



**The Impact of Domain Knowledge and
Cognitive Fit on User's Cognitive and Affective
States:
An Exploratory Analysis Using Biometrics in the
Context of Business Information Visualization**

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Abstract:

It is well known that there is an impact of viewers' cognitive fit on decision performance in the context of information visualization. It has been suggested that domain knowledge impacts the formation of cognitive fit, decision performance, and the underlying cognitive effort. There is a lack of knowledge about the interplay of domain knowledge and cognitive fit impact on users' cognitive and affective states. In this exploratory research we will explore this relationship and resulting user cognitive and affective states through the use of biometrics devices (eye tracking, facial expression, and Galvanic Skin Response)

1. Background
2. Theory and Propositions
3. Methodology
4. Current State
5. Next Steps

Introduction

In this research we will focus on the impact domain knowledge and cognitive fit have in our cognitive process and affective states. We believe the combination of these factors allow for a smoother cognitive process and decreases frustration. By demonstrating the difference on how people with high domain knowledge and people with low domain knowledge respond to data representations that embrace cognitive fit (task-appropriate/traditional format) and those who do not (absence-of-task-relevant-information/unexpected format) we aim to explore the impact of domain knowledge in user performance.

Business Information Visualization

DEFINITION

“Business Information Visualization or the use of computer-supported, interactive , visual representation of business data to amplify cognition to achieve a better understanding of business (process, data, and behaviors) to improve decision making” (Bacic, Fadlalla 2016).

“BIV elements aligned with five nonverbal mental abilities: interaction, exploration, business acumen, relevant data, analytics, statistics, representation, perception, cognition, cognitive effort, memory and storytelling” (Bacic, Fadlalla 2016).

Table 1. Business Information Visualization Elements.

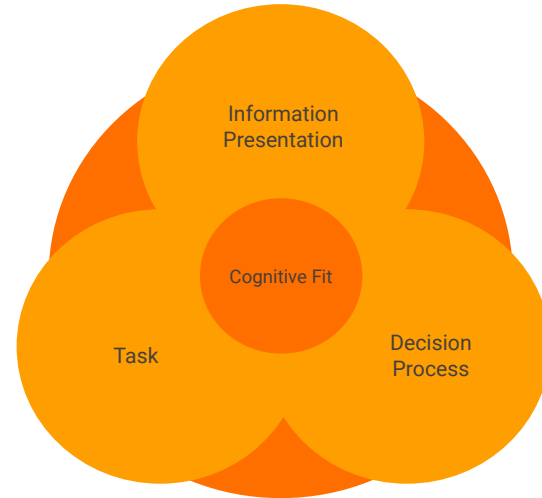
Human IQ Dimensions	BIV Elements
Fluid Intelligence	Interaction
	Exploration
Domain-specific Knowledge	Business Acumen
	Relevant Data
Quantitative Reasoning	Analytics
	Statistics
Visual-Spatial Processing	Representation
	Perception
	Cognition
Working and Short Term Memory	Cognitive Effort
	Memory
	Storytelling

Business Information Visualization

COGNITIVE FIT AND COGNITIVE EFFORT

Cognitive effort takes place when engaging in a cognitive process

Data representations that embrace the cognitive fit theory, reduce the need of additional cognitive effort



Decision performance
= Δ Cognitive Effort

Domain Knowledge (DK)

DEFINITION

Expertise the person has on the subject at hand. Facilitates person's cognitive effort and requires less effort due to familiarity on the matter.

INFORMATION RETRIEVAL

Cognitive ability to retrieve information from signals sent from short-term memory to the long-term memory.

Must be packed with resources to quickly access and recover information

MEASURING

Assessments, certifications, subject experts, outstanding grades, questionnaires, Cochran-Weis, Shanteau

Cognitive Fit

DEFINITION

“...Cognitive fit as matching problem representation to task to include the fit of individual problem-solving skills to both the problem representation and the task” (Vessey and Galletta)

BEST FIT ORIGINAL EXAMPLE (VESSEY GALLETTA)

Spatial tasks → Graphics

Symbolic tasks → Tables

Since then, context of task and data representation has grown and included a wide variety of tasks and representations

COGNITIVE EFFORT

Effort to generate, retain, retrieve, and transform visualizations to the subject's processing abilities

The more complex the task or graphic, the more cognitive effort it requires.

TRADITIONAL VS UNEXPECTED

Visualizations where the task matches the graphic will be known as “traditional visualization”

Visualizations where the task does not match the data representation will be known as “unexpected data representation”

Biometrics

DEFINITION

Measures subjects' involuntary body reactions

Show unconscious responses to subjects' affective state toward business visualization

EYE TRACKER

Tracks subjects' eye motion, placed under computer monitor

How subject reads information

FACIAL EXPRESSION

Record subjects' face to catch emotions while engaging in the thought process

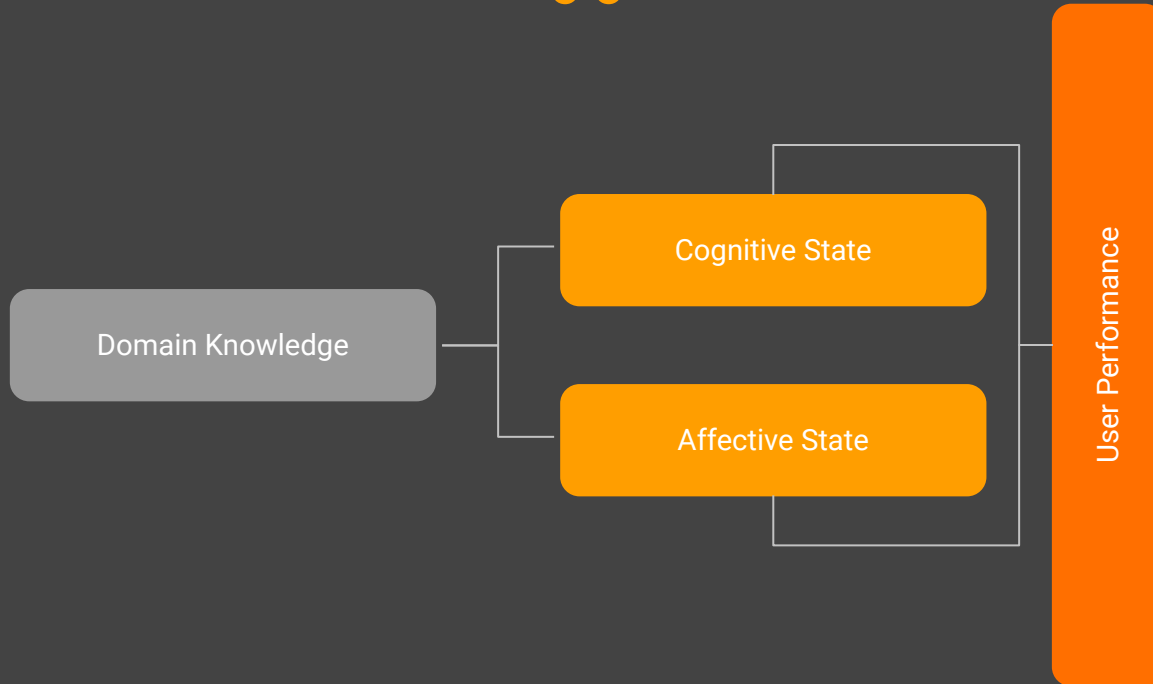
GALVANIC SKIN RESPONSE (GSR)

Measures changes in the subjects' sweat glands activity that reflects emotional state

Check out latency and phasic outbursts

Stimulated → event-related skin conductance response

Not stimulated → non-stimulus locked skin conductance



THEORY AND
HYPOTHESIS
DEVELOPMENT

HYPOTHESES - USER COGNITIVE

H1: For tasks that require specific DK, users with higher level of DK will experience higher stress/arousal when presented with unexpected data representation format, compared to users with lower level of DK

H2: For tasks that do not require specific DK, users with higher level of specific DK will not experience higher arousal when presented with unexpected data representation format, compared to users with lower level of specific DK

H3: For tasks that require specific Dk, users with higher level of DK will experience higher average fixation duration when presented with unexpected data representation format, compared to users with lower level of DK

H4: For tasks that do not require specific DK, users with higher level of specific DK will not experience higher average fixation duration when presented with unexpected data representation format, compared to users with lower level of specific DK

THEORY AND
HYPOTHESIS
DEVELOPMENT

HYPOTHESES - AFFECTIVE STATES

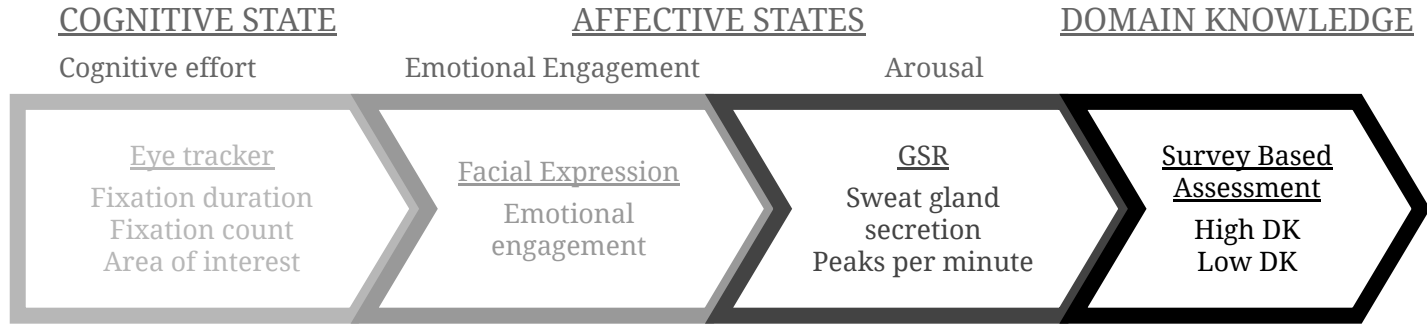
H5: For tasks that require specific DK, users with higher level of DK will experience higher fixation count when presented with unexpected data representation format, compared to users with lower level of DK

H6: For tasks that do not require specific DK, users with higher level of specific DK will not experience higher fixation count when presented with unexpected data representation format, compared to users with lower level of specific DK

H7: For tasks that require specific Dk, users with higher emotional engagement when presented data representation format, compared to users with lower level of DK

H8: For tasks that do not require specific DK, users with higher level of specific DK will not experience emotional engagement count when presented with unexpected data representation format, compared to users with lower level of specific DK

Variable Definition



*task and representation will be defined separately for each experiment

Equipment

IMOTIONS

Eye-tracker software platform, integrate with Smart Eye AI - X Tracker

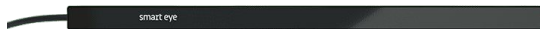
SMART EYE AI - X TRACKER

Eye-tracker tool used with iMotions

Sample Rate: 60Hz

Accuracy: 0.5 degrees (typ.)

Precision: 0.1 degrees (typ.)



Smart eye tracker AI - X tracker

QUALTRICS

Survey platform

SHIMMER3 GSR

Galvanic Skin Response equipment

Measurement range: 10K - 4.7

M Ω (.2uS - 100 uS) +/- 10%.

22k-680 k Ω (1.5-45uS) +/- 3%

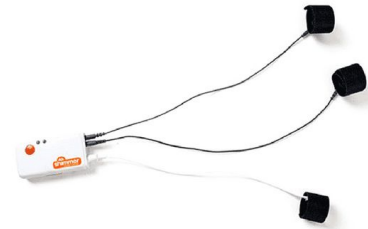
Frequency range: DC-15.9Hz

AFFECTIVA

HD camera captures facial expression

iMotions facial expression module analyzes data

We will take a look at the 7 basic emotions: joy, anger, fear, disgust, contempt.



shimmer 3 GSR



SUBJECTS

College students - higher level education

All majors welcomed



EXPERIMENTAL DESIGN

First assessment -- Subjects given mundane task using 2 representations to establish baseline to show the impact of cognitive fit is uniform across subjects without the need of DK

Second assessment -- Consists on tasks and data representations that require financial DK in order to solve the task accurately, effectively, and efficiently

Experts → upper half assessment, high DK

Non-experts → lower half assessment, low DK



DOMAIN KNOWLEDGE TEST

Financial statements are one of the primary means by which economic information about a firm is communicated to interested users. The four main financial statements are:

- Liability Statement, Assets Statement, Income Statement, Cash Flow Statement
- Balance Sheet, Cash Flow Statement, Income Statement, Tax Statement
- Balance Sheet, Income Statement, Retained Earnings Statement, Cash Flow Statement
- Cash Flow Statement, Balance Sheet, Revenues, Expenses

Review the following items and state whether they are an asset, liability, stockholders' equity, revenue, or expense account. Please 'drag' items into appropriate group.

Items	Asset	Liability	Stockholder's Equity	Revenue	Expense
Salary Expense					
Supplies on hand					
Land					
Interest Earned Capital					
Bank Accounts					
Receivable Sales					
Retained Earnings Cost of Goods Sold Salaries					
Payable					
Repairs and Maintenance Patents					
Investment in XYZ Company					

You have obtained the following data for the Cardinal Company:

Sales	\$200,00	Sales	
Gross profit ratio	40%	Profit margin ratio	5%
Profit margin ratio	5%	Income tax rate	20%

Based on the above data determine Cardinal Company's Income Taxes Chapter 3 page 66.

- \$16,000
- \$2,000
- \$600
- \$45,000

The following data are available for three consecutive years of the Orazco Corporation. What is the

missing amount for **Dividends in Year 2**

	Year 1	Year 2
Retained Earnings, beginning balance	\$70,000	?
Net Income	25,000	14,000
Dividends	35,000	?

Retained Earnings, ending balance **\$96,000 \$98,000**

(page 203 - Chapter 6)

- \$16,000
- \$14,000
- \$12,000
- \$16,000

The Gibraltar Football Equipment Company gives you the following data regarding one of its inventory items, football helmets:

Date	Quantity (units)	Cost per Unit
Beginning	60	\$150
2/28 purchase	110	125
6/28 purchase	90	122
10/4 purchase	80	120

The ending inventory consisted of 85 units Determine the cost of ending inventory using LIFO Page 423 - Chapter 9

- \$10,200
- \$9,727
- \$10,925
- \$11,650

Commuter Air, a small commuter airline, purchased an airplane for \$6 million. The president of the company is trying to decide how to depreciate the plane. The asset (plane) has a 10-year life and has an estimated residual value of \$600,000.

She asks you to calculate the annual depreciation for the first year (year 1) under double-declining-balance depreciation method. Select correct answer.

Chapter 10 (p.492)

- \$550,000
- \$1,200,000
- \$1,100,000
- \$600,000

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Procedure:

- 1) Enter the firms you wish to invest in order beginning with the firm with the lowest Total Liabilities.
- 2) Invest only in firms that meet the decision rules.

Decision Rules

- 1) Total liabilities less than or equal to \$78,000.
- 2) Notes Payable no more than 50% of Total Liabilities
- 3) Accounts Payable no more than 10% of Total Liabilities

Firm	Liabilities					Total Liabilities
	Accounts Payable	Accrued Expenses	Notes Payable	Bonds Payable		
Firm A	7,500	16,500	35,000	22,500		81,500
Firm B	6,000	14,500	45,000	13,000		78,500
Firm C	4,000	18,000	30,000	16,000		68,000
Firm D	5,000	15,000	33,000	17,000		70,000
Firm E	6,000	15,500	38,500	25,000		85,000
Firm F	6,500	16,000	34,000	17,000		73,500

Firm A

Firm B

Firm C

Firm D

Firm E

Firm F



FIRST EXPERIMENT

% Difference in Numbe..



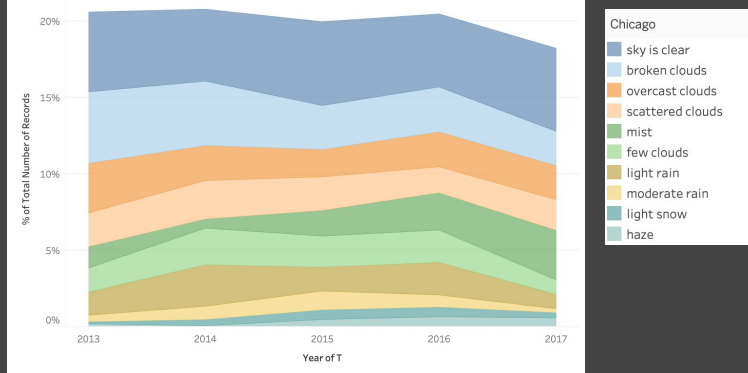
1. Which of the following weather categories has had the biggest percentage increase from 2014 to 2015?
- a. Mist b. Moderate rain c. Broken clouds d. Haze

Chicago's Weather Description - % Difference

Chicago	☁	2012	2013	2014	2015	2016	2017
sky is clear			504.2%	-9.9%	16.5%	-12.8%	13.6%
broken clouds			466.2%	-9.8%	-31.7%	2.0%	-23.5%
overcast clouds			135.2%	-29.5%	-21.9%	27.9%	-2.5%
scattered clouds			384.9%	14.0%	-12.7%	-22.7%	17.7%
mist			106.5%	-57.3%	182.0%	45.2%	33.3%
few clouds			312.3%	53.2%	-15.1%	4.1%	-55.8%
light rain			473.4%	77.9%	-42.5%	36.5%	-55.5%
moderate rain			794.7%	108.2%	41.8%	-35.9%	-68.3%
light snow				179.7%	57.0%	0.4%	-45.0%
haze				-29.4%	-68.1%	717.4%	39.4%

Traditional

Chicago's Weather Description - % of total



Unexpected



SECOND EXPERIMENT

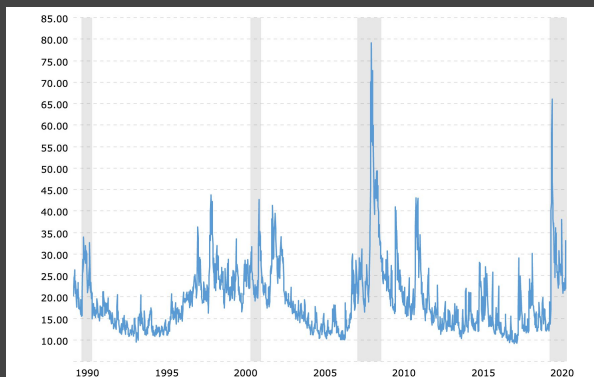
1. Which 2 years have the highest spike in volatility?

a. 2001 & 2019

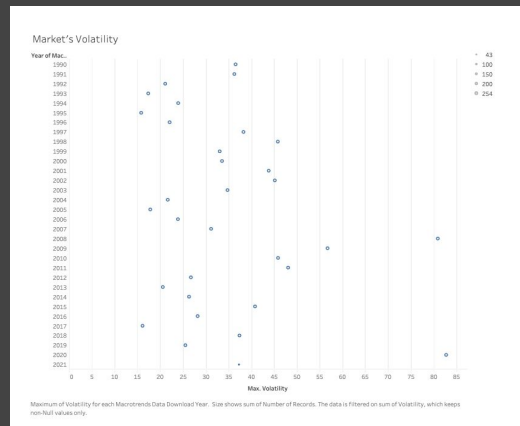
b. 2006 & 1998

c. 2008 & 2020

d. 2007 & 2010



Traditional



Unexpected



SECOND EXPERIMENT

You are trying to understand actual monthly revenue information for a particular product in six firms relative to expenses

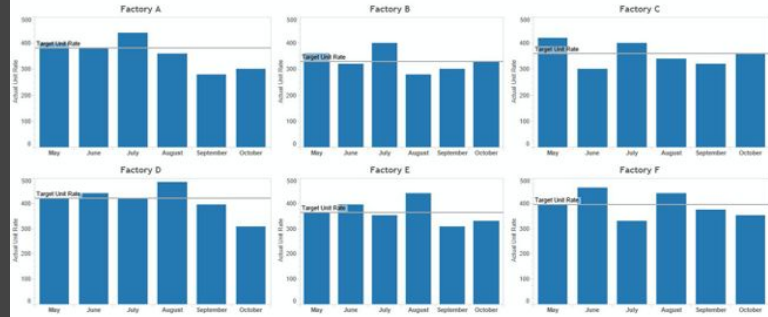
How much are Revenues above Expenses for Factory E in the month of July?

Firms	May		June		Jul		August		September		October	
	Revenues	Expenses	Revenues	Expenses	Revenues	Expenses	Revenues	Expenses	Revenues	Expenses	Revenues	Expenses
Firm A	400.0	380.0	380.0	380.0	360.0	380.0	440.0	380.0	280.0	380.0	300.0	380.0
Firm B	360.0	330.0	320.0	330.0	280.0	330.0	400.0	330.0	300.0	330.0	330.0	330.0
Firm C	420.0	360.0	300.0	360.0	340.0	360.0	400.0	360.0	320.0	360.0	360.0	360.0
Firm D	418.0	420.0	440.0	418.0	484.0	418.0	418.0	418.0	396.0	418.0	308.0	418.0
Firm E	363.0	360.0	396.0	360.0	440.0	360.0	352.0	360.0	308.0	360.0	330.0	360.0
Firm F	396.0	396.0	462.0	396.0	440.0	396.0	330.0	396.0	374.0	396.0	362.0	396.0

Select correct answer
A) 70 B) 65 C) 85 D) 80 E) None

You are trying to understand actual monthly Activity Based Costing information for a particular activity in three factories relative to a target unit rate.

How much is the actual unit rate above target for Factory B in the month of July?



Select correct answer
A) 60 B) 75 C) 70 D) -10 E) None

✓ **EXPERIMENTAL PROCEDURE**

Provide subjects with test to assess their domain knowledge.

5 minute check up -- Subjects asked a couple of questions not related to business information visualizations, just to calibrate the GSR, eye tracker, and affectiva.

Experimental procedure -- Show participants business information visualizations

 Provide experiment 1 to see effects of cognitive states and affective states

 Provide experiment 2 to see effects of cognitive states and affective states

Eye tracker → bottom of the monitor

Facial recognition → software integrated in monitor

GSR → attached to subject's body

Unlimited time, mixing levels of difficulty, no external distractions



PROPOSED STATISTICAL ANALYSIS

Recommendation

Use ANOVA to look for interaction effects between data visualization and subjects with domain knowledge

If statistically significant, advance with pairwise t-test

Pairwise t-test will determine if domain knowledge has an impact on cognitive effort, arousal, and emotional engagement

NEXT STEPS

NEXT STEPS

□□□□□

- 1. Accepted proposal
- 2. Literature review
- 3. Model
- 4. Hypothesis development
- 5. IRB approval
- 6. Manuscript (steps 1 - 5)
- 7. Data collection
- 8. Data analysis

We were unable to proceed with data collection due to university policies not allowing in person data collection due to SARS-Covid restrictions

Works Cited

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