and assesses the changes of comprehension in the target domain. For example, in the metaphor "love is a rose", if the source concept *rose* is manipulated as "withered rose", one would infer that the target concept *love* (intimate relationship) is difficult to maintain. The phenomenon that understanding the target concept consistently changes with the manipulation of the source concept is called *metaphoric transfer effects*. We will examine metaphoric transfer effects in information visualization through several experiments.

3. RESEARCH HYPOTHESIS

Information visualization integrates many variables in one or more images. It is challenging for novice users to remember many mappings in a short time. Even professionals feel difficult to make a decision involving complicated variables. Cognitive processing theory proposes that people have limited mental capability to process every perspective of given information in given time [42]. Metaphors activate schemas in the mental structures that contain abstract representations of accumulated knowledge on the categories of similar stimuli stored in long-term memory [19]. The schematic information is not in isolation, but structured and complex. For example, one's schema for a flower may contain sensory experiences about the fragrance of that particular plant (e.g., the sweet odor of roses), different growing stages of a flower (bud or full blooming), appearances of flowers (shape of daisy, roses and lilies), and growers' delight at harvest time. A metaphor can automatically activate a series of relevant concepts available to frame unfamiliar information, and hence ease interpretation [27]. Users can allocate the limited working cognition resources into interpretation and inferences, rather than remembering the semantic meaning of visual tokens. Therefore, they perceive easy processing of the information framed by metaphors. Cognition research defined the subjective ease of attempting a cognitive task stimulus as cognitive fluency [3]. We accordingly hypothesize

H_1: Users can process information visualization framed by metaphors with higher cognitive fluency.

Information visualization is often used to persuade the audience [34]. The trust on the information is very important to enhance the persuasive power. Previous research indicates that the experience of high cognitive fluency could engender more trust on the information [39]. Generally, people infer and make judgment relying on the knowledge that can be processed logically. The absent of adequate knowledge pushes people to information unrelated to the logical solution [33], i.e. information provided via the peripheral route (vs. the central route) [33], such as sources of information and aesthetic qualities. The cognitive fluency during information processing provides an important cue to imply truth [38]. For example, Reber and Schwarz's experiment manipulate color contrasts of statements and their backgrounds to differ the difficulty to read. As expected, the participants were more likely to believe the easy-to-read statement to be true [36]. Therefore, we hypothesize that

H_2: Using metaphors to encode information can enhance the audience's trust on the information.

Apart from the visual fluency manipulated by color contrast in the previous experiment, other forms of fluency (e.g. linguistic fluency and easy to encode information, etc.) can also lift peoples' confidence on their subsequent reaction to the information [3][22][23]. Based on these experiments, we hypothesize that:

H_3: Users are more confident on their judgment when information visualization framed by metaphors.

People infer the target concept using selected knowledge, due to the similarity of features and structures, as well as causal relations and other relational knowledge [27]. A target concept can be explained in terms of multiple source concepts. For instance, the target concept of love can be expressed by diverse source concepts (love is a journey, or love is a song). The attributes of source concepts, as the basis of inference, may imply information that the original data do not contain.

Morris et al. investigated how metaphors influence investors in stock market [32]. This research describes the stock market as either an agent (volitional action, e.g. Nasdaq climbed higher) or an object (movement of an inanimate object, e.g. Nasdaq was pushed higher). Experiments proved that agent metaphors occurred more frequently on up-days than down-days and especially so when the trends were relatively steady as opposed to unsteady [32]. As this research explained, people believed acceding trajectory evokes impression of high animacy, which would be caused by enduring internal property, i.e. the volitional action. In contrast, the descending trajectory suggests inanimacy, as a result of lack of external forces. Two kinds of information would trigger corresponding features applying to information reasoning. Therefore, a metaphor does not repeat data, but strongly influences the audience with implication of additional but unrelated semantic meanings. We can hypothesize:

H_4: Irrelevant attributes implied by the source concept interfere with users' inferences in information visualization.

4. EMPIRICAL RESEARCH

We have designed experiments to testify the hypotheses proposed in the last section and report in this section.

4.1 Stimuli Design

We create two versions of information visualization on the investment in education in different states of the USA in 2008 as the stimuli for the experiment. Three variables are illustrated, including the *total investment*, the *ratio of private investment to the total investment* and the *average investment on every student in each state*. The difference of those two versions is manipulated both visually and literally. The version for the experiment group represents information using RoseShape Glyphs [8], which contain metaphors of plant and cultivation. In contrast, the version for the control group maps variables to equilateral polygons, which are seldom associated with any specific objects. The two versions of stimuli represent variables to visual attributes structurally consistent, as shown in Table 1. For both versions, the sizes of the signs indicate the total investment on education, redder colors represent higher ratios of private investment, and more complicated curves or more sectors indicate higher average investments.

Table 1: The Mapping Relationships of Experimental Stimuli

Semantics	Experiment stimuli for experiment group	Experiment stimuli for control group
Total investment	Radius	Radius
Ratio of private investment	Yellow to dark red	Yellow to dark red
Average investment	Number of petals	Number of edges

The explanations of the graphics differ in term of metaphors. The brief introduction of the metaphoric version introduces concepts of cultivation to match the flower metaphor (see Figure 1). In contrast, the introduction to the control group strictly excludes any metaphoric information (see Figure 2).

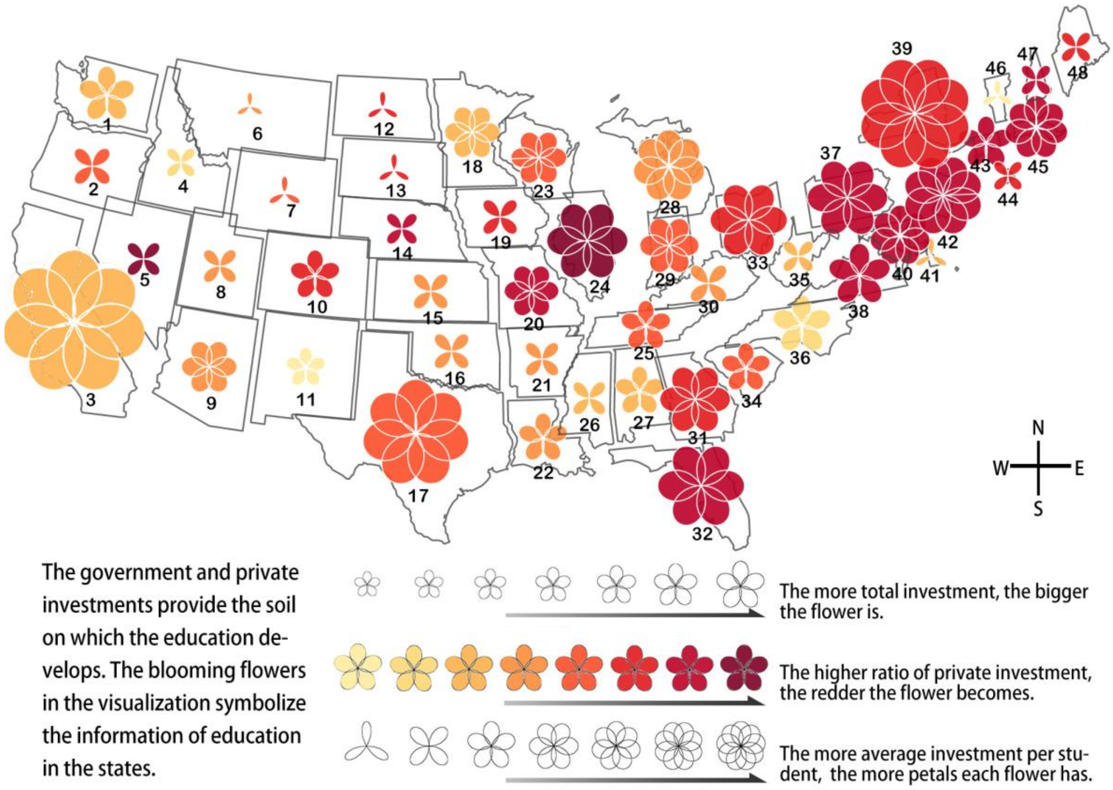

Figure 1: The experiment Stimuli Design for the Experiment Group

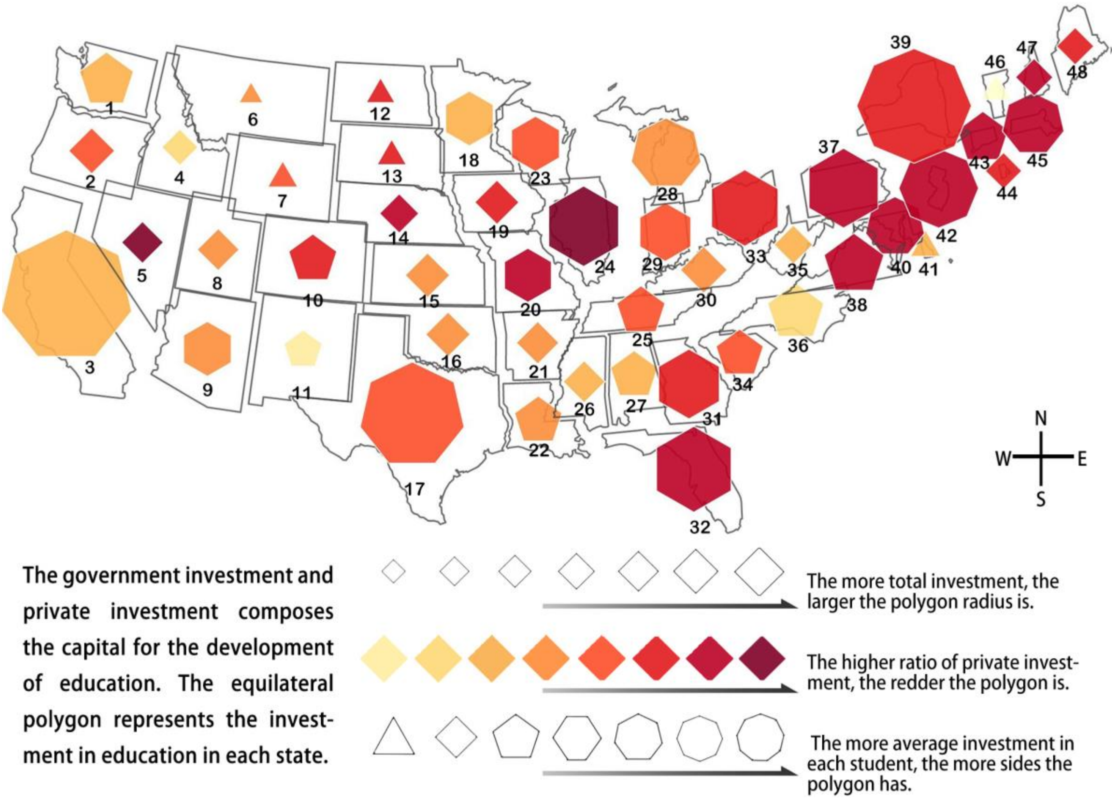

Figure 2: The experiment Stimuli Design for the Control Group

4.2 Questionnaire

The questionnaire is composed of three types of questions, which test participants' performances on visual information processing fluency, accuracy of inferences and confidences in information processing. All questions are shown as Table 2.

The first type of questions asks participants to find the number of states that match the attributes described in the questions. Five questions in this type are asked. The first three are simple, each focusing on only one attribute of the signs. The other two questions involve two attributes of the visual symbols. These five questions evaluate the participants' performances of visual information interpretation. After answering the questions, participants were asked to measure their perceived difficulty on a 7-point scale (1=very easy, 7=very difficult).

Table 2: The Questionnaire

No.	Question	Correct answer	Notes
1	Which states got the largest amount of total investment?	3	Evaluate the perceived difficulty
2	The east coast had higher ratio of private investments than the west coast? (Choices: 1. right; 2, wrong; 3. cannot judge)	1	Evaluate the perceived difficulty
3	What is in common between States 42 and 39? (Choices: 1. total investment; 2. private investment; 3. average investment)	3	Evaluate the perceived difficulty
4	Of the states with the highest ratios of private investments, which one had the least total investment?	5	Evaluate the perceived difficulty
5	Which state in the west coast had both the least total investment and least average investment?	6	Evaluate the perceived difficulty
6	State 17 state had a high total amount of investment, but above average in both private and average investments. How true would you consider the statement? (1=unbelievable, 7=very convincing)	-	-
7	Comparing with State 39, State 3 had higher total investment, lower average investment and lower ratio of private investment. How true would you consider the statement? (1=unbelievable, 7=very convincing)	-	-
8	For the experiment group: Slow watering in the spring makes flowers grow steadily. According to the information given in this graph, the east coast's education _________ the west coast. (Choices: 1. grew faster than; 2. is the same as; 3. grew more slowly than; 4. unable to judge) For the control group: good education policy can exert a positive impact. According to the information given in this graph, the east coast's education is _________ than the west coast. (Choices: 1. more advanced 2. the same 3. less advanced 4. unable to judge)	4	Report how confident participants make such a judgment.
9	According to the information given in this graphic, the east coast' education was _________ in 2008 than the west coast. Choices for the experiment group: 1. more fruitful; 2.the same; 3. less fruitful; 4. unable to judge Choices for the control group: 1.more advanced; 2.the same; 3. less advanced; 4. unable to judge	4	Report how confident participants make such a judgment.
10	How many are right answers you believe in the above 9 questions?	-	-

The second type of questions asks participants how much they believe the given statements are true on a 7-point scale (1=very incredible, 7=very convincing). Question 6 describes education information of particular states. Question 7 compares the education information of two states. Visualization is often used as evidences to persuade the audience. These two questions simulate the persuasion scenario in which information is given to the audience, who has to make a true or false choice by comparing the visual information and literal information.

The third type of questions aims at testing participants' performance with interfering pieces of information. To test the participants' performance in processing information via peripheral route, we intentionally provide insufficient information for the participants to answer questions. Question 8 asks the participants to judge between the east and west coasts which grew faster in education. Question 9 asks the participants to predict which part of the nation achieved more educational advances in 2008. Neither education growing nor education advancement is clearly defined or directly supported by given information in the visualization. Having completed Questions 1-7, the participants felt difficulty to understand our intention. The interference information is given using metaphoric and non-metaphoric expressions as illustrated in Table 2. Question 8 highlights interfering information in the question by comparing the education policy to slow watering, while Question 9 manipulates the metaphoric statement in the choices. Using such questions indirectly related to the visualization, we attempt to guide the participants to build a link between the benefit of slow watering and educational policy, and the link between agricultural harvests and education advances. We provide four choices for each question, including three predictions and an answer "unable to judge". If the participants successfully build such links, they would choose Option 1. The participants also recorded their confidences on their judgments.

Having answered those 9 questions, the participants were asked to guess how many right answers they made. This question is used to test the overall confidence of the participants to all the answers. We expect that the participants of the experiment group would be more confident to their answers than participants of the control group.

4.3 Main Study

We conducted an on-line survey using the service at http://www.sojump.com/. A sample of 100 people randomly drawn predominantly from the mainland China participated in the experiments. The pool consists of more than 170 million unique members. Participants with at least 12 years of education were randomly selected from 100 thousand members and were paid 2 RMB each to complete this test. Of the 100 participants, 55% are female and 45% are male. No significant difference in education level is found between the experiment group and the control group. To assure double blind trials, all participants finished the test from a unique IP address. According to our pretest on 3 invited participants, the average of total time spent on the test is 768 seconds, with minimum of 502 seconds. It is almost impossible to answer all the questions in 120 seconds. We therefore removed the test records submitted within 120 seconds. We also exclude the records submitted 1367 seconds (Average+3SD) after the starting time.

The participants were told to take a test of logical reasoning for academic research, and need to answer questions through information visualization and literal illustrations as quickly as possible.

4.4 RESULTS AND ANALYSIS

4.4.1 Fluency of information processing

The participants' self-reported evaluations of perceived difficulty of the first five questions reflect the fluency of information processing. High processing fluency is an important criterion of good design. The participants in the experiment group reported less mean of subjective difficulty for Questions 1-5 than the participants in the control group did (illustrated in Table 3). We use independent sample *t*-test to analyze collected data of participants' information processing. The difference of subjective difficulty between the experiment and control groups is significant, with $p_{\text{question 1-4}} < .05$, and $p_{\text{question 5}} < .1$. Therefore, using metaphors in information visualization can indeed decrease one's perceived difficulty as expected in Hypothesis 1.

Table 3: Subjective difficulty of Information Processing for Questions 1-5

Question No.	Group	Mean Difficulty	Standard Deviation	F	P
1	Experiment group	3.27	1.783	3.745	.000
	Control group	4.57	1.513		
2	Experiment group	2.73	1.723	.087	.000
	Control group	4.00	1.908		
3	Experiment group	2.98	1.768	.104	.003
	Control group	4.02	1.783		
4	Experiment group	3.75	2.088	4.197	.023
	Control group	4.65	1.683		
5	Experiment group	3.67	1.917	1.785	.052
	Control group	4.33	1.633		

4.4.2 Processing time

The experiment group spent on average 382 seconds to complete the test, while the control group spent on average 340 seconds. We use independent sample *t*-test to process the data. The results show that F=0.138, and p=0.217> .1. Therefore, the difference between the times taken on both groups is insignificant.

We prime the metaphoric transfer effect visually and literally. The stimuli for the experiment group are visually more complex than those for the control group, and hence supposed to require more time to process. It is hard to determine whether applying metaphors would reduce the processing time of more complex visualizations. To discover the effect of metaphors in information processing, and exclude the influence of visual complexity, we conducted a complementary experiment. We designed another test using the same questions and literal explanation as those for the control group, but adopting RoseShape glyphs as visual stimuli. 60 more participants in the same website were invited to complete the test. We use independent sample *t*-test to analyze the data collected in this experiment and the data of control group in the previous experiment. The experiment reports $M_{RoseShape}$=400.89, $M_{Polygon}$=329.98, F=0.118, p=0.095< .1. The difference in completion time is significant. Clearly, without literal metaphoric priming, the complex visual stimuli for the experiment group indeed required more time. Therefore, literal metaphoric priming can reduce the time needed to complete the test.

People inclined to assume that complex visual stimuli are more difficult and therefore taking longer time to process. This experiment breaks such an idea previously taken for granted. Although the participants in the experiment group indeed spent more time to complete the test, they reported lower perceived difficulty for the stimuli of higher visual complexity. Literal metaphoric priming overcomes the conventionally believed disadvantage of visual complexity.

4.4.3 Rate of correct answers

The accuracy of information interpretation was tested by the rate of correct answers in our experiment. We use binary logistic regression to analyze the rate of correct answers (illustrated in Table 4).

The experiment group provided more correct answers to Questions 1-5 than the control group did. In particular, for Questions 1, 2 and 4, the difference in the rate of correctness is significant. We therefore conclude that using metaphors in information visualization would enhance the correctness of information interpretation.

4.4.4 Confidence in information processing

Questions 6-10 test how confident a participant makes a judgment on a statement and inferences based on the given information. The participants showed no difference in the judgments of a true statement on the attributes of certain states in Questions 6 and 7.

In the test for using the peripheral route, the participants showed significant difference in their confidences in the inference on insufficient information in Question 8, but not in Question 9. The difference may be caused by different priming strategies adopted in Questions 8 and 9. In Question 8, the priming words are elaborated in the directions of the question. The priming words in Question 9 appear in the choices provided, with only one more adjective for description. The latter method of priming has much weaker effect than the former. Consistent to the function of metaphors in linguistic rhetoric [27], elaboration on the concept of source domain enhances the effect of meaning entailment. Without abundant rendering with metaphoric expression, the transfer effect cannot activate.

In the overall estimate for the number of correct answers in Question 10, $M_{experiment\ group}$= 7.61, $M_{control\ group}$= 6.41, F=0.712, and p = .03 < .05. The participants in the experiment group expected significantly more correct answers than those in the control group did. This implies that the experiment group was more confident in their overall information processing, including interpretation, judgment and inference.

We analyze the relationship between the subjective difficulty and the confidence of information processing using ANOVA. We measure the perceived difficulty by the average of perceived difficulty of the first five questions, and the confidence of information processing by the expected number of correct answers to all the questions. The results show F = 2.82, and p = .003<. 01. The subjective difficulty has significant influences on the confidence of information processing.

Table 4: The Rate of Correctness of Information Interpretation (Questions 1-5)

Question No.		Experiment group	Control group	Total number of answers	B	S.E,	Wals	df	Sig.	Exp (B)
1	Right	30	13	43	-1.529	.435	12.363	1	.000	.217
	Wrong	19	38	57						
2	Right	45	40	85	-1.129	.623	3.286	1	.070	.323
	Wrong	4	11	15						
3	Right	32	27	59	-.472	.413	1.307	1	.253	.624
	Wrong	17	24	41						
4	Right	18	15	33	-.332	.427	.604	1	.437	.718
	Wrong	31	36	67						
5	Right	37	26	63	-1.087	.435	6.255	1	.012	.337
	Wrong	12	25	37						

4.4.5 *Backfire effect of metaphoric transfer on inferences*

As many as 95% and 88% of participants failed to answer Questions 8 and 9 correctly. No significant difference in the rates of correct answers is found between the two groups. Yet the control group has a small advantage to answer correctly.

The experiment group has significantly more possibility of being induced (p= .012< .05), showing that the participants used the peripheral route to make a decision, and the metaphoric transfer effect interfered information inferences.

Traditional metaphoric transfer in linguistic studies indicates that the link from source concept to target concept is inhibitory to many associations. For example, to understand the sentence "he is a fox", readers tend to admit that "he is cleaver", rather than consider him as a night person like a fox. The direction of association is determined by the context. However, metaphors in visualization are generally lack of clear definitions or evidences to confirm the inhibitory association. Once designers illustrate the mapping relationships in a poetic language, the visualization probably transfers primary meanings and derived meanings from the source domain to the target domain. The derived meaning which is logically irrelevant to the target domain entails. Without enough concern of the possibility of such interferences, users are likely to be induced.

Table 5: The confidence of judgments and inferences (Questions 6-10)

Question No.	Group	Mean Confidence	S.D. of Confidence	F	p
6	Experiment group	5.49	1.401	0.129	.567
	Control group	5.33	1.322		
7	Experiment group	5.18	1.845	7.649	.458
	Control group	5.41	1.152		
8	Experiment group	5.69	1.245	.017	.318
	Control group	5.45	1.172		
9	Experiment group	5.65	1.147	.009	.046
	Control group	5.18	1.212		
10	Experiment group	7.61	1.835	.712	.003
	Control group	6.41	2.071		

Table 6: The Rate of misleading answers in information understanding (Questions 8 and 9)

Question No.		Experiment group	Control group	Sum of right and wrong answers	B	S.E,	Wals	df	Sig.	Exp (B)
8	Right	2	3	5	-.561	.503	1.248	1	.264	.570
	Wrong	47	48	95						
9	Right	5	7	12	-.801	.447	3.220	1	.073	.449
	Wrong	44	44	88						

5. DISCUSSION

In conclusion, using metaphors in information visualization can enhance users' fluency of information processing, and hence increase their confidence in subsequent interpretation, inferences and judgment. Although the participants perceived less difficulty to the stimuli with metaphoric transfer effect, they spent more time in information visualization. This fact breaks the assumption that perceived difficulty (high information fluency) always indicates less time in information processing. In previous research, the time spent on information processing is often seen as the indicator of perceived difficulty. The result of our research indicates that information processing time and perceived difficulty do not always positively correlate.

In our experiment, the strategy of metaphoric transfer can partially improve the accuracy of information interpretation, but hinder information inferences. Previous research emphasizes the overall benefit of metaphors in information visualization, without adequate investigation in the influence on different stages of information processing. Our research shows that the participants had higher possibility to be induced by intentionally implied inferential information when using the peripheral route to made a judgment. In practice, misleading information may be intentionally designed for persuasive purposes, or unconsciously provided. Knowing the pro and cons of metaphoric transfer effect on information visualization can help designers and users to make a precise evaluation when information is given metaphorically.

Linguistic metaphor research proves that the audience tends to believe the content to be true if a metaphor is used. Our experiment primed metaphoric effect using both visual and literal stimuli. The participants were asked to evaluate two true statements. As a result, no significant differences were shown. The potential difference of the effect of metaphors between linguistic form and visual form is therefore worth of further exploration in future research.

Cognitive psychologists distinguish visual complexity and perceptual complexity [31]. The former emphasizes the perceived complexity during the pre-attentive stage, such as more objects, more asymmetrical attributes and dissimilarity between objects.

The latter involves semantic interpretation, i.e. figuring out the signifier of visual stimuli. Generally, minimalism is the principle of a good design in information visualization. A complex icon is often unreservedly considered to be inferior to a simpler one. Our research has, however, denied this assertion. Our experiment exemplified the possibility to reverse the disadvantage of visual complexity. Metaphoric transfer effect provides an approach through which visual complexity obtains clearer order for interpretation by taking conventional schemas as references. Therefore, the impact of visual complexity should be re-visited in the context of both visual stimuli and literal stimuli.

Previous understanding of visual metaphors in information visualization is oversimplified, primarily ignoring the effect of metaphoric transfer effect on different activities of information visualization. The discussions mainly focus on adequate information scenarios in inferences, ignoring the persuasiveness when information is inadequate or insufficient. This research has explored users' reactions when information visualization stimuli are processed via the peripheral route. As early as in 1954, Huff indicated the typical lies of bar charts and curve graphs when intentionally manipulating the scale on the vertical axis [19]. This study reveals another type of lies inherent in the visual metaphor transfer effects, and reminds designers and users that metaphors in information visualization could be a double-edged sword in visual communication.

6. FUTURE RESEARCH

The participants in our experiment were not exposed to information visualization, and randomly selected online. Expert users may be better skilled in interpretation, inferences and judgment and more experienced to avoid mistakes. Future research should take the attributes of different groups of users into account, including prior knowledge, goals of information processing and the attributes and constrains in information visualization. Those variables may influence visual information processing.

A vast number of metaphors could be classified into limited primary categories. Johnson proposed typical 27 imaginary image schemas, including container, balance, path, connection, and surface et al [21]. Lakoff conclude 7 typical metaphors universal in languages, including container, source-path-target, connection, part-whole, edge, before-after and front-back [25]. Apart from limited basic shapes and structures, such as pie chart, bar chart, and tree map et al., information visualization designers use metaphors to illustrate the semantic meanings of visual stimuli. They bring additional information inherent in the source domain into the target domain out of viewers' expectations through metaphoric languages. Communication effects when a type of metaphor is paired with a type of visual element are worth further investigation. One has to pay extra attention to the influence of the inconsistency between visual stimuli and the metaphoric illustration and the interference caused by entailment from the source concept to the target concepts. More experiments using different scenarios of information visualization are needed to testify and consolidate the conclusions in our research. Comprehensive experiments could further explain the relationships between processing fluency and accuracy.

7. ACKNOWLEDGEMENT

The first author is supported by China Postdoctoral Science Foundation (Grant No: 2014M561178). The authors would like to thank Zhuang Cai for his generation of visualization images used in this paper.

References

[1] Adams, F. M., and Osgood, C. E., 1973. A Cross-Cultural Study of the Affective Meanings of Color. *Journal of Cross-Cultural Psychology*, 4, 2, 135–156.

[2] Alba, J. W., and Hasher, L., 1983. Is Memory Schematic, *Psychological Bulletin*, 93, 203–231.

[3] Alter, A. L. and Oppenheimer, D. M., 2009. Uniting the Tribes of Fluency to Form a Metacognitive Nation, *Personality and Social Psychology Review*, 13, 3, 219–235.

[4] Barr, P., Khaled, R., Noble, J. and Biddle, R., 2005. A Taxonomic analysis of User-Interface Metaphors in the Microsoft Office Project Gallery, (Newcastle, Australia, 2005, January/February) *Australasian User Interface Conference*, 109-117

[5] Barthers, R., 1977. *Image Music Text*, New York: Hill and Wang.

[6] Belke, B., Leder, H., and Strobach, T., 2010. Cognitive Fluency: High-Level Processing Dynamics in Art Appreciation, *Psychology of Aesthetics, Creativity, and the Arts*, 4, 4, 214–222.

[7] Borgo, R. K., Chung, D.H.S., Maguire, E., Laramee, R.S., Hauer, H., Ward, M. and Chen, M., 2013. *Glyph-Based Visualization: Foundations, Design Guidelines, Techniques and Applications*, *The 34th Annual Conference of the European Association for Computer Graphics* (Girona,Spain, May 6-10, 2013) DOI= 10.2312/conf/EG2013/stars/039-063

[8] Cai, Z., Li, Y.-N., Zheng, X.S. and Zhang, K., 2015. Applying Feature Integration Theory to Glyph-based Information Visualization, *IEEE Pacific Visualization 2015, The 8th IEEE Pacific Visualization Symposium* (Hangzhou, China, April 15-17, 2015)

[9] Cantor, N., and Mischel, W., 1979. Prototypes in Person Perception. In L. Berkowitz (Ed.), *Advances in Experimental Social Psychology*, 12, 3–52. Academic Press, New York, NY.

[10] Cohen, C. E., and Ebbeson, E. G., 1979. Observational Goals and Schema Activation: A Theoretical Framework for Behavior Perception. *Journal of Experimental Social Psychology*, 15, 305–329.

[11] Card, S., Mack, R. and Kellog, W., 1988. Interface Metaphors and User Interface Design. In Hellander, M. (ed): *Handbook of Human Computer Interaction*, Elsevier Science Publisher.

[12] Cayli, M., Cobanoglu, M.C., and Balcisoy, S., 2013. GlyphLink: An Interactive Visualization Approach for Semantic Graphs, *Journal of Visual Languages and Computing*, 24, 463–471

[13] Cybulski, J. L., Keller, S., and Saundage, D., 2014. Metaphors in Interactive Visual Analytics, Proceedings of *The 2014 Visual Information Communication International Symposium 14* (Sydney, Australia, August 5-8, 2014), 212-215, VINCI'14, ACM New York, NY.

[14] Ditto, P. H., and Lopez, D. F., 1992. Motivated Skepticism: Use of Differential Decision Criteria for Preferred and

Nonpreferred Conclusions. *Journal of Personality and Social Psychology*, 63, 568 –584.

[15] Fiske, S. T., and Taylor, S. E., 1991. *Social cognition*. Random House, NYC, NY

[16] Gombrich, E.H., 1960. *Art and Illusion: A Study in the Psychology of Pictorial Representation*, Princeton University Press, Princeton, NJ.

[17] Heukelman, D. and Obono, S.E., 2009. Exploring the African Village Metaphor for Computer User Interface Icons. *Proceedings of the 2009 Annual Research Conference of the South African Institute of Computer Scientists and Information Technologists*, SAICSIT '09, ACM New York, NY:132-140, DOI=10.1145/1632149.1632167

[18] Howell, M., Love, S., and Turner, M., 2005. Spatial Metaphors for a Speech-Based Mobile City Guide Service, *Journal of Personal and Ubiquitous Computing*, 9, 1, 32-45

[19] Huff, D., 1954. *How to Lie With Statistics*, WW Norton and Company, NYC, NY.

[20] Indurkhya, B., 2007. Rationality and Reasoning with Metaphors, *New Ideas in Psychology*. 25. 16–36.

[21] Johnson, M., 1987. *The Body in the Mind: The Bodily Basis of Meaning, Imagination, and Reason,* University of Chicago Press, Chicago, IL

[22] Kelley, C. M., and Lindsay, D. S., 1993. Remembering Mistaken for Knowing: Ease of Retrieval as a Basis for Confidence in Answers to General Knowledge Questions. *Journal of Memory and Language*, 32, 1-24.

[23] Koriat, A., 1993. How do We Know that We Know? The Accessibility Model of the Feeling of Knowing. *Psychological Review*, 100, 609-639.

[24] Lakoff, G., 1992. The Contemporary Theory of Metaphor, in Ortony, Andrew (eds.) *Metaphor and though* (2nd edition), Cambridge University Press, Cambridge, UK.

[25] Lakoff, G., 1987.*Women, Fire, and Dangerous Things What Categories Reveal about The Mind*. University of Chicago Press, Chicago, IL

[26] Lakoff, G. and Johnsen, M., 2003. *Metaphors We Live By*. The University of Chicago Press, London, UK

[27] Landau, M. J., Meier, B. P., and Keefer, L. A. 2010. A Metaphor-Enriched Social Cognition. *Psychological Bulletin*. 136, 6, 1045-1067.

[28] Lei, S. T. and Zhang, K., 2011. Visual signatures for financial time series. *In Proceedings of the 2011 Visual Information Communication International Symposium*. Article 16. (Hong Kong, China, August 4-5, 2011) VINCI'11, ACM New York, NY.

[29] Lin, S., Fortuna, J. Kulkarni, C., Stone, M. and Heer, J., 2013. Selecting Semantically-Resonant Colors for Data Visualization, *in Proceedings of the 34th Annual Conference of the European Association for Computer Graphics* (Girona,Spain, May 6-10, 2013) Eurographics Conference on Visualization (EuroVis), Vol. 32, No. 3.

[30] Mamassian, P., 2008. Ambiguities and Conventions in the Perception of Visual Art, *Vision Research*, 48, 20, 2143–2153.

[31] Miceli G.N., Scopelliti I. andDonato C., 2014. Breaking Through Complexity: Visual and Conceptual Dimensions in Logo Evaluation across Exposures, *Psychology and Marketing*, 31, 10, 886–899.

[32] Morris, M. W., Sheldon, O. J., Ames, D. R., and Young, M. J., 2007. Metaphors and the Market: Consequences and Preconditions of Agent and Object Metaphors in Stock Market Commentary. *Organizational Behavior and Human Decision Processes*, 102, 174–192.

[33] Petty, R. E. and Cacioppo, J. T., 1986, *Communication and Persuasion: Central and Peripheral Routes to Attitude Change*. Springer-Verlag, New York, NY.

[34] Pandey, A. V. and Manivannan, A., Nov, O. and Satterthwait e, M. L. and Bertini, E., 2013. The Persuasive Power of Data Visualization (July 31, 2014). *IEEE Transactions on Visualization and Computer Graphics*; DOI = 10. 1109/TVCG.2014.2346419.

[35] Raja, F., Hawkey, K., Hsu, S., Wang, K.-L. C. and Beznosov, K., 2011. A Brick Wall, a Locked Door, and a Bandit: a Physical Security Metaphor for Firewall Warnings, *Symposium on Usable Privacy and Security* (Pittsburgh, PA. July 20-22, 2011). SOUPS '11 ,ACM New York, NY

[36] Reber, R., and Schwarz, N., 1999. Effects of Perceptual Fluency on Judgments of Truth. *Consciousness and Cognition*, 8, 338-342.

[37] Ropinski, T., Oeltze, S., Preim, B., 2011. Survey of Glyph-Based Visualization Techniques for Spatial Multivariate Medical Data, *Computers and Graphics*, 35, 392–401

[38] Schwarz, N., Sanna, L. J., Skurnik, I., and Yoon, C., 2007. Metacognitive Experiences and the Intricacies of Setting People Straight: Implications for Debiasing and Public Information Campaigns. *Advances in Experimental Social Psychology*, 39, 127-161.

[39] Song, H. and Schwarz, N., 2010. If It's Easy to Read, It's Easy to Do, Pretty, Good, and True, *The Psychologis*t, 23, 2,108-111

[40] Ware, C., 2004. *Information Visualization: Perception for Design*, Morgan Kaufmann, San Francisco, CA

[41] Winkielman, P., Schwarz, N. Fazendeiro, T., and Reber, R., 2003. The Hedonic Marking of Processing Fluency: Implications for Evaluative Judgment, In J. Musch and K. C. Klauer (Eds.), *The Psychology of Evaluation: Affective Processes in Cognition and Emotion*. Erlbaum, Inc, Mahwah, NJ

[42] Ziemkiewicz, C. and Kosara, R., 2008. The Shaping of Information by Visual Metaphors, *IEEE Transactions on Visualization and Computer Graphics*, 14, 6, 1269-1276 .