


A Multi-Level Typology of Abstract Visualization Tasks

Matthew Brehmer and
Tamara Munzner

IEEE InfoVis '13
Oct 15, 2013


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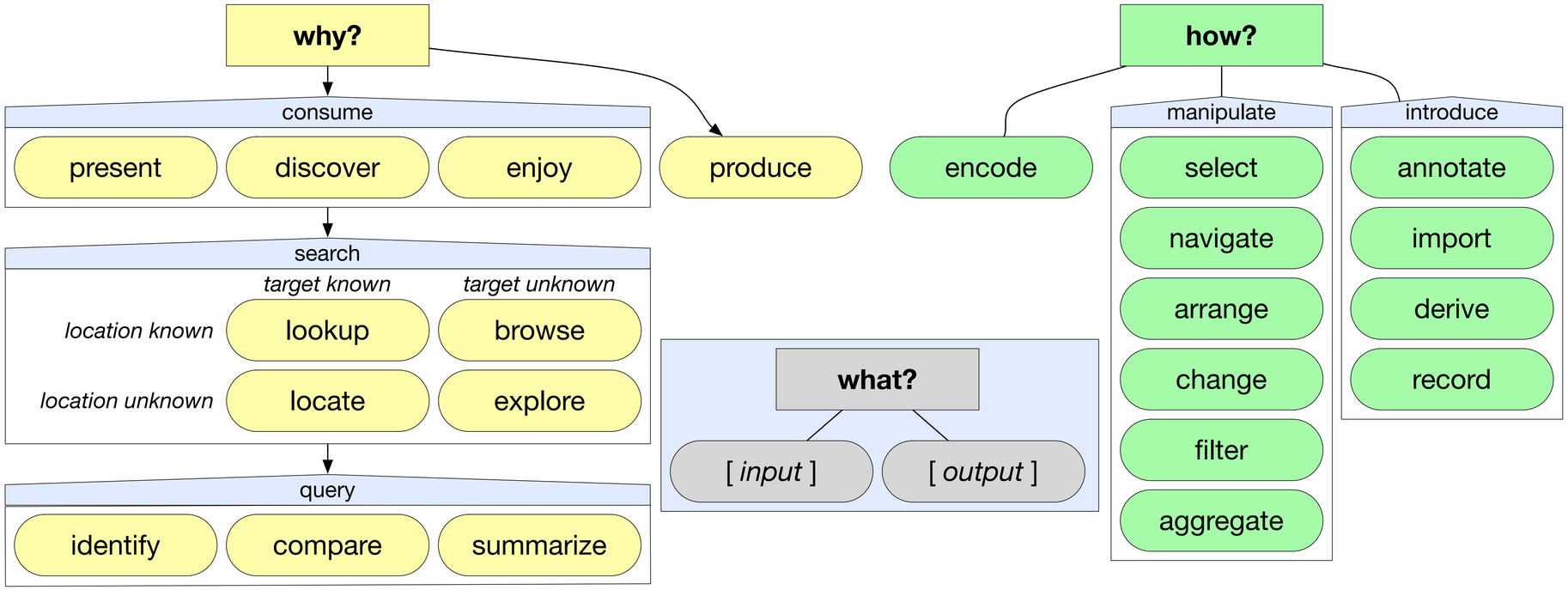

Contributions

Contributions

Framework for analyzing **tasks**, a conceptual **typology** bridging **low** and **high** levels of abstraction

Contributions

Framework for analyzing **tasks**, a conceptual **typology** bridging **low** and **high** levels of abstraction

Integrating and **extending** previous work

Contributions

Framework for analyzing **tasks**, a conceptual **typology** bridging **low** and **high** levels of abstraction

Integrating and **extending** previous work

Visual notation for describing **sequences** of **tasks**
→ clarify **means** and **ends**

Motivation

specific

broad

en.wikipedia.org/wiki/File:Brick_wall_close-up_view.jpg

commons.wikimedia.org/wiki/File:Barley_crop_-blue_sky-4May2008.jpg

- **describe** for field study
- **generate** for design study
- **evaluate** for both

Motivation *specific* *broad*

"I hit a wall. I need a better way to analyze my data."

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- **describe** for field study
- **generate** for design study
- **evaluate** for both

- **describe** for textbook analysis framework

Motivation *specific* *broad*

"I hit a wall. I need a better way to analyze my data."

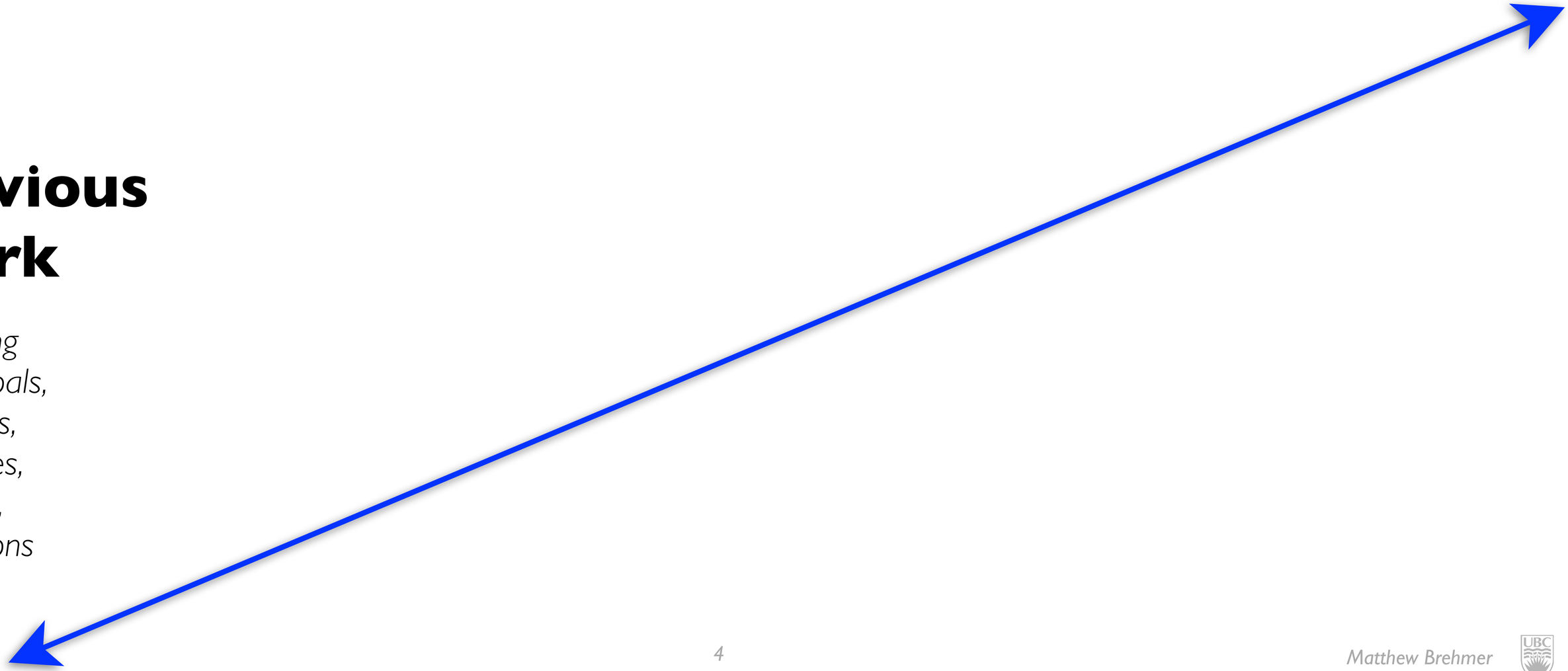
"What does the visualization community know about tasks?"

en.wikipedia.org/wiki/File:Brick_wall_close-up_view.jpg

commons.wikimedia.org/wiki/File:Barley_crop_-blue_sky-4May2008.jpg

Previous Work

Classifying
Tasks, Goals,
Intentions,
Objectives,
Activities,
Interactions

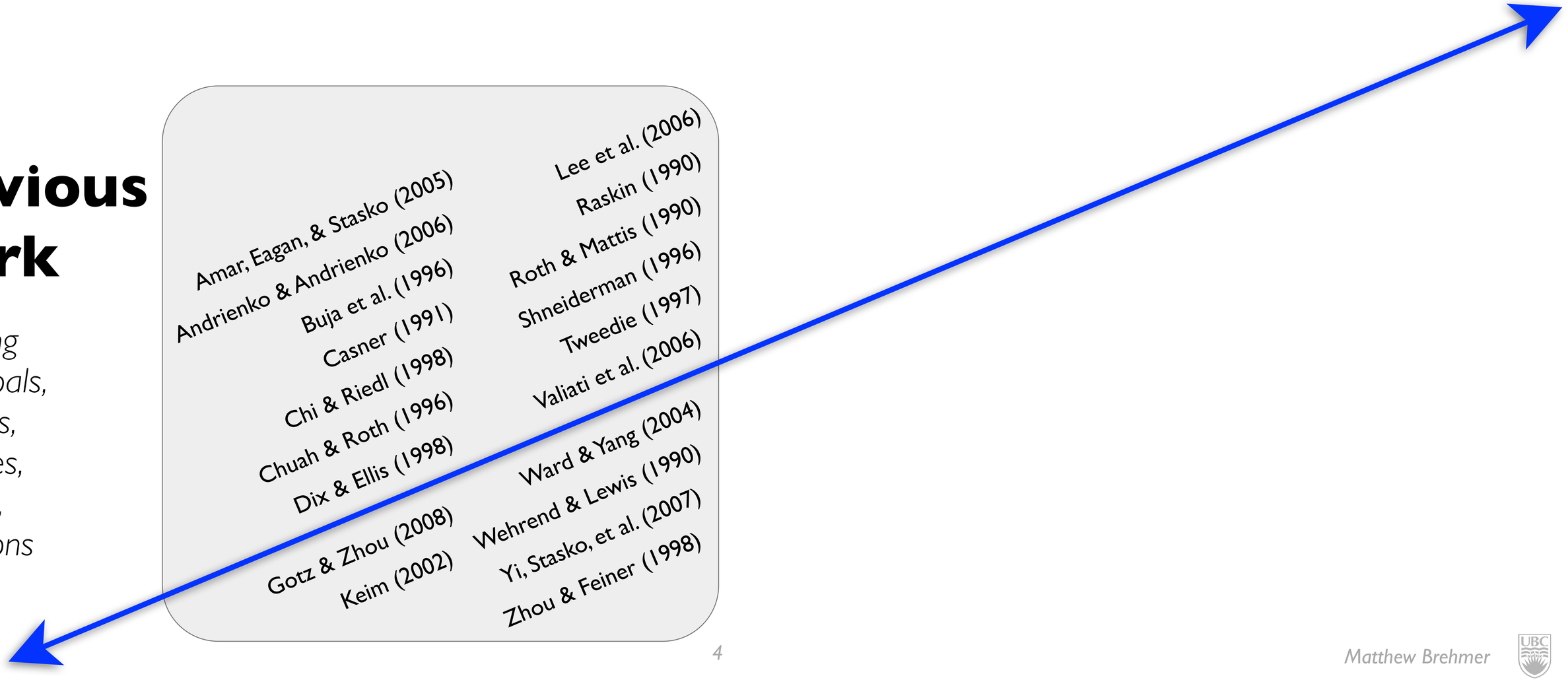


interaction & visual encoding **techniques**

low level of abstraction
e.g. *"retrieve value"*

Previous Work

Classifying Tasks, Goals, Intentions, Objectives, Activities, Interactions



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e.g. *"retrieve value"*

high level of abstraction
e.g. *"integration of insight"*

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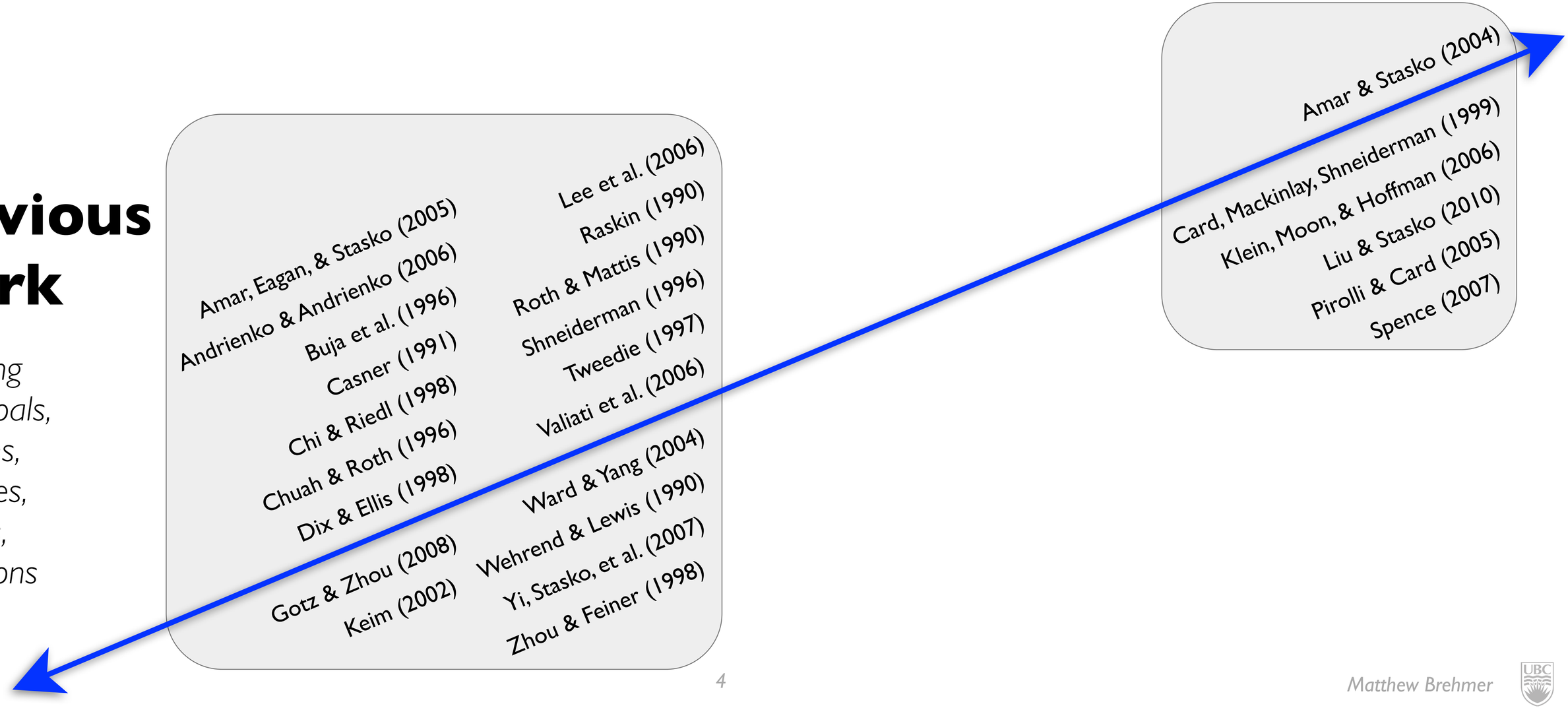

interaction & visual encoding **techniques**

low level of abstraction
e.g. *"retrieve value"*

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e.g. *"integration of insight"*

Previous Work

Classifying Tasks, Goals, Intentions, Objectives, Activities, Interactions

Amar, Eagan, & Stasko (2005)
Andrienko & Andrienko (2006)
Buja et al. (1996)
Casner (1991)
Chi & Riedl (1998)
Chuah & Roth (1996)
Dix & Ellis (1998)
Gotz & Zhou (2008)
Keim (2002)
Lee et al. (2006)
Raskin (1990)
Roth & Mattis (1990)
Shneiderman (1996)
Tweedie (1997)
Valiati et al. (2006)
Ward & Yang (2004)
Wehrend & Lewis (1990)
Yi, Stasko, et al. (2007)
Zhou & Feiner (1998)

Amar & Stasko (2004)
Card, Mackinlay, Shneiderman (1999)
Klein, Moon, & Hoffman (2006)
Liu & Stasko (2010)
Pirolli & Card (2005)
Spence (2007)

A mid-level gap?
Meyer, Sedlmair, & Munzner (BELIV 2012)

interaction & visual encoding **techniques**

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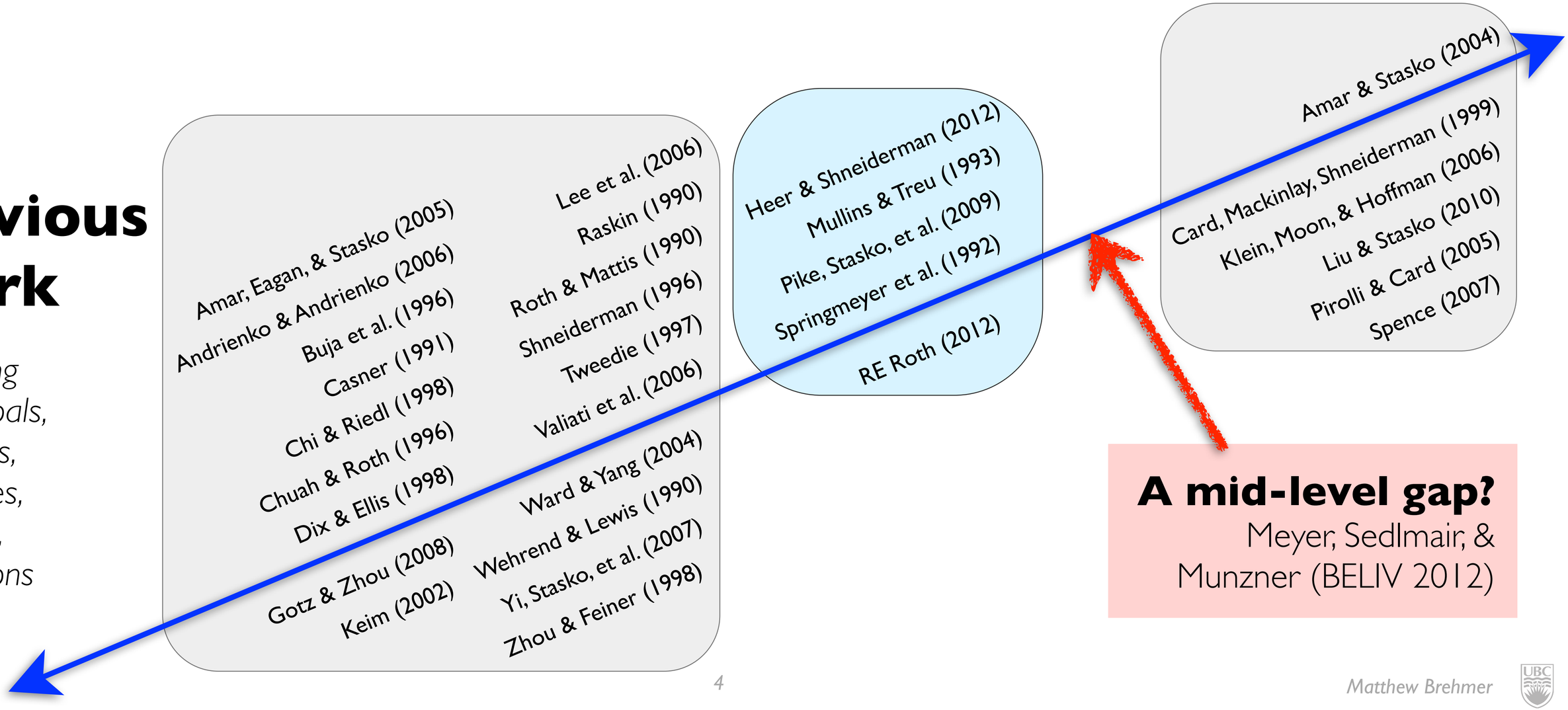


A mid-level gap?
Meyer, Sedlmair, & Munzner (BELIV 2012)

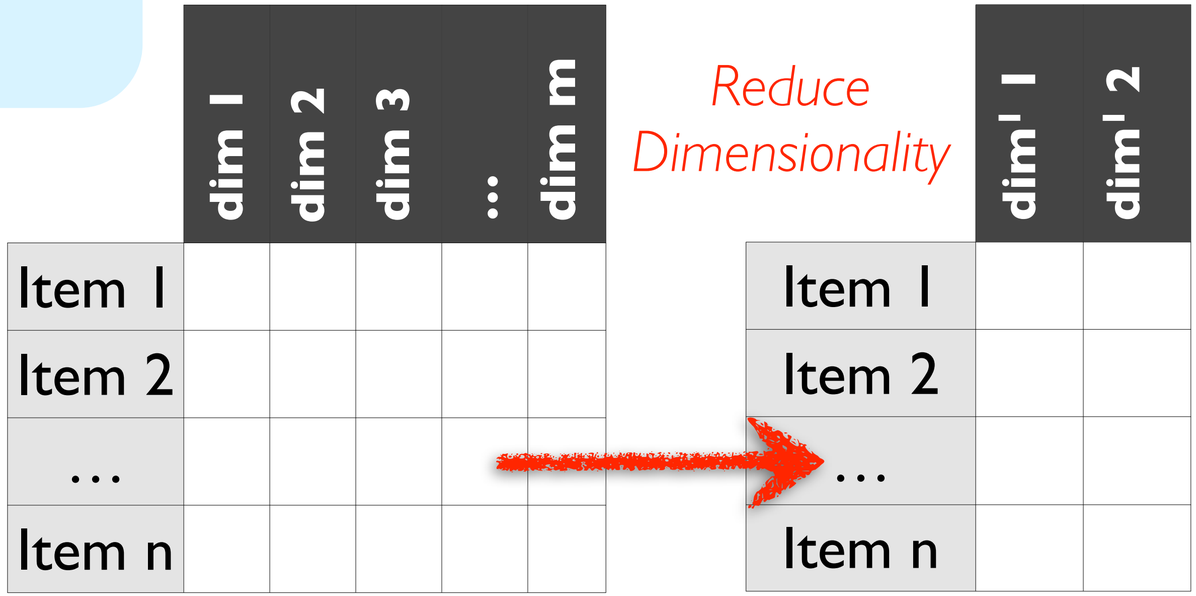
Means and **Ends**

DERIVE

Means and **Ends**

Derive as **End**

DERIVE



Means and **Ends**

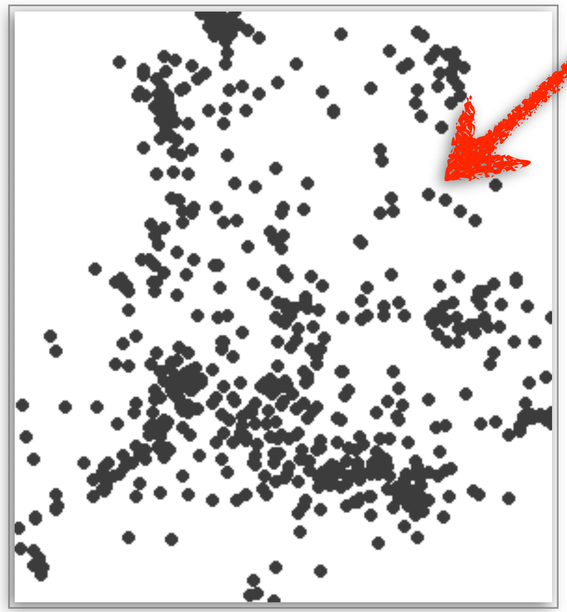
DERIVE

Derive as **Means**

	dim 1	dim 2	dim 3	..	dim m
Item 1					
Item 2					
…					
Item n					

Reduce Dimensionality

	dim' 1	dim' 2
Item 1		
Item 2		
…		
Item n		



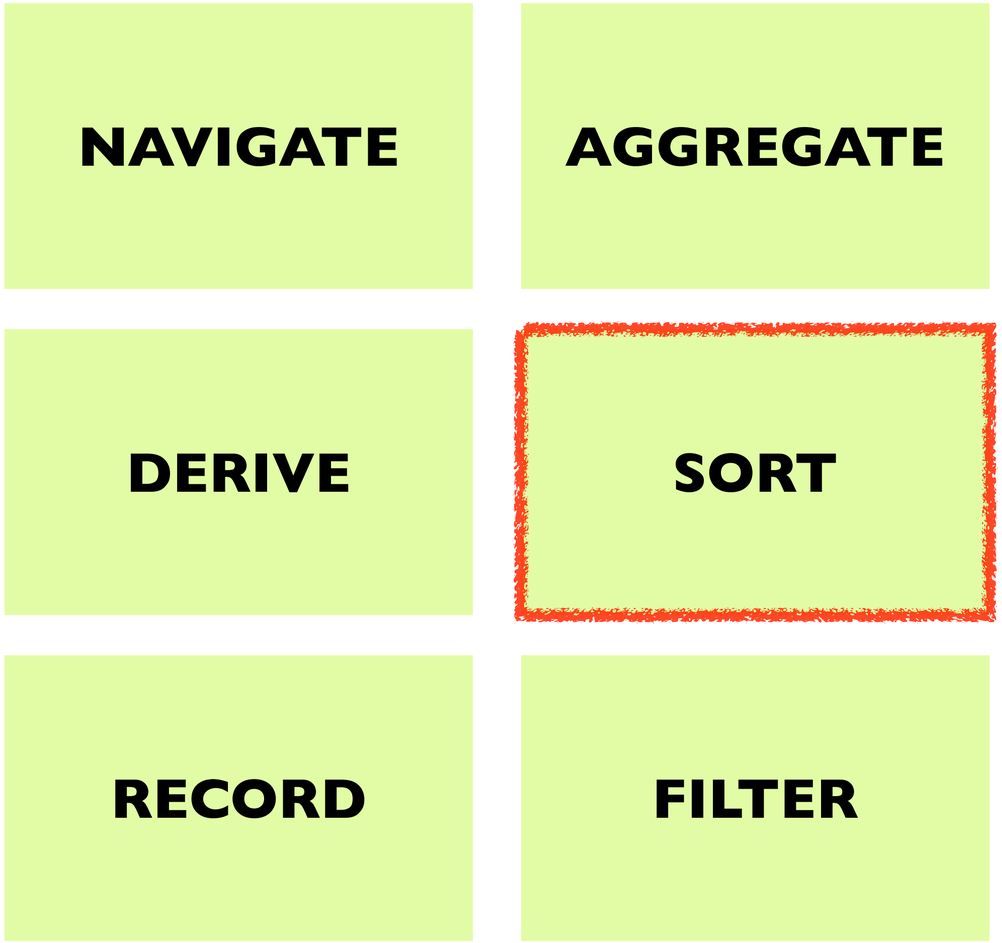
Means and **Ends**

DERIVE

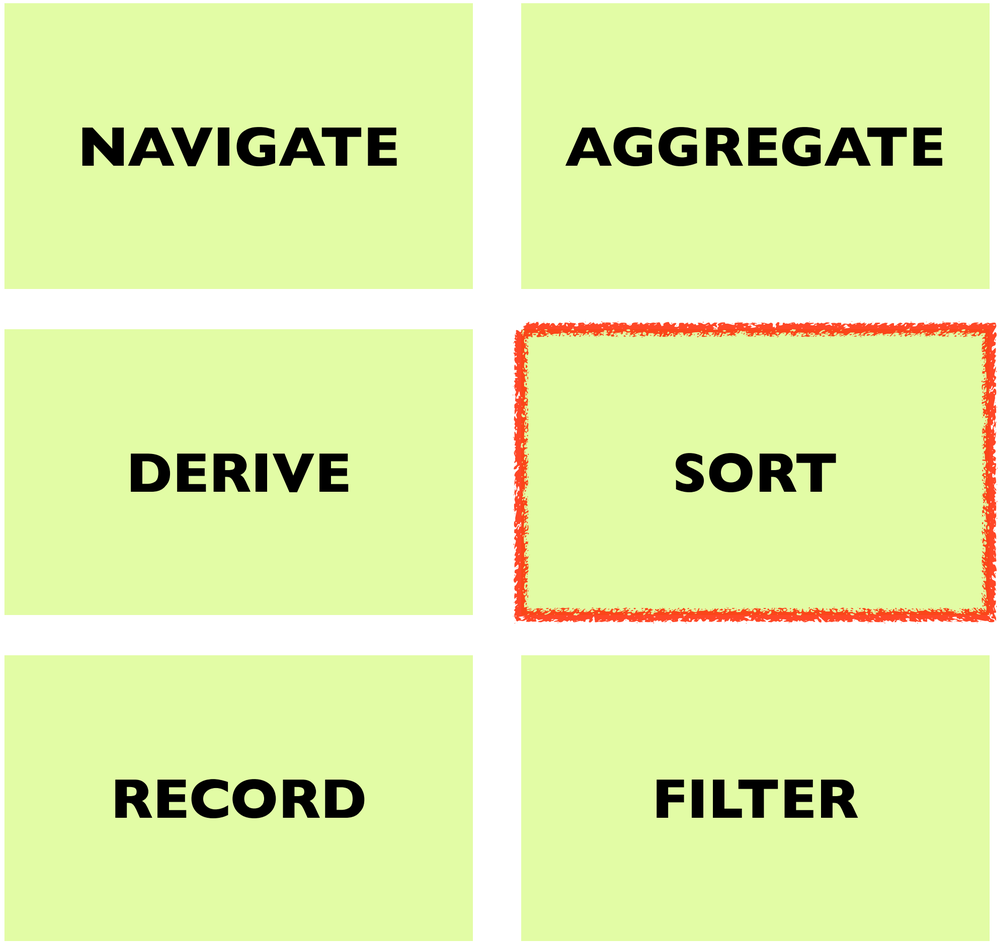
Means and **Ends**

NAVIGATE	**AGGREGATE**
DERIVE	**SORT**
RECORD	**FILTER**

Means and **Ends**

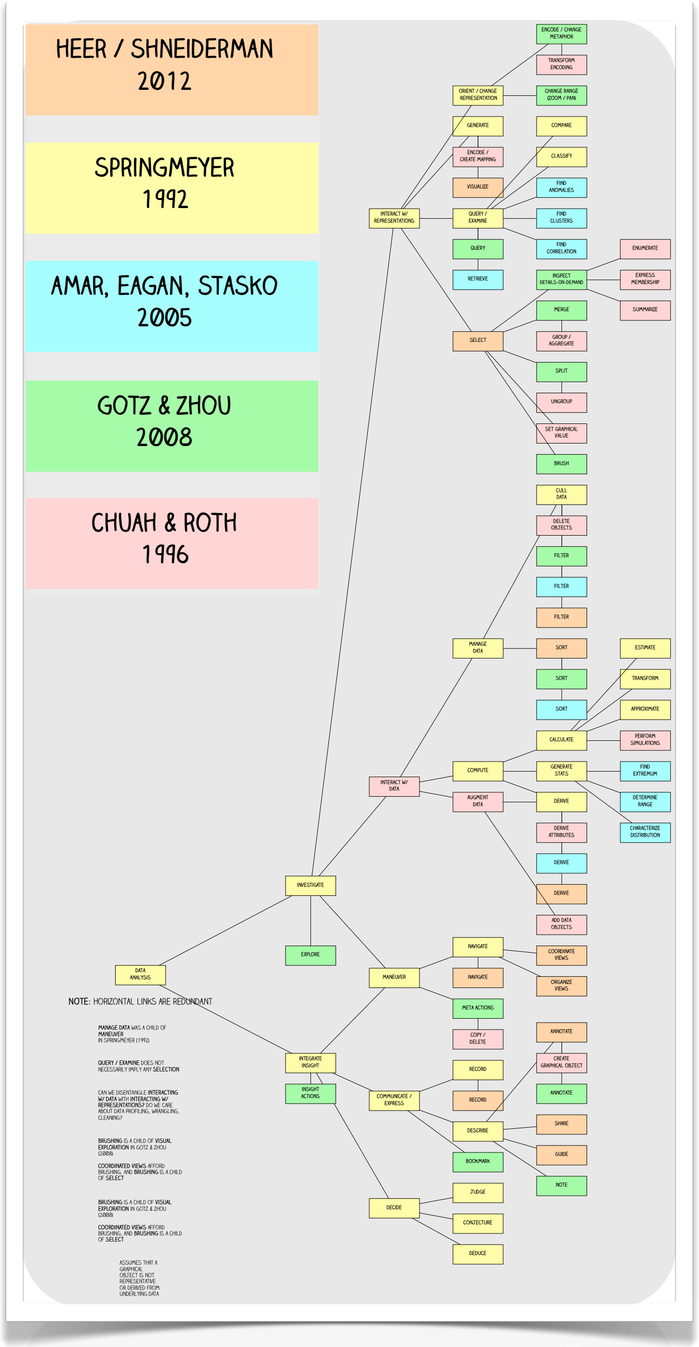


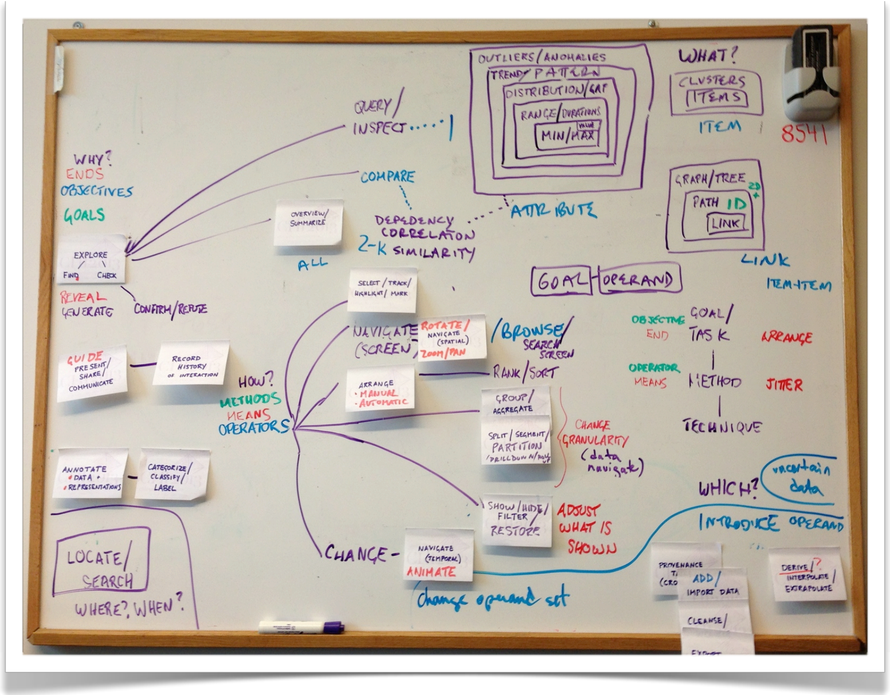
Means and **Ends**



Inputs and **Outputs**

Our Method





1. read and think
2. *code*: arrange and abstract
3. simplify and repeat…

coding of literature
rather than empirical study with expert visualization users

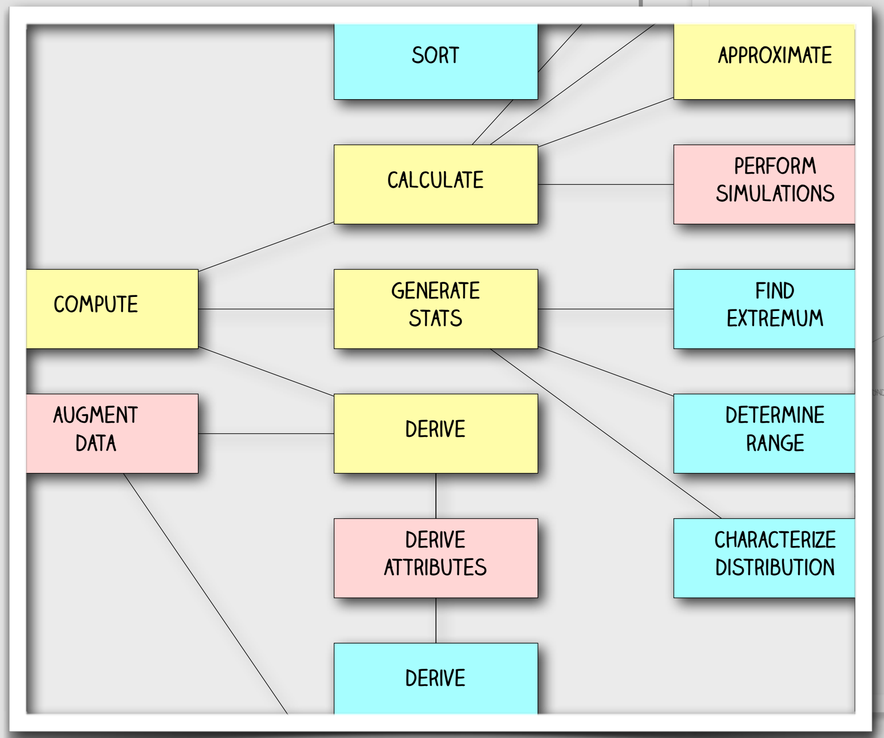
HEER / SHNEIDERMAN
2012

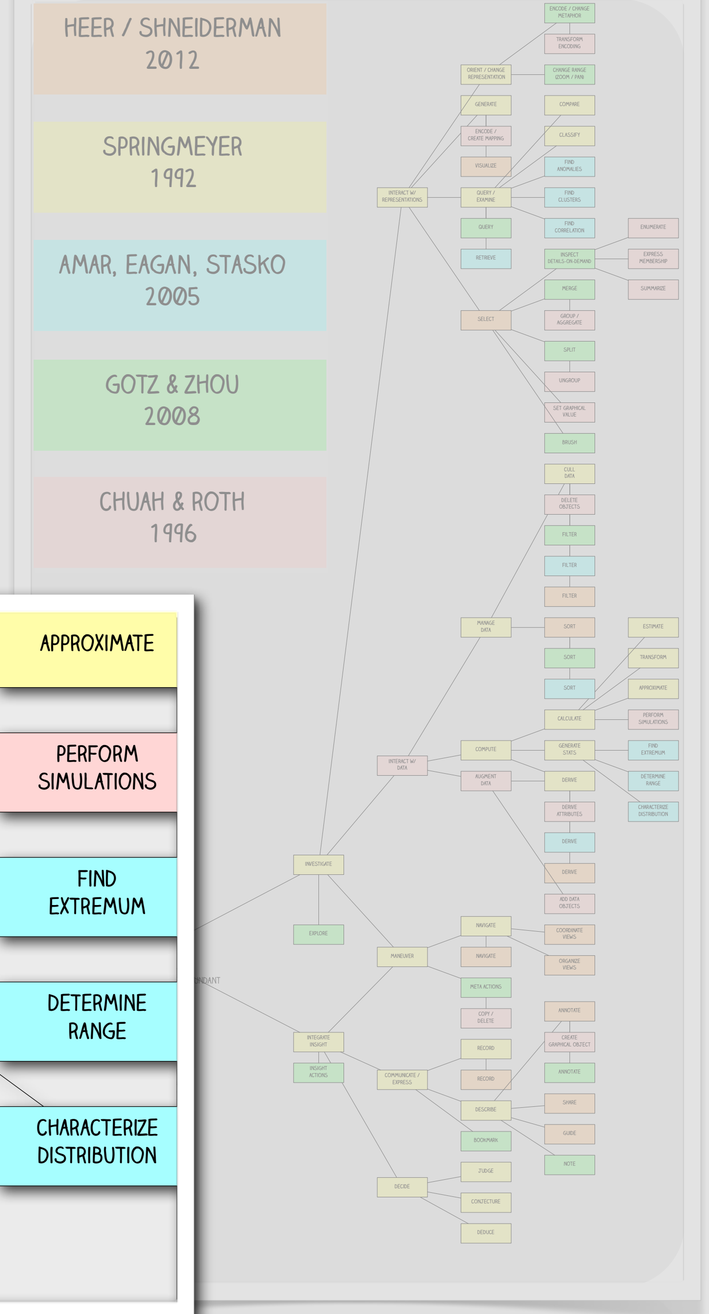
SPRINGMEYER
1992

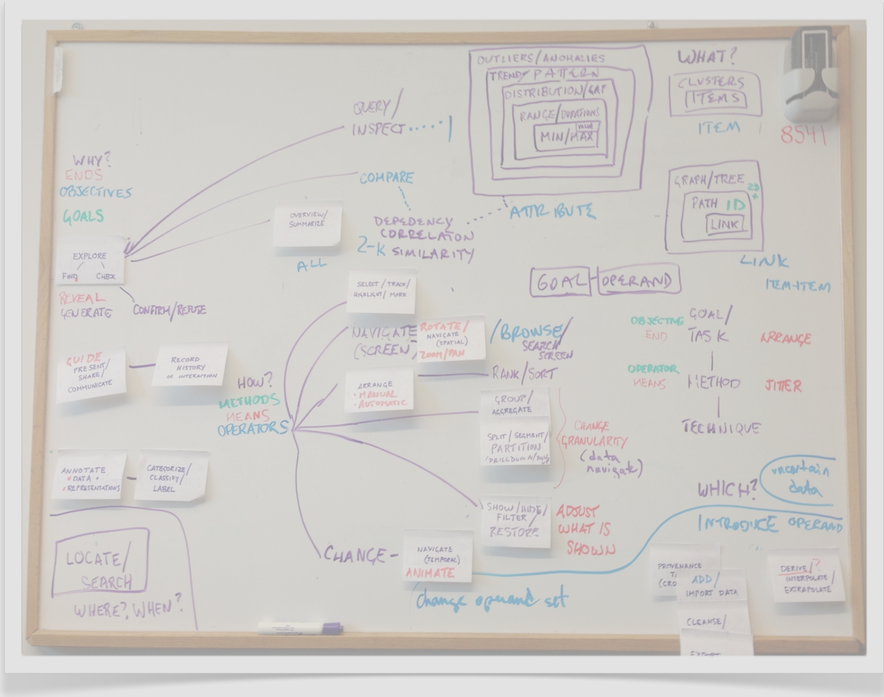
AMAR, EAGAN, STASKO
2005

GOTZ & ZHOU
2008

CHUAH & ROTH
1996







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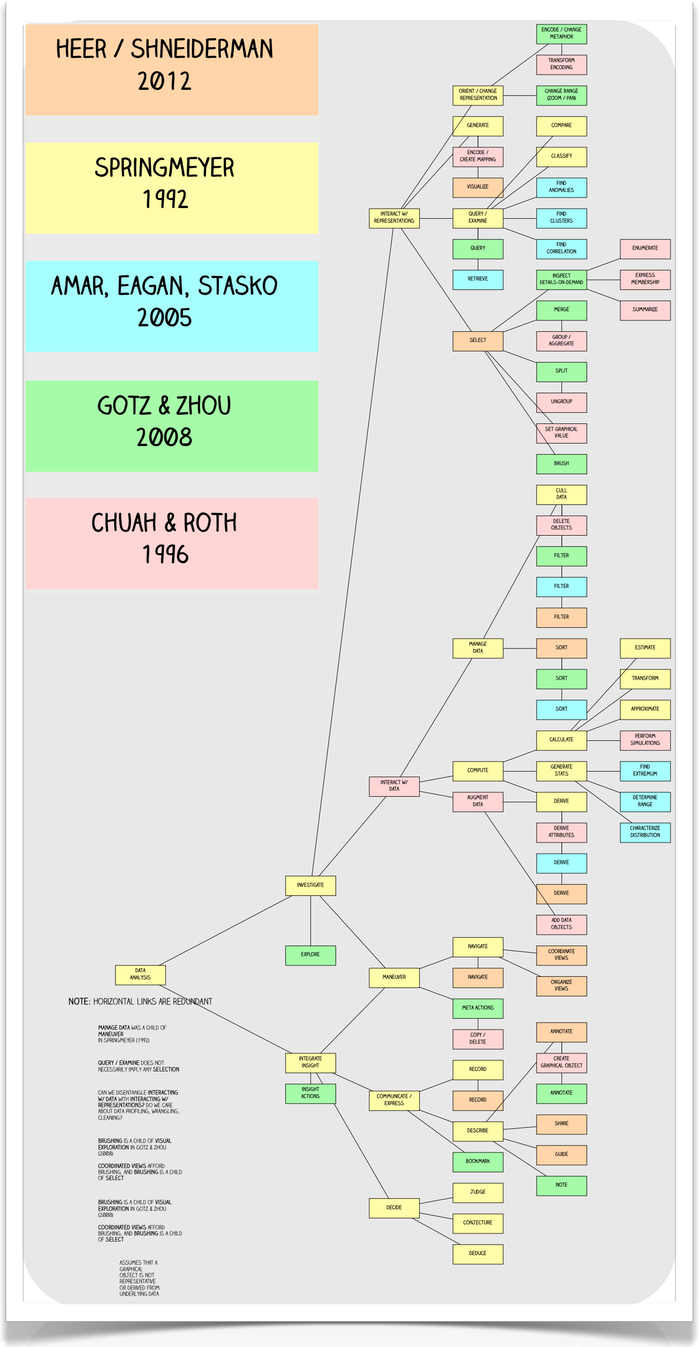

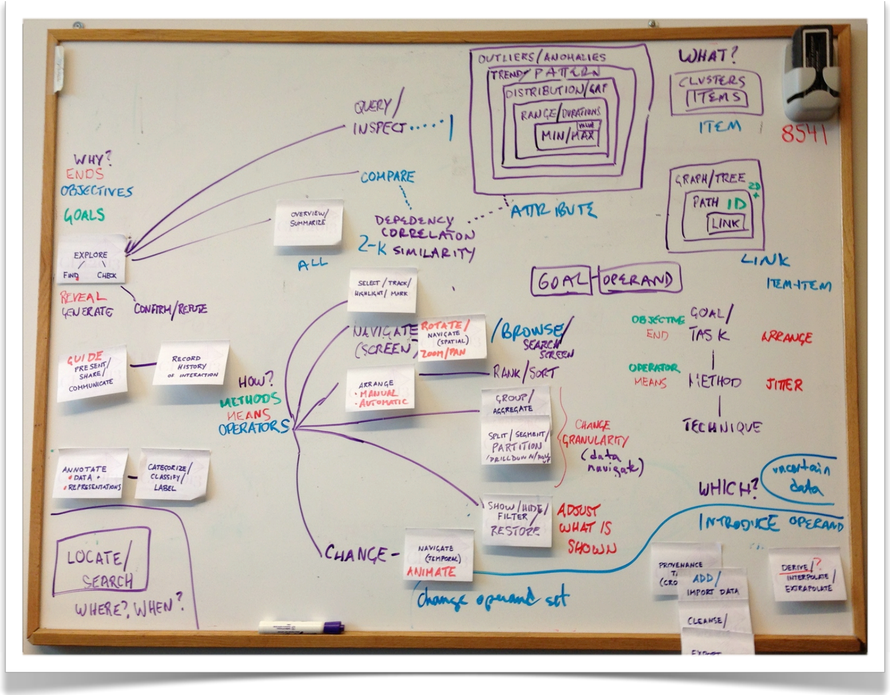

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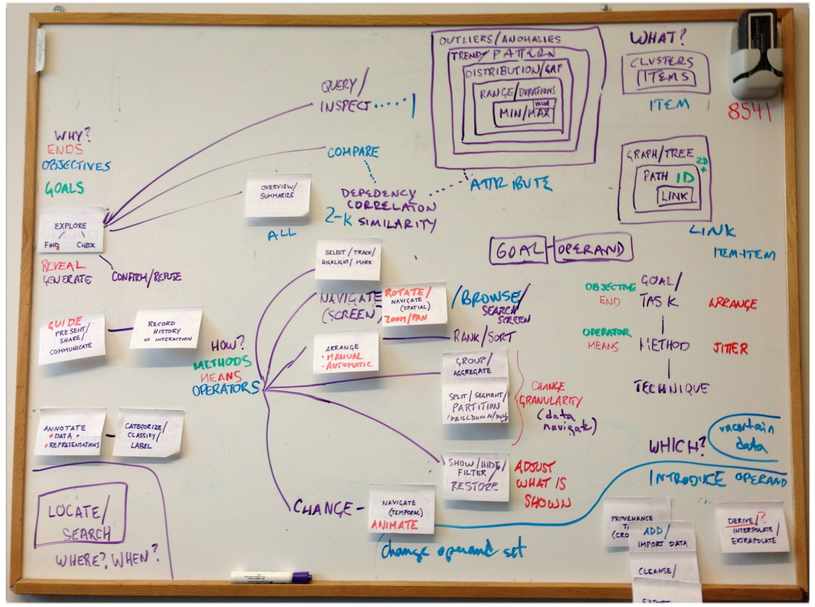
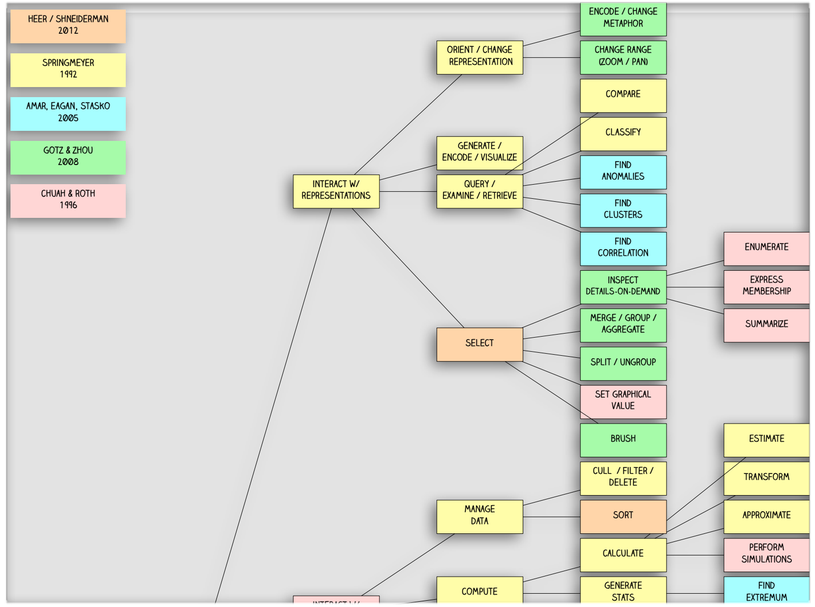

WHY?
ENDS
OBJECTIVES
GOALS
EXPLORE
FIND
CHECK
REVEAL
ELABORATE
CONFIRM/REFUTE
GUIDE
PRESENT/
SHARE/
COMMUNICATE
RECORD
HISTORY
OF INTERACTION
HOW?
METHODS
MEANS
OPERATORS
ANNOTATE
DATA +
REPRESENTATIONS
CATEGORIZE/
CLASSIFY/
LABEL
LOCATE/
SEARCH
WHERE? WHEN?
QUERY/
INSPECT
COMPARE
OVERVIEW/
SUMMARIZE
ALL
DEPENDENCY
CORRELATION
2-K SIMILARITY
OUTLIERS/ANOMALIES
TRENDS/PATTERN
DISTRIBUTION/CAT
RANGE/EXTREMA
MIN/MAX
ATTRIBUTE
WHAT?
CLUSTERS
ITEM
GRAPH/TREE
PATH
ID
LINK
LINK
ITEM-ITEM
GOAL/OPERAND
SELECT/TRAN/
BACKLIST/MARK
NAVIGATE
(SPATIAL)
ZOOM/PAN
ROTATE/
ABSTRACT
MANUAL
AUTOMATIC
BROWSE/
SEARCH
SCREEN
RANK/SORT
GROUP/
AGGREGATE
SPLIT/SEGMENT/
PARTITION
CHANGE
GRANULARITY
(data navigat)
SHOW/HIDE/
FILTER/
RESTORE
ADJUST
WHAT IS
SHOWN
NAVIGATE
(TEMPORAL)
ANIMATE
change operand set
OBJECTIVE
END
GOAL/
TASK
OPERATOR
MEANS
METHOD
TECHNIQUE
WHICH?
uncertain
data
INTRODUCE OPERAND
PROVENANCE
TO
CURD
ADD/
IMPORT DATA
CLEANSE/
DERIVE/?
INTERPOLATE/
EXTRAPOLATE
CHANGE-
8541


HEER / SHNEIDERMAN 2012
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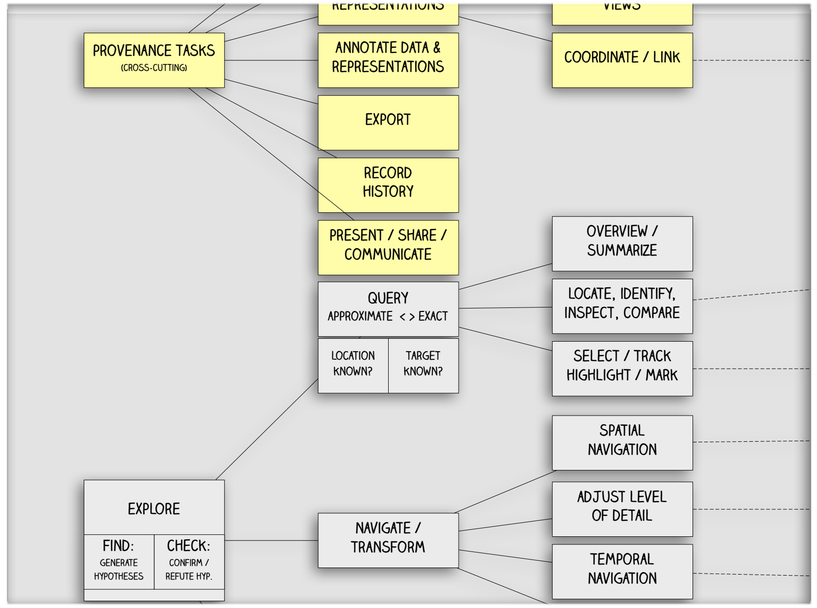
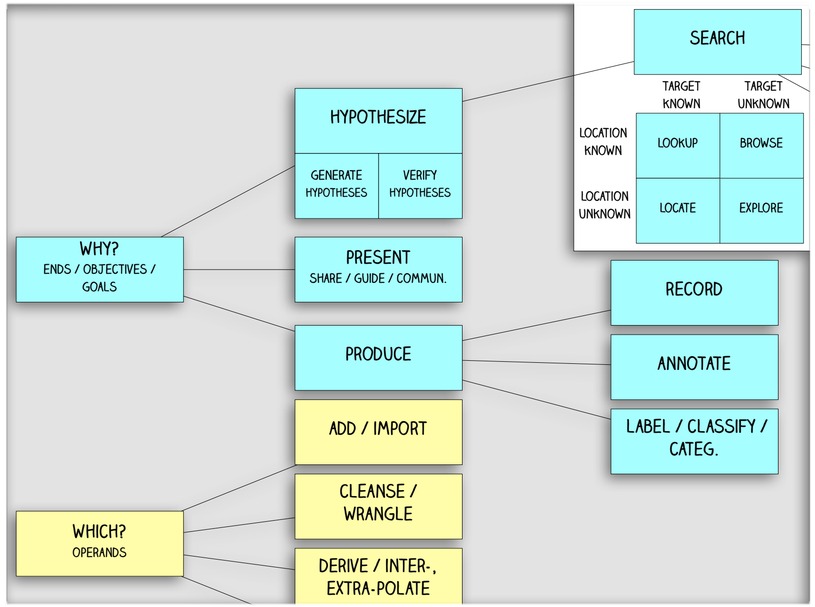
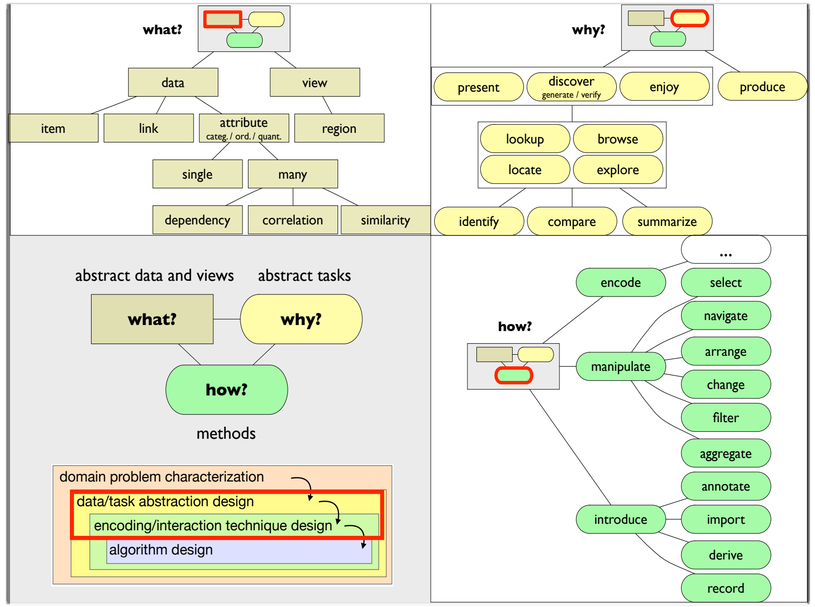
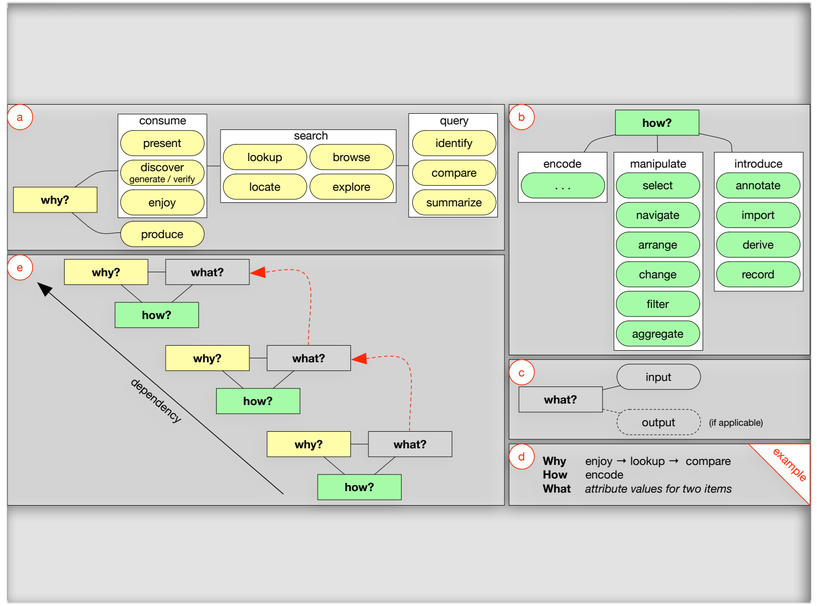
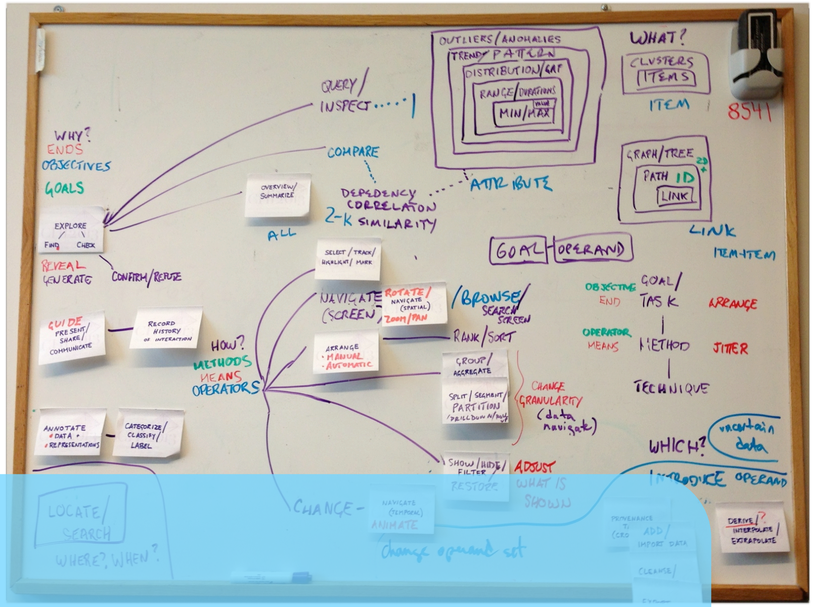
INTERACT W/ REPRESENTATIONS
ORIENT / CHANGE REPRESENTATION
GENERATE / ENCODE / VISUALIZE
QUERY / EXAMINE / RETRIEVE
SELECT
MANAGE DATA
COMPUTE
ENCODE / CHANGE METAPHOR
CHANGE RANGE (ZOOM / PAN)
COMPARE
CLASSIFY
FIND ANOMALIES
FIND CLUSTERS
FIND CORRELATION
INSPECT DETAILS-ON-DEMAND
MERGE / GROUP / AGGREGATE
SPLIT / UNGROUP
SET GRAPHICAL VALUE
BRUSH
CULL / FILTER / DELETE
SORT
CALCULATE
GENERATE STATS
ENUMERATE
EXPRESS MEMBERSHIP
SUMMARIZE
ESTIMATE
TRANSFORM
APPROXIMATE
PERFORM SIMULATIONS
FIND EXTREMUM


PROVENANCE TASKS
(CROSS-CUTTING)
ANNOTATE DATA & REPRESENTATIONS
EXPORT
RECORD HISTORY
PRESENT / SHARE / COMMUNICATE
QUERY
APPROXIMATE < > EXACT
LOCATION KNOWN?
TARGET KNOWN?
EXPLORE
FIND:
GENERATE HYPOTHESES
CHECK:
CONFIRM / REFUTE HYP.
NAVIGATE / TRANSFORM
COORDINATE / LINK
OVERVIEW / SUMMARIZE
LOCATE, IDENTIFY, INSPECT, COMPARE
SELECT / TRACK HIGHLIGHT / MARK
SPATIAL NAVIGATION
ADJUST LEVEL OF DETAIL
TEMPORAL NAVIGATION


WHY?
ENDS / OBJECTIVES / GOALS
HYPOTHESIZE
GENERATE HYPOTHESES
VERIFY HYPOTHESES
PRESENT
SHARE / GUIDE / COMMUN.
PRODUCE
ADD / IMPORT
CLEANSE / WRANGLE
DERIVE / INTER-, EXTRA-POLATE
WHICH?
OPERANDS
RECORD
ANNOTATE
LABEL / CLASSIFY / CATEG.
SEARCH
TARGET KNOWN
TARGET UNKNOWN
LOCATION KNOWN
LOCATION UNKNOWN
LOOKUP
BROWSE
LOCATE
EXPLORE


what?
data
view
item
link
attribute
categ. / ord. / quant.
region
single
many
dependency
correlation
similarity
why?
present
discover
generate / verify
enjoy
produce
lookup
browse
locate
explore
identify
compare
summarize
abstract data and views
abstract tasks
what?
why?
how?
methods
how?
encode
manipulate
introduce
...
select
navigate
arrange
change
filter
aggregate
annotate
import
derive
record
domain problem characterization
data/task abstraction design
encoding/interaction technique design
algorithm design


a
why?
consume
present
discover
generate / verify
enjoy
produce
search
lookup
browse
locate
explore
query
identify
compare
summarize
b
how?
encode
. . .
manipulate
select
navigate
arrange
change
filter
aggregate
introduce
annotate
import
derive
record
e
why?
what?
how?
why?
what?
how?
why?
what?
how?
dependency
c
what?
input
output
(if applicable)
d
Why enjoy → lookup → compare
How encode
What attribute values for two items
example


WHY?
ENDS
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HOW?
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OPERATORS
WHAT?
WHICH?
OUTLIERS / ANOMALIES
TREND / PATTERN
DISTRIBUTION / CAT
RANGE / EXTREMES
MIN / MAX
CLUSTERS
ITEM
GRAPH / TREE
PATH
ID
LINK
ATTRIBUTE
LINK
ITEM-ITEM
QUERY / INSPECT
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DEPENDENCY
CORRELATION
2-K SIMILARITY
OVERVIEW / SUMMARIZE
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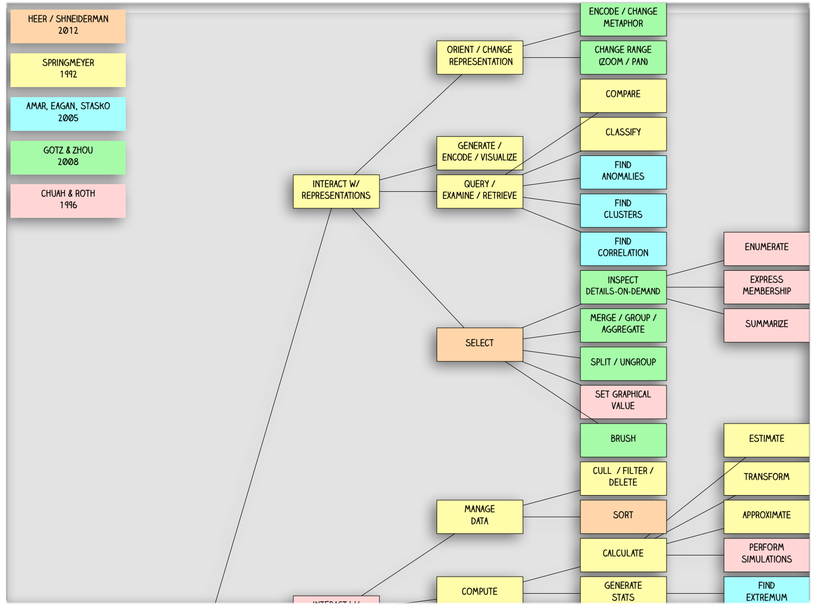
GOAL / OPERAND
OBJECTIVE
END
GOAL / TASK
OPERATOR
MEANS
METHOD
TECHNIQUE
EXPLORE
FIND
CHECK
REVEAL
CONFIRM / REFUTE
SELECT / TRACK / HIGHLIGHT / MARK
NAVIGATE (SPATIAL)
ZOOM / PAN
BROWSE / SEARCH SCREEN
RANK / SORT
ARRANGE
MANUAL
AUTOMATIC
GROUP / AGGREGATE
SPLIT / SEGMENT / PARTITION
CHANGE GRANULARITY
(data navigat)
ANNOTATE
CATEGORIZE / CLASSIFY / LABEL
SHOW / HIDE / FILTER
RESTORE
ADJUST
WHAT IS SHOWN
CHANGE
NAVIGATE (TEMPORAL)
ANIMATE
change operand set
LOCATE / SEARCH
WHERE? WHEN?
PROVENANCE
TO (CRD)
ADD / IMPORT DATA
CLEANSE
DERIVE / INTERPOLATE / EXTRAPOLATE
RECORD / HISTORY of INTERACTION
PRESENT / SHARE / COMMUNICATE
8541


HEER / SHNEIDERMAN 2012
SPRINGMEYER 1992
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INTERACT W/ REPRESENTATIONS
ORIENT / CHANGE REPRESENTATION
ENCODE / CHANGE METAPHOR
CHANGE RANGE (ZOOM / PAN)
GENERATE / ENCODE / VISUALIZE
COMPARE
CLASSIFY
QUERY / EXAMINE / RETRIEVE
FIND ANOMALIES
FIND CLUSTERS
FIND CORRELATION
SELECT
ENUMERATE
INSPECT DETAILS-ON-DEMAND
EXPRESS MEMBERSHIP
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SUMMARIZE
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CULL / FILTER / DELETE
TRANSFORM
MANAGE DATA
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CALCULATE
PERFORM SIMULATIONS
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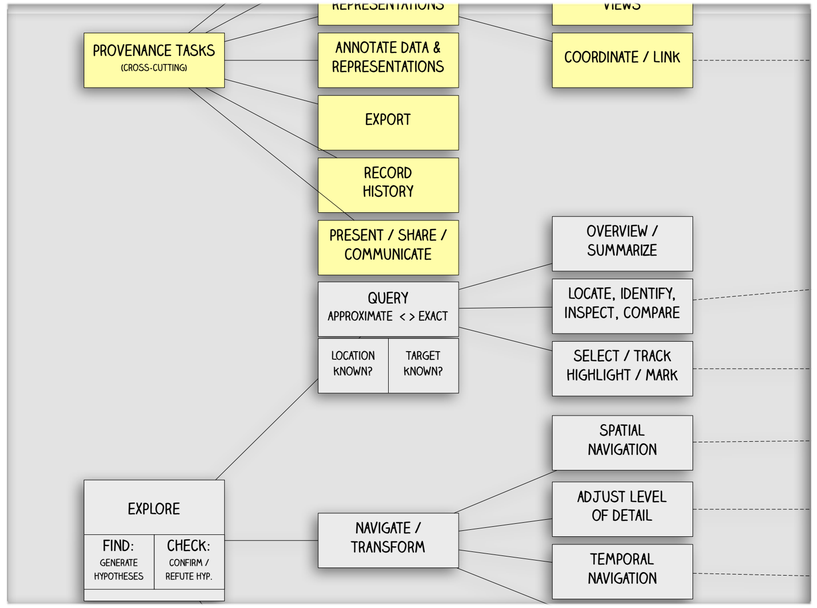
FIND EXTREMUM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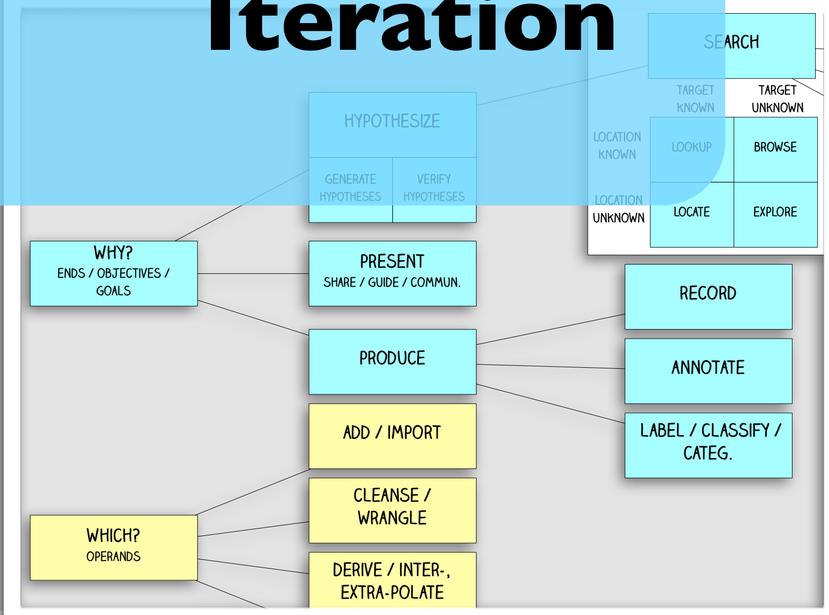
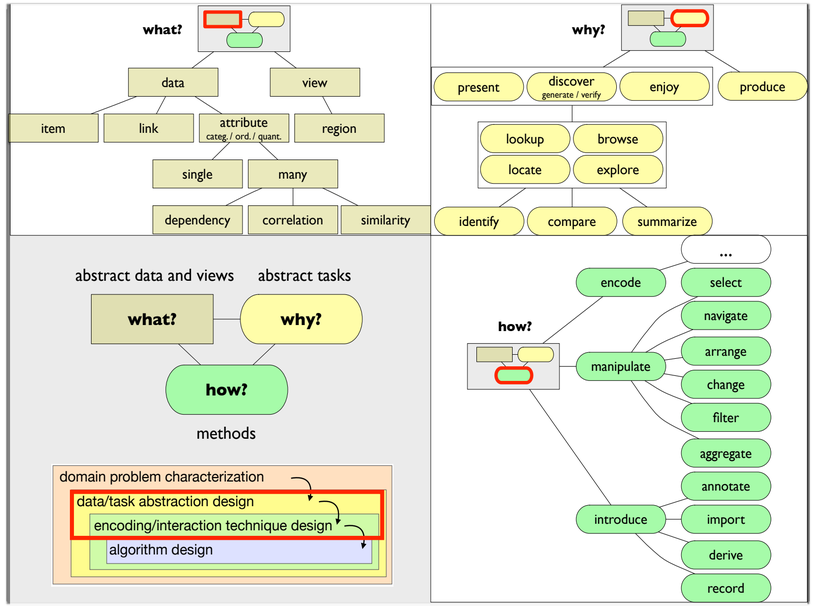
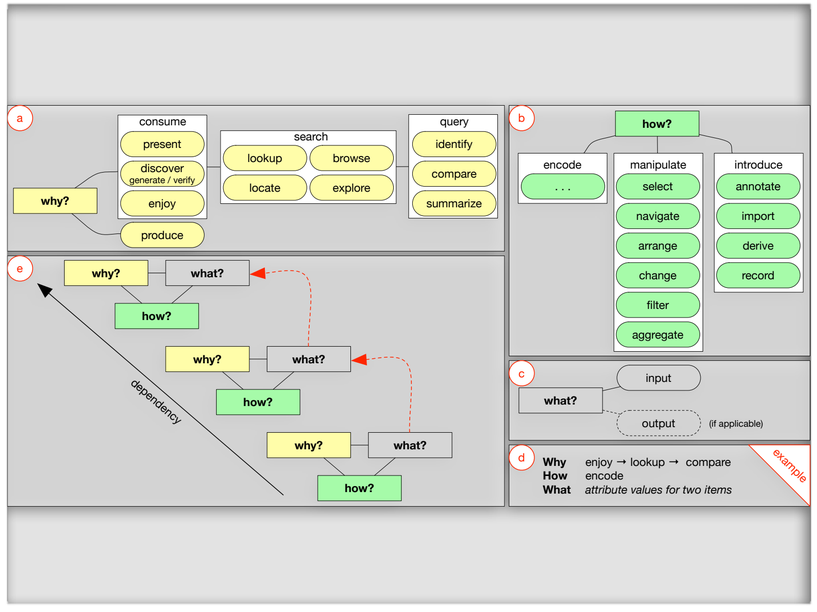
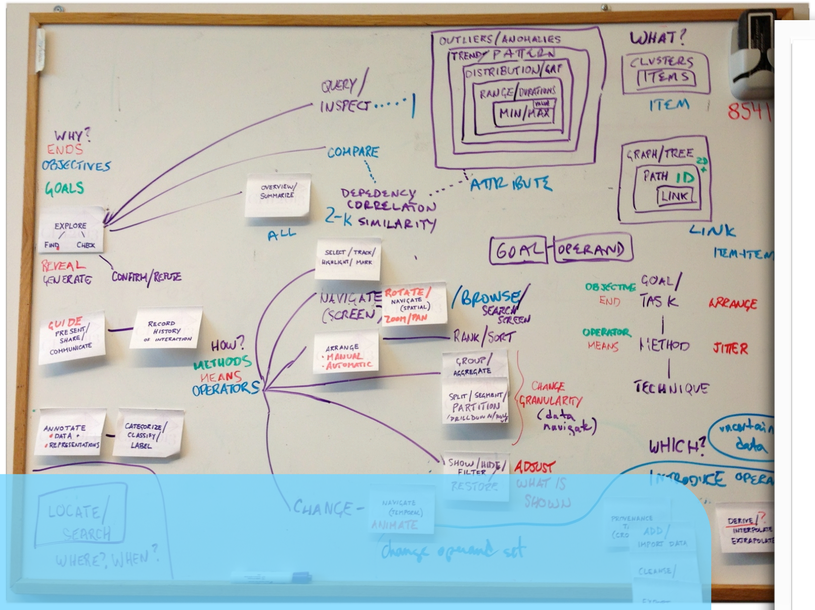
QUERY
APPROXIMATE < > EXACT
LOCATE, IDENTIFY, INSPECT, COMPARE
LOCATION KNOWN?
TARGET KNOWN?
SELECT / TRACK HIGHLIGHT / MARK
EXPLORE
FIND:
GENERATE HYPOTHESES
CHECK:
CONFIRM / REFUTE HYP.
NAVIGATE / TRANSFORM
SPATIAL NAVIGATION
ADJUST LEVEL OF DETAIL
TEMPORAL NAVIGATION

Iteration

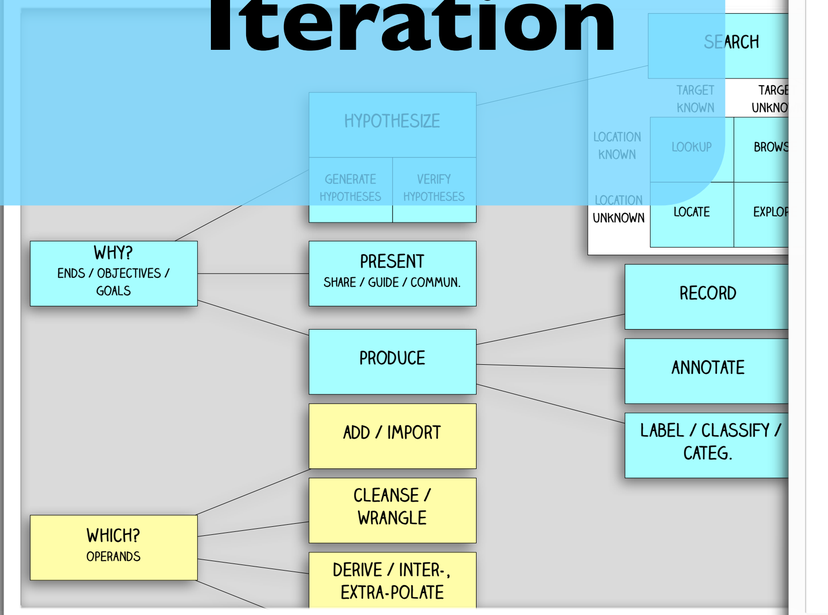

SEARCH
TARGET KNOWN
TARGET UNKNOWN
LOCATION KNOWN
LOCATION UNKNOWN
LOOKUP
BROWSE
LOCATE
EXPLORE
HYPOTHESIZE
GENERATE HYPOTHESES
VERIFY HYPOTHESES
WHY?
ENDS / OBJECTIVES / GOALS
PRESENT
SHARE / GUIDE / COMMUN.
PRODUCE
ADD / IMPORT
CLEANSE / WRANGLE
DERIVE / INTER-, EXTRA-POLATE
WHICH?
OPERANDS
RECORD
ANNOTATE
LABEL / CLASSIFY / CATEG.

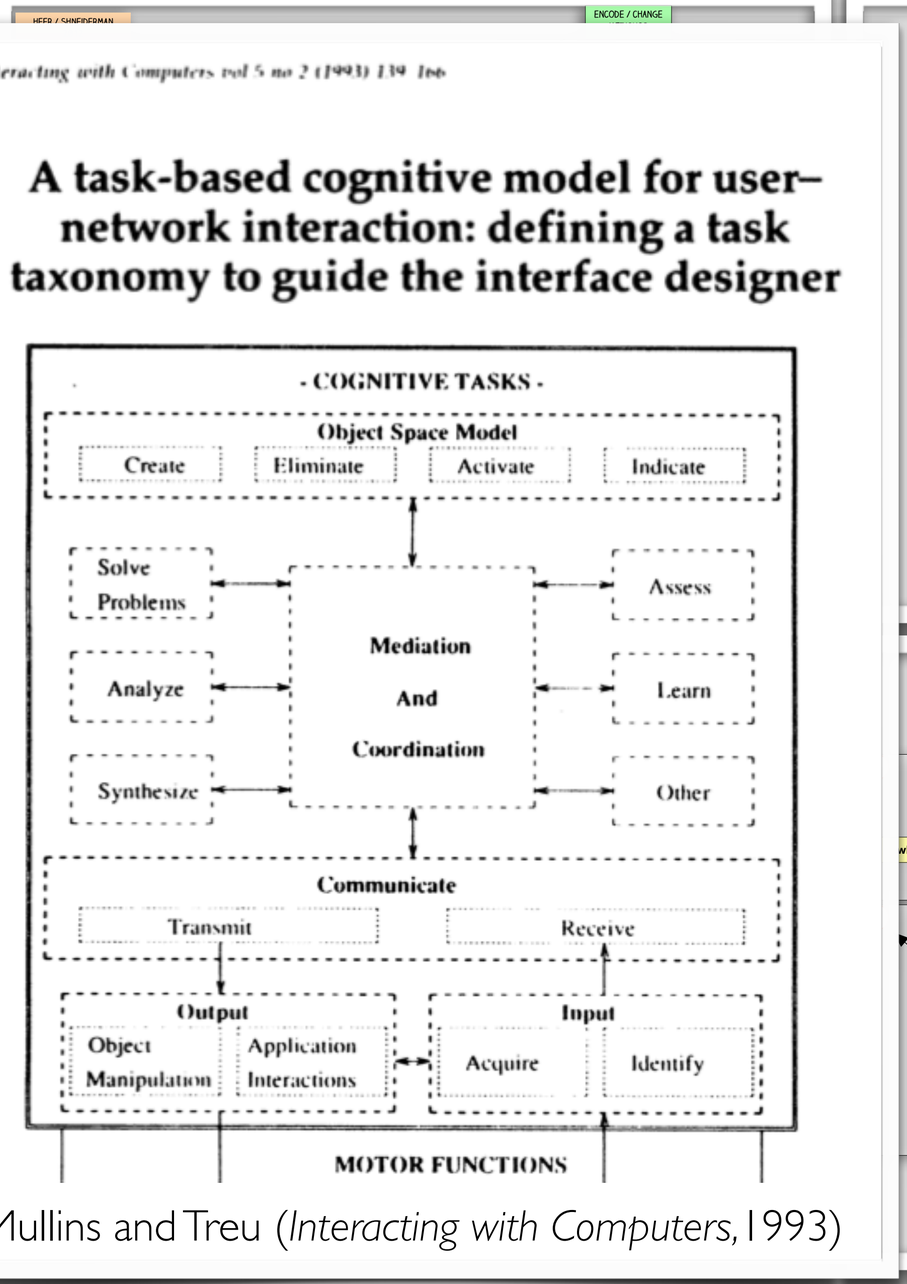

what?
data
view
item
link
attribute
categ. / ord. / quant.
region
single
many
dependency
correlation
similarity
why?
present
discover
generate / verify
enjoy
produce
lookup
browse
locate
explore
identify
compare
summarize
abstract data and views
abstract tasks
what?
why?
how?
methods
how?
...
encode
select
navigate
arrange
change
filter
aggregate
annotate
import
derive
record
manipulate
introduce
domain problem characterization
data/task abstraction design
encoding/interaction technique design
algorithm design


a
why?
consume
present
discover
generate / verify
enjoy
produce
search
lookup
browse
locate
explore
query
identify
compare
summarize
b
how?
encode
. . .
manipulate
select
navigate
arrange
change
filter
aggregate
introduce
annotate
import
derive
record
e
why?
what?
how?
dependency
c
what?
input
output
(if applicable)
d
Why
How
What
enjoy → lookup → compare
encode
attribute values for two items
example

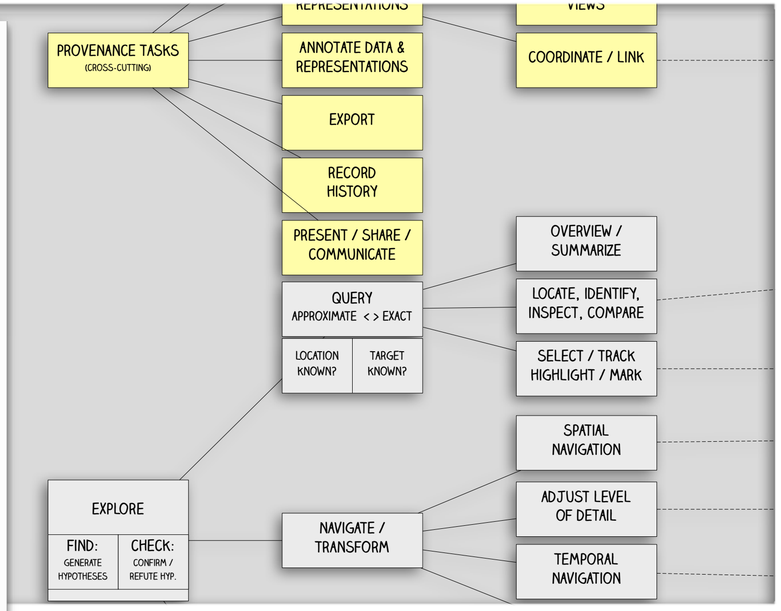


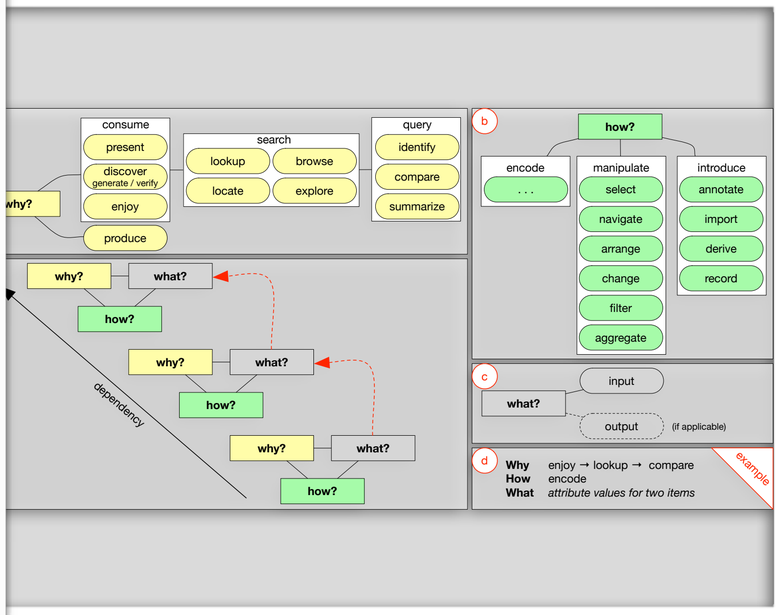
Iteration

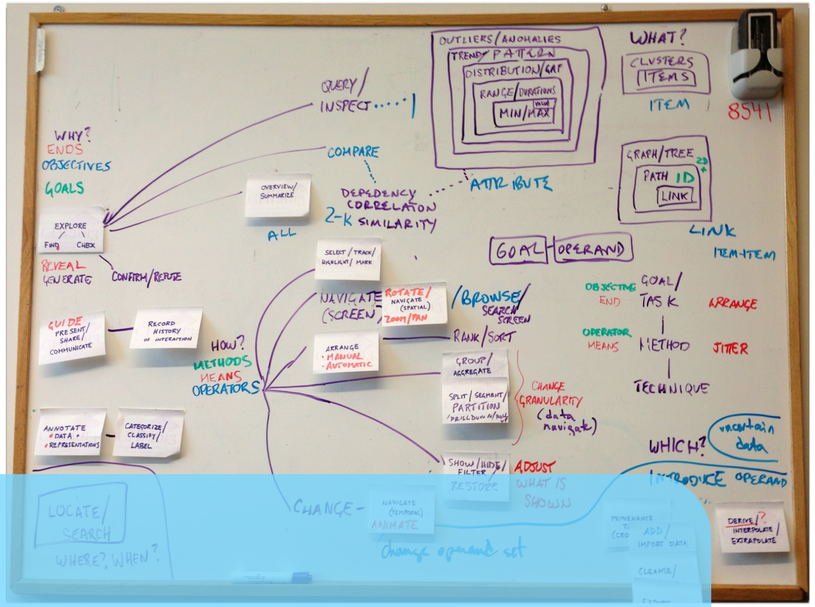


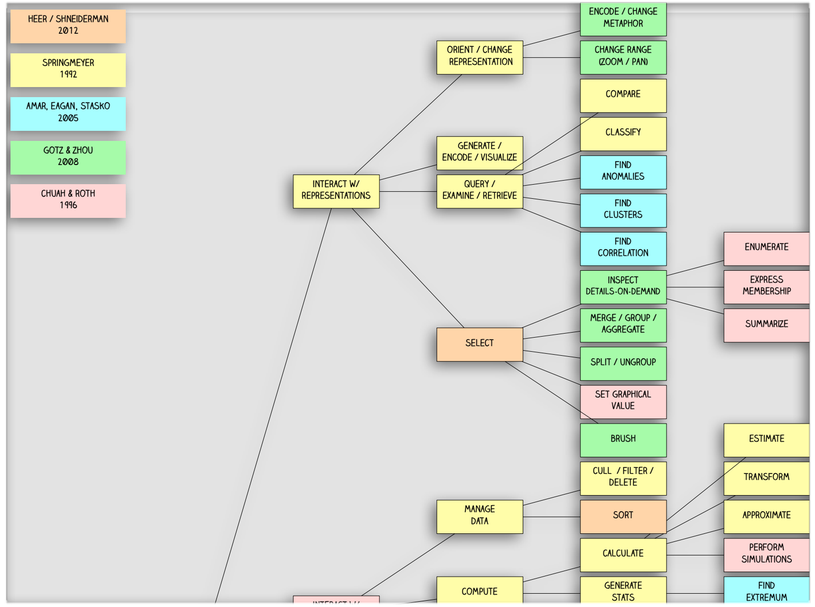


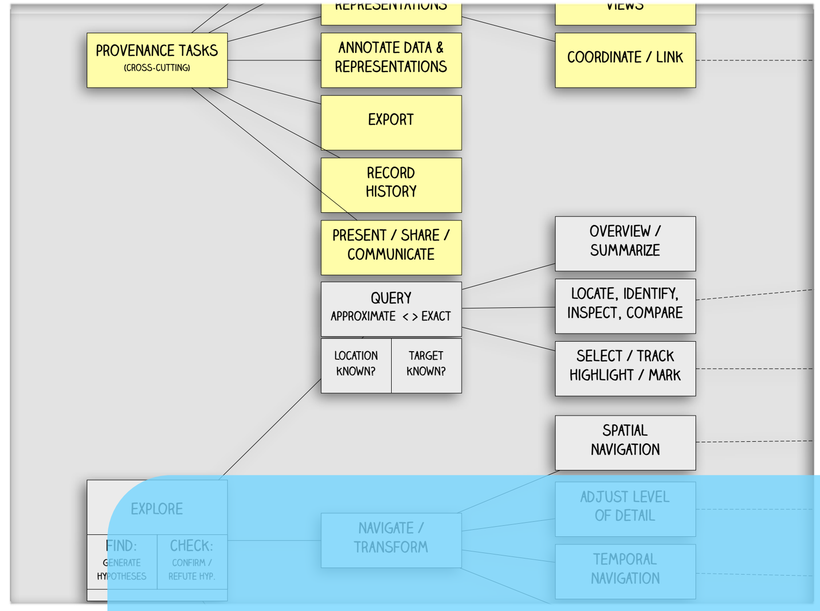
Mullins and Treu (*Interacting with Computers*, 1993)





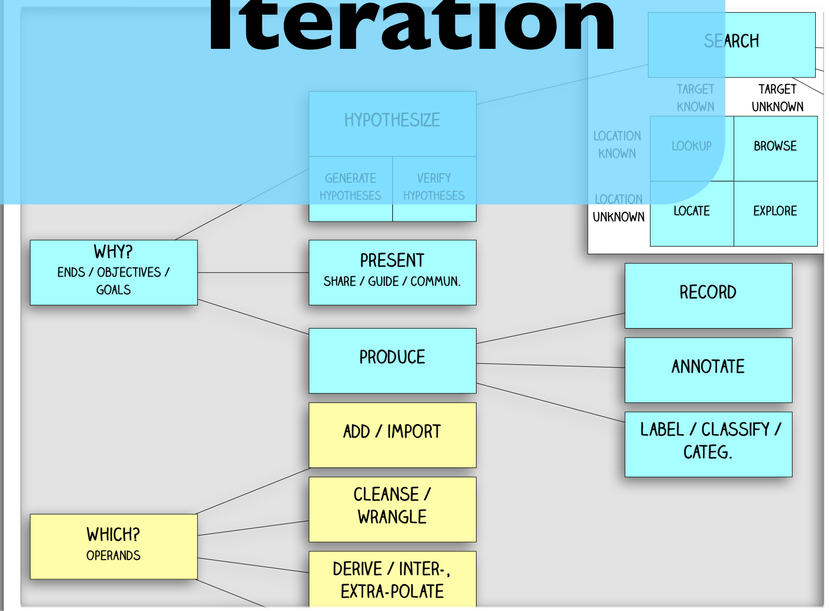


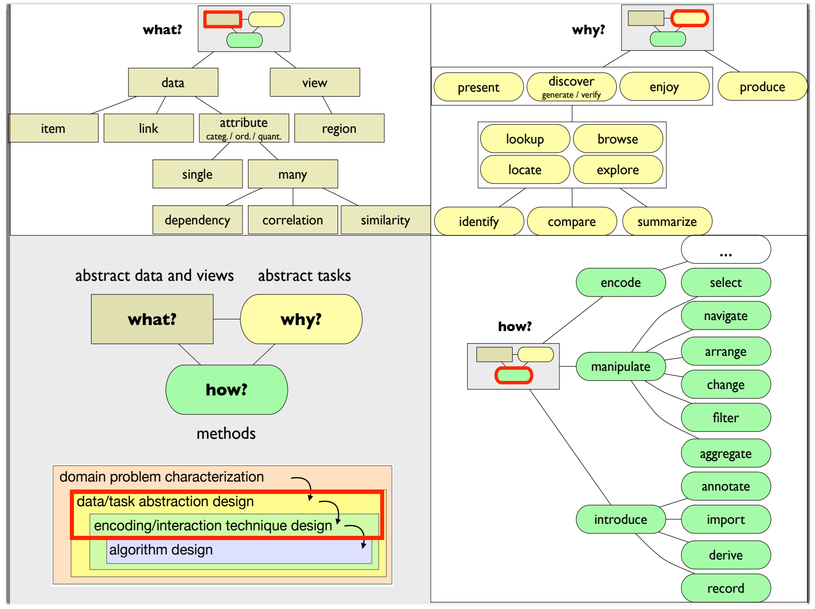


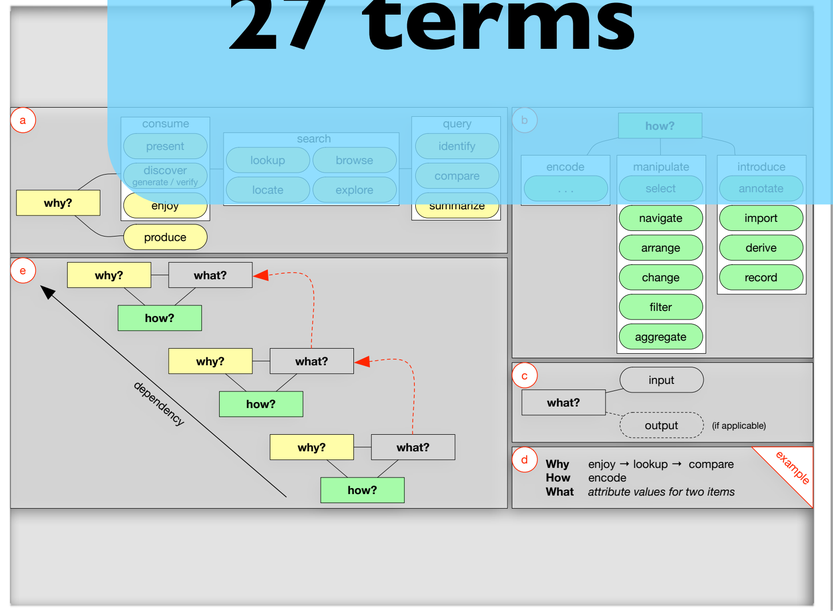


Iteration

27 terms







Mapping our **Vocabulary** to Previous Work

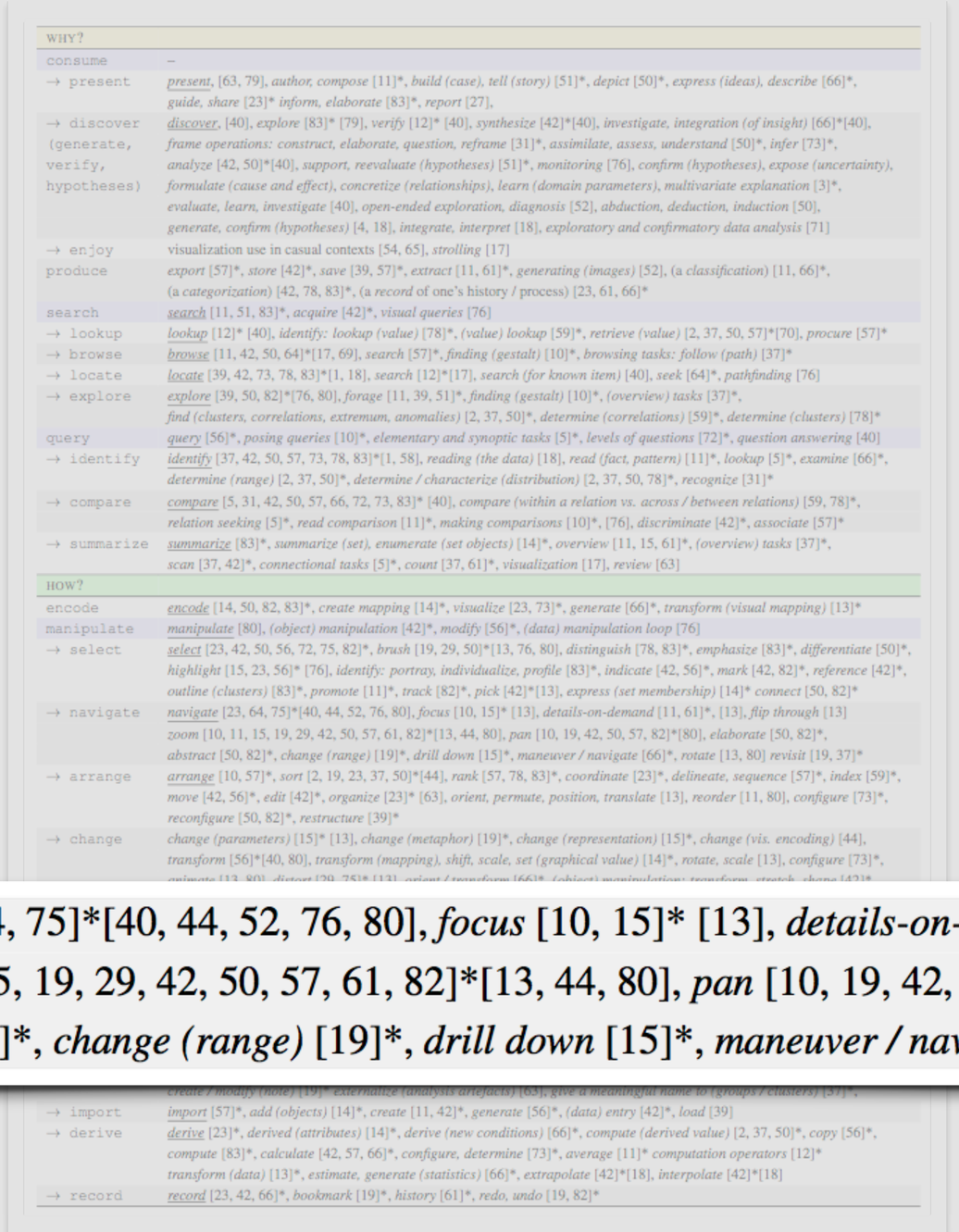
WHY?	
consume	–
→ present	*present*, [63, 79], *author, compose* [11]*, *build (case), tell (story)* [51]*, *depict* [50]*, *express (ideas), describe* [66]*, *guide, share* [23]* *inform, elaborate* [83]*, *report* [27],
→ discover (generate, verify, hypotheses)	*discover*, [40], *explore* [83]* [79], *verify* [12]* [40], *synthesize* [42]*[40], *investigate, integration (of insight)* [66]*[40], *frame operations: construct, elaborate, question, reframe* [31]*, *assimilate, assess, understand* [50]*, *infer* [73]*, *analyze* [42, 50]*[40], *support, reevaluate (hypotheses)* [51]*, *monitoring* [76], *confirm (hypotheses), expose (uncertainty), formulate (cause and effect), concretize (relationships), learn (domain parameters), multivariate explanation* [3]*, *evaluate, learn, investigate* [40], *open-ended exploration, diagnosis* [52], *abduction, deduction, induction* [50], *generate, confirm (hypotheses)* [4, 18], *integrate, interpret* [18], *exploratory and confirmatory data analysis* [71]
→ enjoy	visualization use in casual contexts [54, 65], *strolling* [17]
produce	*export* [57]*, *store* [42]*, *save* [39, 57]*, *extract* [11, 61]*, *generating (images)* [52], (a *classification*) [11, 66]*, (a *categorization*) [42, 78, 83]*, (a *record* of one's history / process) [23, 61, 66]*
search	*search* [11, 51, 83]*, *acquire* [42]*, *visual queries* [76]
→ lookup	*lookup* [12]* [40], *identify: lookup (value)* [78]*, *(value) lookup* [59]*, *retrieve (value)* [2, 37, 50, 57]*[70], *procure* [57]*
→ browse	*browse* [11, 42, 50, 64]*[17, 69], *search* [57]*, *finding (gestalt)* [10]*, *browsing tasks: follow (path)* [37]*
→ locate	*locate* [39, 42, 73, 78, 83]*[1, 18], *search* [12]*[17], *search (for known item)* [40], *seek* [64]*, *pathfinding* [76]
→ explore	*explore* [39, 50, 82]*[76, 80], *forage* [11, 39, 51]*, *finding (gestalt)* [10]*, *(overview) tasks* [37]*, *find (clusters, correlations, extremum, anomalies)* [2, 37, 50]*, *determine (correlations)* [59]*, *determine (clusters)* [78]*
query	*query* [56]*, *posing queries* [10]*, *elementary and synoptic tasks* [5]*, *levels of questions* [72]*, *question answering* [40]
→ identify	*identify* [37, 42, 50, 57, 73, 78, 83]*[1, 58], *reading (the data)* [18], *read (fact, pattern)* [11]*, *lookup* [5]*, *examine* [66]*, *determine (range)* [2, 37, 50]*, *determine / characterize (distribution)* [2, 37, 50, 78]*, *recognize* [31]*
→ compare	*compare* [5, 31, 42, 50, 57, 66, 72, 73, 83]* [40], *compare (within a relation vs. across / between relations)* [59, 78]*, *relation seeking* [5]*, *read comparison* [11]*, *making comparisons* [10]*, [76], *discriminate* [42]*, *associate* [57]*
→ summarize	*summarize* [83]*, *summarize (set), enumerate (set objects)* [14]*, *overview* [11, 15, 61]*, *(overview) tasks* [37]*, *scan* [37, 42]*, *connectional tasks* [5]*, *count* [37, 61]*, *visualization* [17], *review* [63]
HOW?	
encode	*encode* [14, 50, 82, 83]*, *create mapping* [14]*, *visualize* [23, 73]*, *generate* [66]*, *transform (visual mapping)* [13]*
manipulate	*manipulate* [80], *(object) manipulation* [42]*, *modify* [56]*, *(data) manipulation loop* [76]
→ select	*select* [23, 42, 50, 56, 72, 75, 82]*, *brush* [19, 29, 50]*[13, 76, 80], *distinguish* [78, 83]*, *emphasize* [83]*, *differentiate* [50]*, *highlight* [15, 23, 56]* [76], *identify: portray, individualize, profile* [83]*, *indicate* [42, 56]*, *mark* [42, 82]*, *reference* [42]*, *outline (clusters)* [83]*, *promote* [11]*, *track* [82]*, *pick* [42]*[13], *express (set membership)* [14]* *connect* [50, 82]*
→ navigate	*navigate* [23, 64, 75]*[40, 44, 52, 76, 80], *focus* [10, 15]* [13], *details-on-demand* [11, 61]*, [13], *flip through* [13] *zoom* [10, 11, 15, 19, 29, 42, 50, 57, 61, 82]*[13, 44, 80], *pan* [10, 19, 42, 50, 57, 82]*[80], *elaborate* [50, 82]*, *abstract* [50, 82]*, *change (range)* [19]*, *drill down* [15]*, *maneuver / navigate* [66]*, *rotate* [13, 80] *revisit* [19, 37]*
→ arrange	*arrange* [10, 57]*, *sort* [2, 19, 23, 37, 50]*[44], *rank* [57, 78, 83]*, *coordinate* [23]*, *delineate, sequence* [57]*, *index* [59]*, *move* [42, 56]*, *edit* [42]*, *organize* [23]* [63], *orient, permute, position, translate* [13], *reorder* [11, 80], *configure* [73]*, *reconfigure* [50, 82]*, *restructure* [39]*
→ change	*change (parameters)* [15]* [13], *change (metaphor)* [19]*, *change (representation)* [15]*, *change (vis. encoding)* [44], *transform* [56]*[40, 80], *transform (mapping), shift, scale, set (graphical value)* [14]*, *rotate, scale* [13], *configure* [73]*, *animate* [13, 80], *distort* [29, 75]* [13], *orient / transform* [66]*, *(object) manipulation: transform, stretch, shape* [42]*, *re-express, re-symbolize, re-project* [57]*, *edit* [42, 57]*, *activate* [56]*
→ filter	*filter* [2, 11, 19, 23, 29, 31, 37, 42, 50, 51, 57, 61, 82]*[44, 70, 80], *subsetting, (value) filtering, (view) filtering* [13], *exclude* [40, 70], *screen: filter, suppress, conceal* [42]*, *maneuver: (data) management / culling* [66]*, *configure* [73]*, *delete (objects, sets, graphical objects)* [14]*, *delete* [11, 19, 56]*, *overlay* [57]*, *restore* [19, 42]*
→ aggregate	*aggregate* [42]*[13, 44], *cluster* [11]*[13], *associate* [42, 78, 83]*, *simplify* [13], *link* [10, 15, 29, 42]*[63, 80], *merge* [19]*, *generalize / merge* [83]*, *assemble* [42]*, *create (set)* [14]*, *split* [19]*, *disassemble* [42]*, *disassociate* [42]*, *reveal: itemize, separate* [83]*, *segregate: ungroup, unlink* [42]*, *withdraw, overlay* [42]*
introduce	*introduce* [42]*
→ annotate	*annotate* [19, 23, 57]*, *add placemark* [82], *create (anchors)* [39]*, *create / copy (graphical objects)* [14]*, *create / modify (note)* [19]* *externalize (analysis artefacts)* [63], *give a meaningful name to (groups / clusters)* [37]*,
→ import	*import* [57]*, *add (objects)* [14]*, *create* [11, 42]*, *generate* [56]*, *(data) entry* [42]*, *load* [39]
→ derive	*derive* [23]*, *derived (attributes)* [14]*, *derive (new conditions)* [66]*, *compute (derived value)* [2, 37, 50]*, *copy* [56]*, *compute* [83]*, *calculate* [42, 57, 66]*, *configure, determine* [73]*, *average* [11]* *computation operators* [12]* *transform (data)* [13]*, *estimate, generate (statistics)* [66]*, *extrapolate* [42]*[18], *interpolate* [42]*[18]
→ record	*record* [23, 42, 66]*, *bookmark* [19]*, *history* [61]*, *redo, undo* [19, 82]*

← **Table 1**:
lookup table of task vocabulary

Our **27** terms
(left column)

Terms from **30** extant classification systems
+ **20** additional references
(right column)

Mapping our **Vocabulary** to Previous Work



WHY?	
consume	–
→ present	*present*, [63, 79], *author, compose* [11]*, *build (case), tell (story)* [51]*, *depict* [50]*, *express (ideas), describe* [66]*, *guide, share* [23]* *inform, elaborate* [83]*, *report* [27],
→ discover (generate, verify, hypotheses)	*discover*, [40], *explore* [83]* [79], *verify* [12]* [40], *synthesize* [42]*[40], *investigate, integration (of insight)* [66]*[40], *frame operations: construct, elaborate, question, reframe* [31]*, *assimilate, assess, understand* [50]*, *infer* [73]*, *analyze* [42, 50]*[40], *support, reevaluate (hypotheses)* [51]*, *monitoring* [76], *confirm (hypotheses), expose (uncertainty), formulate (cause and effect), concretize (relationships), learn (domain parameters), multivariate explanation* [3]*, *evaluate, learn, investigate* [40], *open-ended exploration, diagnosis* [52], *abduction, deduction, induction* [50], *generate, confirm (hypotheses)* [4, 18], *integrate, interpret* [18], *exploratory and confirmatory data analysis* [71]
→ enjoy	visualization use in casual contexts [54, 65], *strolling* [17]
produce	*export* [57]*, *store* [42]*, *save* [39, 57]*, *extract* [11, 61]*, *generating (images)* [52], (a *classification*) [11, 66]*, (a *categorization*) [42, 78, 83]*, (a *record* of one's history / process) [23, 61, 66]*
search	*search* [11, 51, 83]*, *acquire* [42]*, *visual queries* [76]
→ lookup	*lookup* [12]* [40], *identify: lookup (value)* [78]*, *(value) lookup* [59]*, *retrieve (value)* [2, 37, 50, 57]*[70], *procure* [57]*
→ browse	*browse* [11, 42, 50, 64]*[17, 69], *search* [57]*, *finding (gestalt)* [10]*, *browsing tasks: follow (path)* [37]*
→ locate	*locate* [39, 42, 73, 78, 83]*[1, 18], *search* [12]*[17], *search (for known item)* [40], *seek* [64]*, *pathfinding* [76]
→ explore	*explore* [39, 50, 82]*[76, 80], *forage* [11, 39, 51]*, *finding (gestalt)* [10]*, *(overview) tasks* [37]*, *find (clusters, correlations, extremum, anomalies)* [2, 37, 50]*, *determine (correlations)* [59]*, *determine (clusters)* [78]*
query	*query* [56]*, *posing queries* [10]*, *elementary and synoptic tasks* [5]*, *levels of questions* [72]*, *question answering* [40]
→ identify	*identify* [37, 42, 50, 57, 73, 78, 83]*[1, 58], *reading (the data)* [18], *read (fact, pattern)* [11]*, *lookup* [5]*, *examine* [66]*, *determine (range)* [2, 37, 50]*, *determine / characterize (distribution)* [2, 37, 50, 78]*, *recognize* [31]*
→ compare	*compare* [5, 31, 42, 50, 57, 66, 72, 73, 83]* [40], *compare (within a relation vs. across / between relations)* [59, 78]*, *relation seeking* [5]*, *read comparison* [11]*, *making comparisons* [10]*, [76], *discriminate* [42]*, *associate* [57]*
→ summarize	*summarize* [83]*, *summarize (set), enumerate (set objects)* [14]*, *overview* [11, 15, 61]*, *(overview) tasks* [37]*, *scan* [37, 42]*, *connectional tasks* [5]*, *count* [37, 61]*, *visualization* [17], *review* [63]
HOW?	
encode	*encode* [14, 50, 82, 83]*, *create mapping* [14]*, *visualize* [23, 73]*, *generate* [66]*, *transform (visual mapping)* [13]*
manipulate	*manipulate* [80], *(object) manipulation* [42]*, *modify* [56]*, *(data) manipulation loop* [76]
→ select	*select* [23, 42, 50, 56, 72, 75, 82]*, *brush* [19, 29, 50]*[13, 76, 80], *distinguish* [78, 83]*, *emphasize* [83]*, *differentiate* [50]*, *highlight* [15, 23, 56]* [76], *identify: portray, individualize, profile* [83]*, *indicate* [42, 56]*, *mark* [42, 82]*, *reference* [42]*, *outline (clusters)* [83]*, *promote* [11]*, *track* [82]*, *pick* [42]*[13], *express (set membership)* [14]* *connect* [50, 82]*
→ navigate	*navigate* [23, 64, 75]*[40, 44, 52, 76, 80], *focus* [10, 15]* [13], *details-on-demand* [11, 61]*, [13], *flip through* [13] *zoom* [10, 11, 15, 19, 29, 42, 50, 57, 61, 82]*[13, 44, 80], *pan* [10, 19, 42, 50, 57, 82]*[80], *elaborate* [50, 82]*, *abstract* [50, 82]*, *change (range)* [19]*, *drill down* [15]*, *maneuver / navigate* [66]*, *rotate* [13, 80] *revisit* [19, 37]*
→ arrange	*arrange* [10, 57]*, *sort* [2, 19, 23, 37, 50]*[44], *rank* [57, 78, 83]*, *coordinate* [23]*, *delineate, sequence* [57]*, *index* [59]*, *move* [42, 56]*, *edit* [42]*, *organize* [23]* [63], *orient, permute, position, translate* [13], *reorder* [11, 80], *configure* [73]*, *reconfigure* [50, 82]*, *restructure* [39]*
→ change	*change (parameters)* [15]* [13], *change (metaphor)* [19]*, *change (representation)* [15]*, *change (vis. encoding)* [44], *transform* [56]*[40, 80], *transform (mapping), shift, scale, set (graphical value)* [14]*, *rotate, scale* [13], *configure* [73]*,
→ import	*import* [57]*, *add (objects)* [14]*, *create* [11, 42]*, *generate* [56]*, *(data) entry* [42]*, *load* [39]
→ derive	*derive* [23]*, *derived (attributes)* [14]*, *derive (new conditions)* [66]*, *compute (derived value)* [2, 37, 50]*, *copy* [56]*, *compute* [83]*, *calculate* [42, 57, 66]*, *configure, determine* [73]*, *average* [11]* *computation operators* [12]* *transform (data)* [13]*, *estimate, generate (statistics)* [66]*, *extrapolate* [42]*[18], *interpolate* [42]*[18]
→ record	*record* [23, 42, 66]*, *bookmark* [19]*, *history* [61]*, *redo, undo* [19, 82]*

← **Table 1**:
lookup table of task vocabulary

Our **27** terms
(left column)

Terms from **30** extant classification systems
(right column)

→ navigate *navigate* [23, 64, 75]*[40, 44, 52, 76, 80], *focus* [10, 15]* [13], *details-on-demand* [11, 61]*, [13], *flip through* [13] *zoom* [10, 11, 15, 19, 29, 42, 50, 57, 61, 82]*[13, 44, 80], *pan* [10, 19, 42, 50, 57, 82]*[80], *elaborate* [50, 82]*, *abstract* [50, 82]*, *change (range)* [19]*, *drill down* [15]*, *maneuver / navigate* [66]*, *rotate* [13, 80] *revisit* [19, 37]*

Mapping our Vocabulary to Previous Work

WHY?	
consume	–
→ present	*present*, [63, 79], *author, compose* [11]*, *build (case), tell (story)* [51]*, *depict* [50]*, *express (ideas), describe* [66]*, *guide, share* [23]* *inform, elaborate* [83]*, *report* [27],
→ discover (generate, verify, hypotheses)	*discover*, [40], *explore* [83]* [79], *verify* [12]* [40], *synthesize* [42]*[40], *investigate, integration (of insight)* [66]*[40], *frame operations: construct, elaborate, question, reframe* [31]*, *assimilate, assess, understand* [50]*, *infer* [73]*, *analyze* [42, 50]*[40], *support, reevaluate (hypotheses)* [51]*, *monitoring* [76], *confirm (hypotheses), expose (uncertainty), formulate (cause and effect), concretize (relationships), learn (domain parameters), multivariate explanation* [3]*, *evaluate, learn, investigate* [40], *open-ended exploration, diagnosis* [52], *abduction, deduction, induction* [50], *generate, confirm (hypotheses)* [4, 18], *integrate, interpret* [18], *exploratory and confirmatory data analysis* [71]
→ enjoy	visualization use in casual contexts [54, 65], *strolling* [17]
→ compare	*compare* [5, 31, 42, 50, 57, 66, 72, 73, 83]* [40], *compare (within a relation vs. across / between relations)* [59, 78]*, *relation seeking* [5]*, *read comparison* [11]*, *making comparisons* [10]*, [76], *discriminate* [42]*, *associate* [57]*
query	*query* [56]*, *posing queries* [10]*, *elementary and synoptic tasks* [5]*, *levels of questions* [72]*, *question answering* [40]
→ identify	*identify* [37, 42, 50, 57, 73, 78, 83]*[1, 58], *reading (the data)* [18], *read (fact, pattern)* [11]*, *lookup* [5]*, *examine* [66]*, *determine (range)* [2, 37, 50]*, *determine / characterize (distribution)* [2, 37, 50, 78]*, *recognize* [31]*
→ compare	*compare* [5, 31, 42, 50, 57, 66, 72, 73, 83]* [40], *compare (within a relation vs. across / between relations)* [59, 78]*, *relation seeking* [5]*, *read comparison* [11]*, *making comparisons* [10]*, [76], *discriminate* [42]*, *associate* [57]*
→ summarize	*summarize* [83]*, *summarize (set), enumerate (set objects)* [14]*, *overview* [11, 15, 61]*, *(overview) tasks* [37]*, *scan* [37, 42]*, *connectional tasks* [5]*, *count* [37, 61]*, *visualization* [17], *review* [63]
HOW?	
encode	*encode* [14, 50, 82, 83]*, *create mapping* [14]*, *visualize* [23, 73]*, *generate* [66]*, *transform (visual mapping)* [13]*
manipulate	*manipulate* [80], *(object) manipulation* [42]*, *modify* [56]*, *(data) manipulation loop* [76]
→ select	*select* [23, 42, 50, 56, 72, 75, 82]*, *brush* [19, 29, 50]*[13, 76, 80], *distinguish* [78, 83]*, *emphasize* [83]*, *differentiate* [50]*, *highlight* [15, 23, 56]* [76], *identify: portray, individualize, profile* [83]*, *indicate* [42, 56]*, *mark* [42, 82]*, *reference* [42]*, *outline (clusters)* [83]*, *promote* [11]*, *track* [82]*, *pick* [42]*[13], *express (set membership)* [14]* *connect* [50, 82]*
→ navigate	*navigate* [23, 64, 75]*[40, 44, 52, 76, 80], *focus* [10, 15]* [13], *details-on-demand* [11, 61]*, [13], *flip through* [13] *zoom* [10, 11, 15, 19, 29, 42, 50, 57, 61, 82]*[13, 44, 80], *pan* [10, 19, 42, 50, 57, 82]*[80], *elaborate* [50, 82]*, *abstract* [50, 82]*, *change (range)* [19]*, *drill down* [15]*, *maneuver / navigate* [66]*, *rotate* [13, 80] *revisit* [19, 37]*
→ arrange	*arrange* [10, 57]*, *sort* [2, 19, 23, 37, 50]*[44], *rank* [57, 78, 83]*, *coordinate* [23]*, *delineate, sequence* [57]*, *index* [59]*, *move* [42, 56]*, *edit* [42]*, *organize* [23]* [63], *orient, permute, position, translate* [13], *reorder* [11, 80], *configure* [73]*, *reconfigure* [50, 82]*, *restructure* [39]*
→ change	*change (parameters)* [15]* [13], *change (metaphor)* [19]*, *change (representation)* [15]*, *change (vis. encoding)* [44], *transform* [56]*[40, 80], *transform (mapping), shift, scale, set (graphical value)* [14]*, *rotate, scale* [13], *configure* [73]*,
→ import	*import* [57]*, *add (objects)* [14]*, *create* [11, 42]*, *generate* [56]*, *(data) entry* [42]*, *load* [39]
→ derive	*derive* [23]*, *derived (attributes)* [14]*, *derive (new conditions)* [66]*, *compute (derived value)* [2, 37, 50]*, *copy* [56]*, *compute* [83]*, *calculate* [42, 57, 66]*, *configure, determine* [73]*, *average* [11]* *computation operators* [12]* *transform (data)* [13]*, *estimate, generate (statistics)* [66]*, *extrapolate* [42]*[18], *interpolate* [42]*[18]
→ record	*record* [23, 42, 66]*, *bookmark* [19]*, *history* [61]*, *redo, undo* [19, 82]*

← **Table 1**:
lookup table of task

Our **27** terms
(left column)

Terms from **30**
extant classification
systems
(right column)

Constructing a Typology

Bottom-Up

previous classification systems

Top-Down

theoretical lenses

Constructing a Typology

Bottom-Up

previous classification systems

Top-Down

theoretical lenses

Stages of Action [1] +
Gulf of Goal Formation [2],
Distributed Cognition [3], *Sensemaking* [4],
Play Theory [5], ***Nested Model*** [6]

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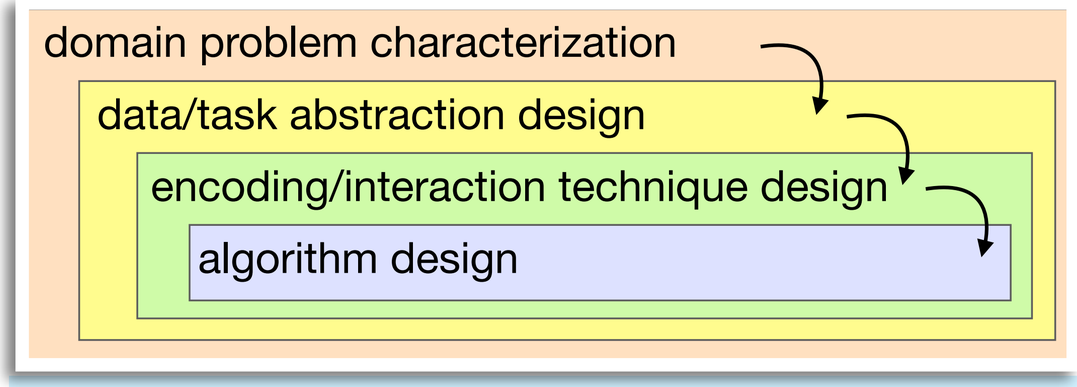

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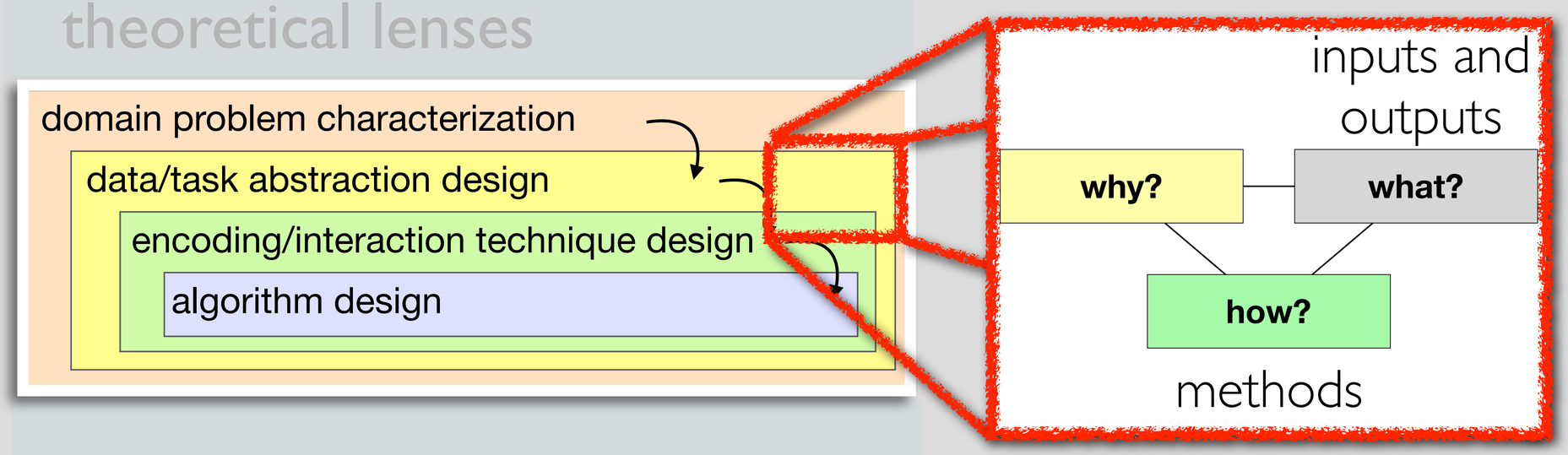

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visual encoding and interaction techniques

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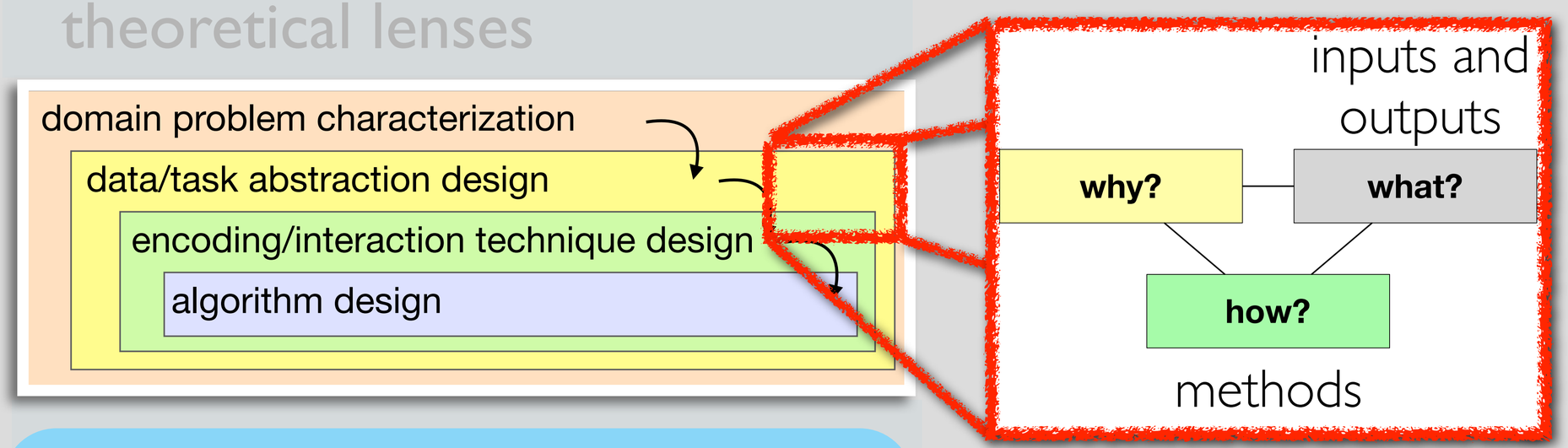

visual encoding and interaction techniques

Why is a task undertaken?
What are the *Inputs* and *Outputs*?
How is the task supported?

[1] Norman (1988)

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Purpose of **Typology**

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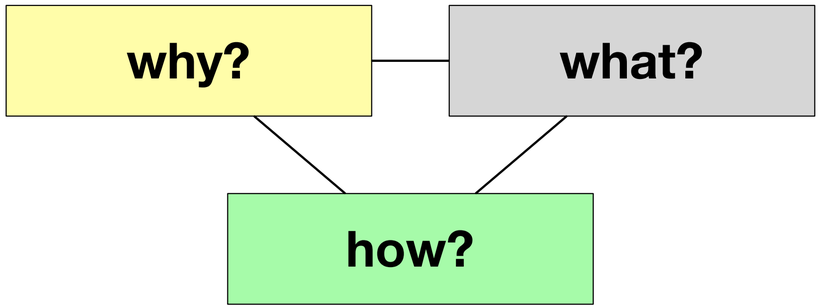
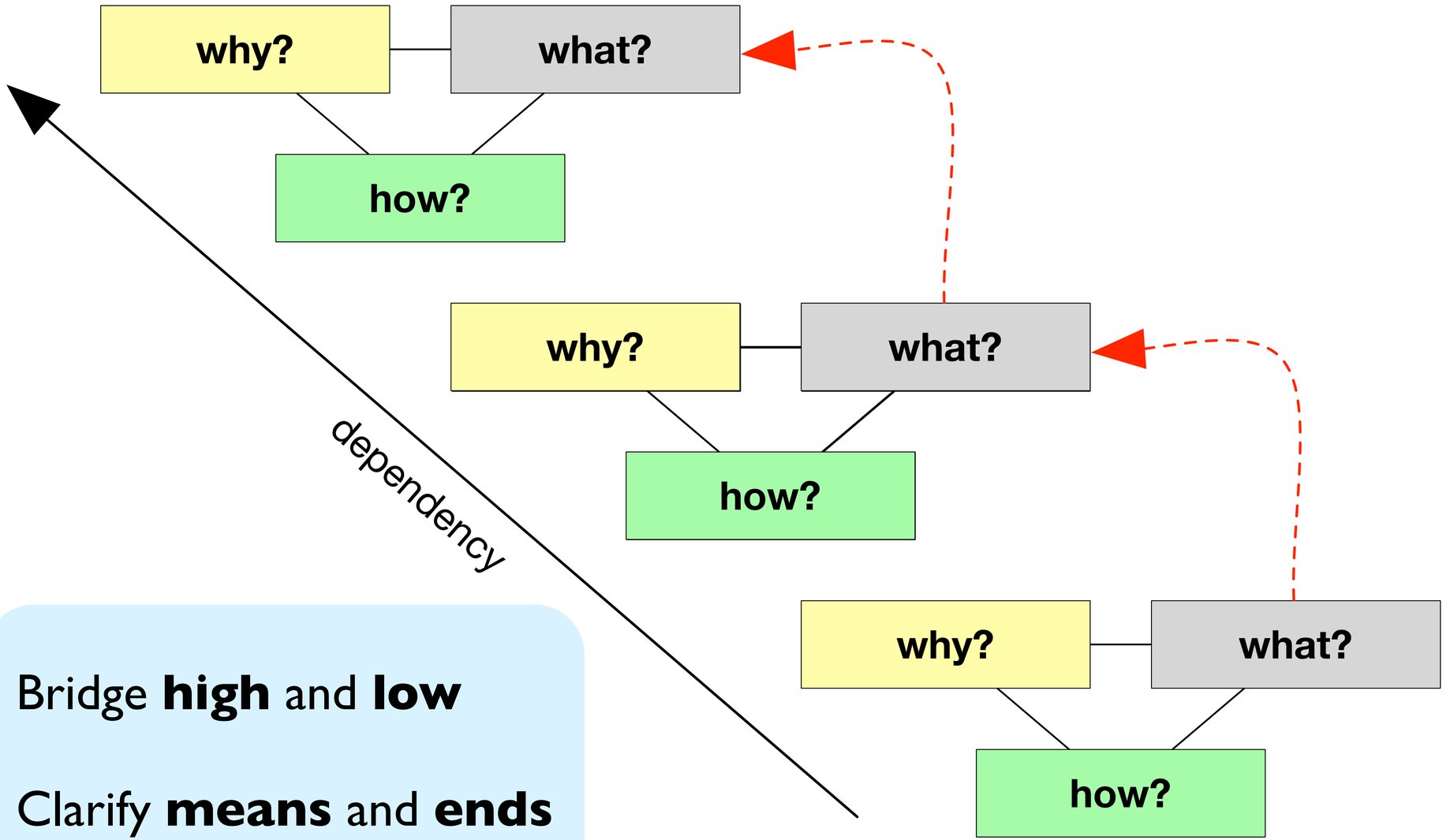


Bridge **high** and **low**

Clarify **means** and **ends**

Describe **sequences**

Purpose of **Typology**



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Multi-Level Typology of Abstract Visualization Tasks

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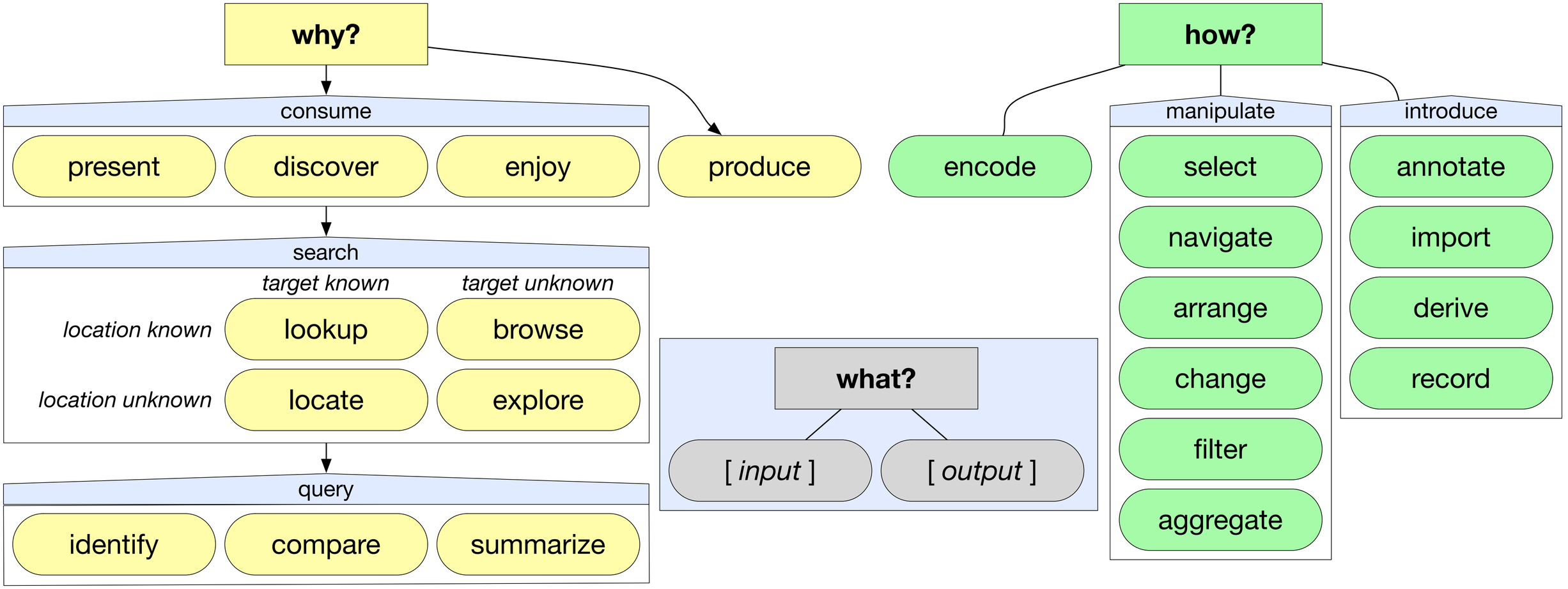
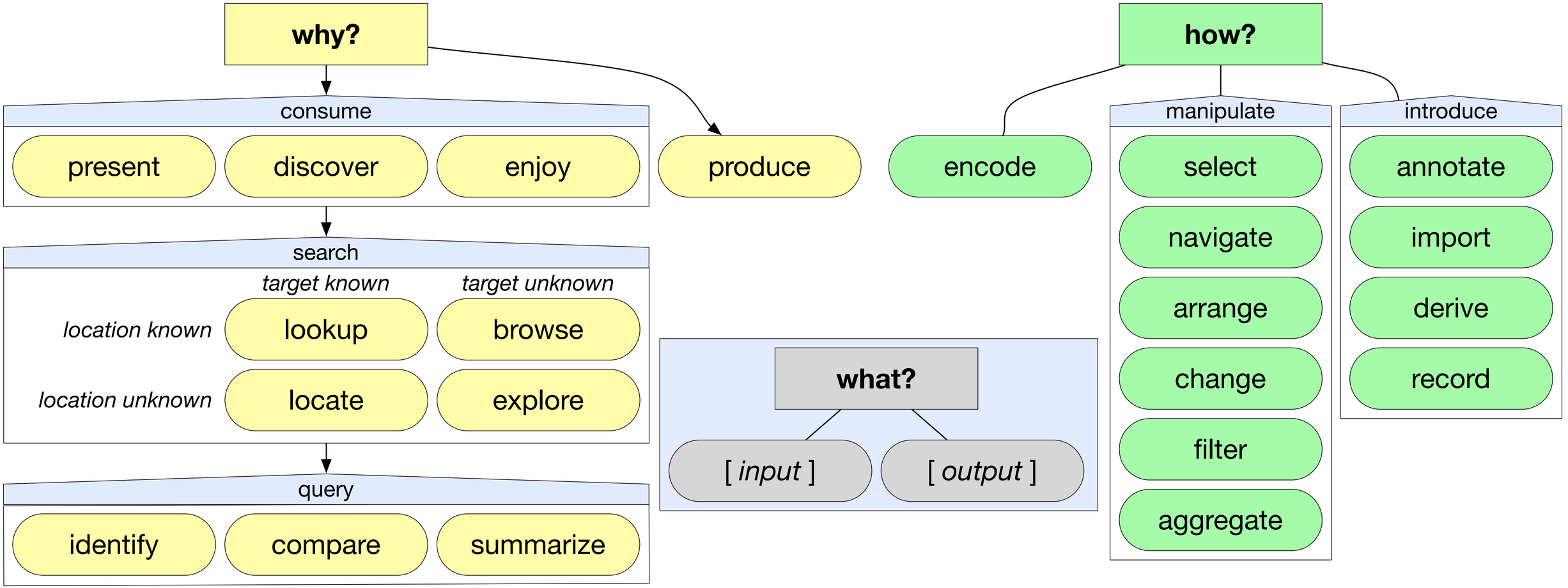


Multi-Level Typology of Abstract Visualization Tasks

{ *why* , *what* , *how* }



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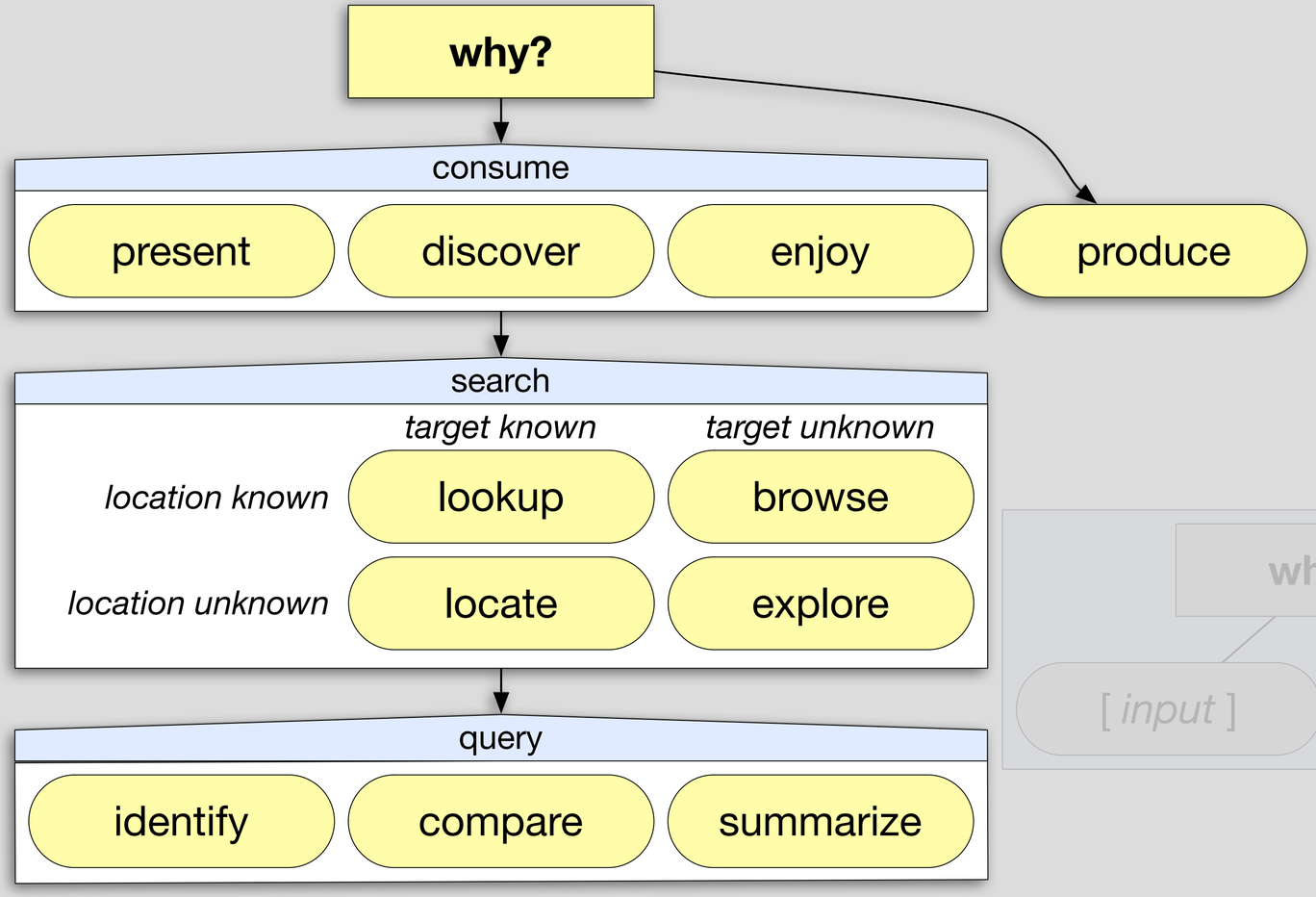
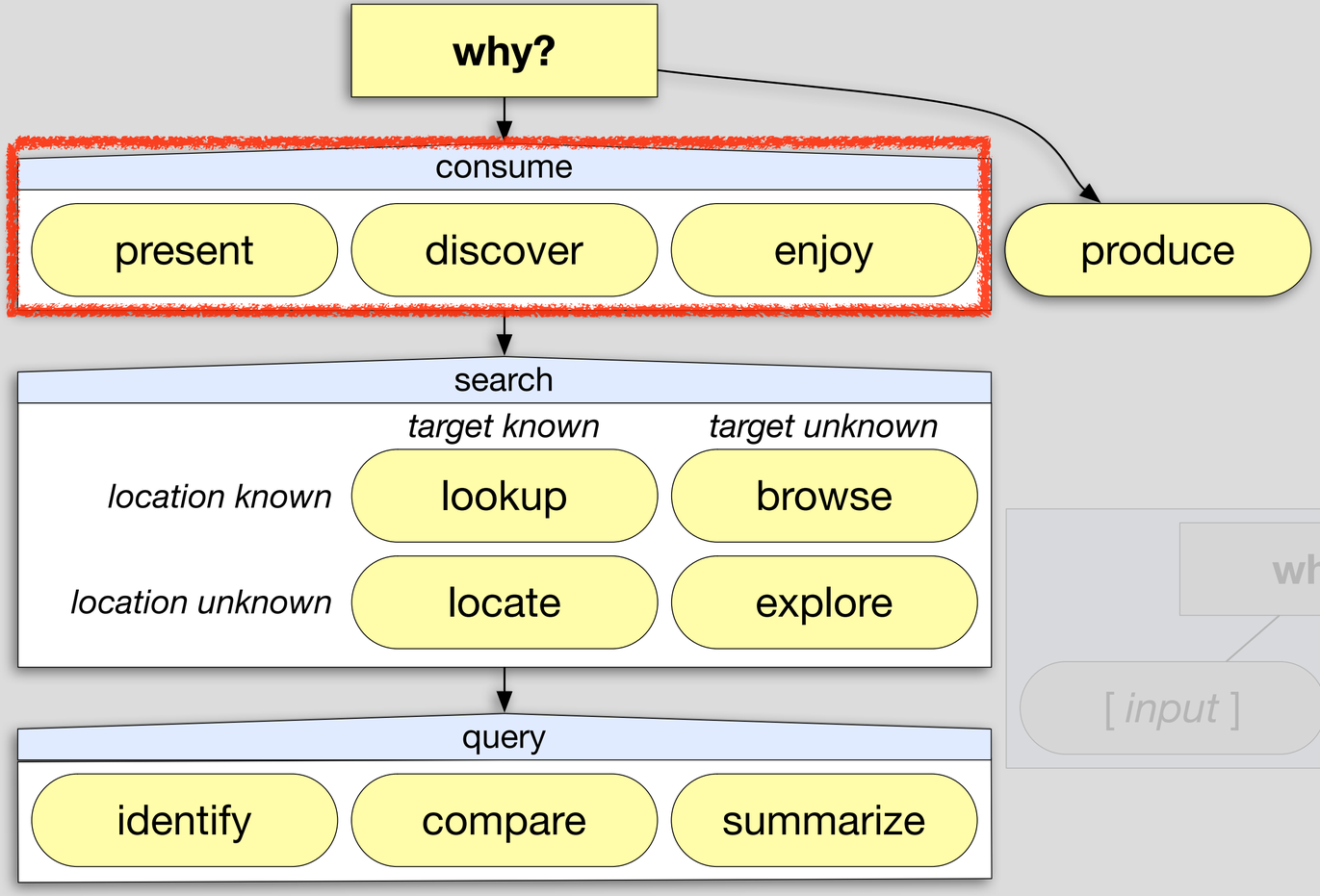


1. Choose either **Consume** or **Produce**

Multi-Level Typology of Abstract Visualization Tasks

{ *why* , *what* , *how* }

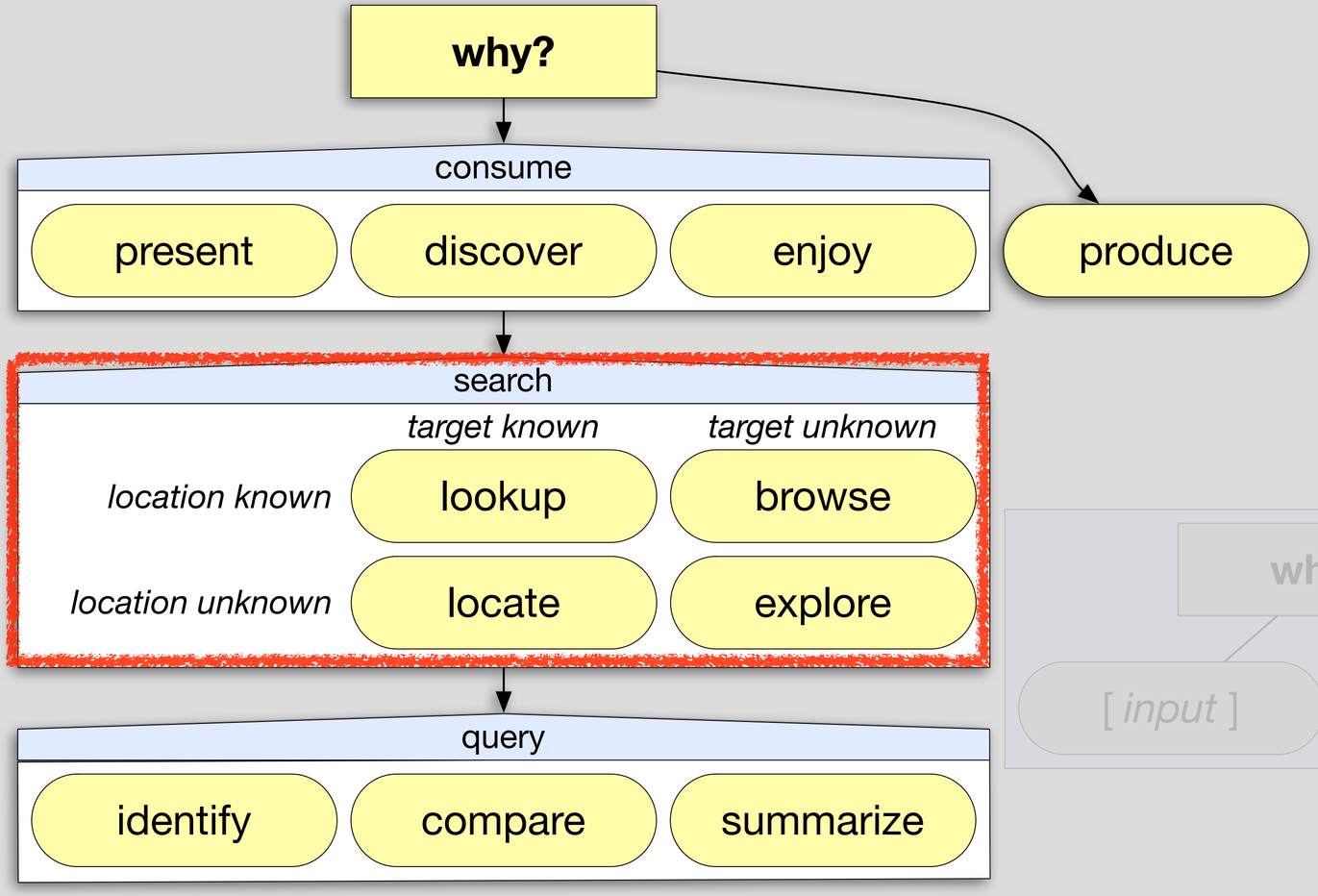


1. Choose either **Consume** or **Produce**

   i. if **Consume** → choose between:
   Present or *Discover* or *Enjoy*

Multi-Level Typology of Abstract Visualization Tasks

{ *why* , *what* , *how* }



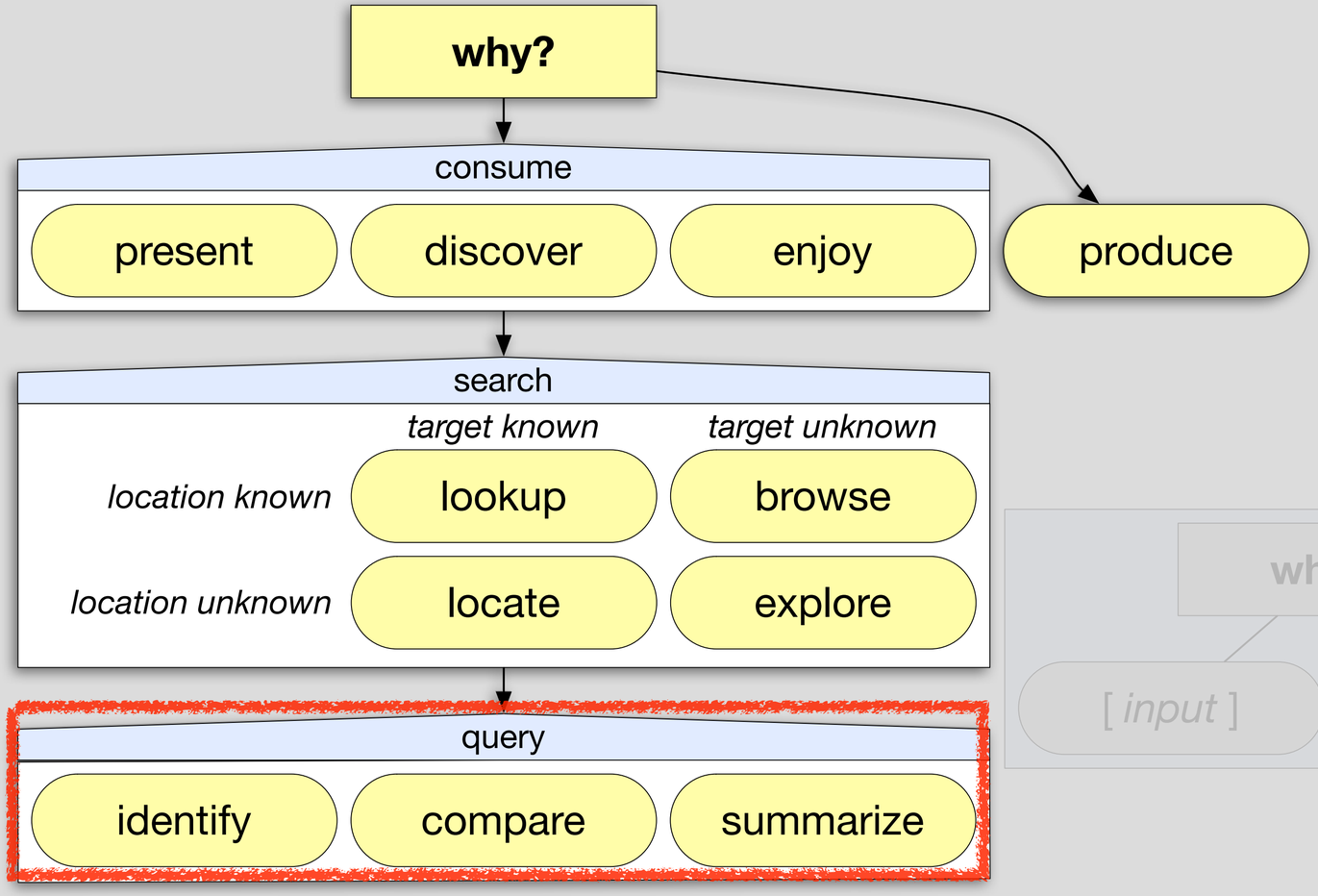
1. Choose either **Consume** or **Produce**

   i. if **Consume** → choose between:
   Present or *Discover* or *Enjoy*

   ii. then **Search** → choose between:
   Lookup or *Browse* or *Locate* or *Explore*

Multi-Level Typology of Abstract Visualization Tasks

{ *why* , *what* , *how* }



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   iii. then **Query** → choose between:
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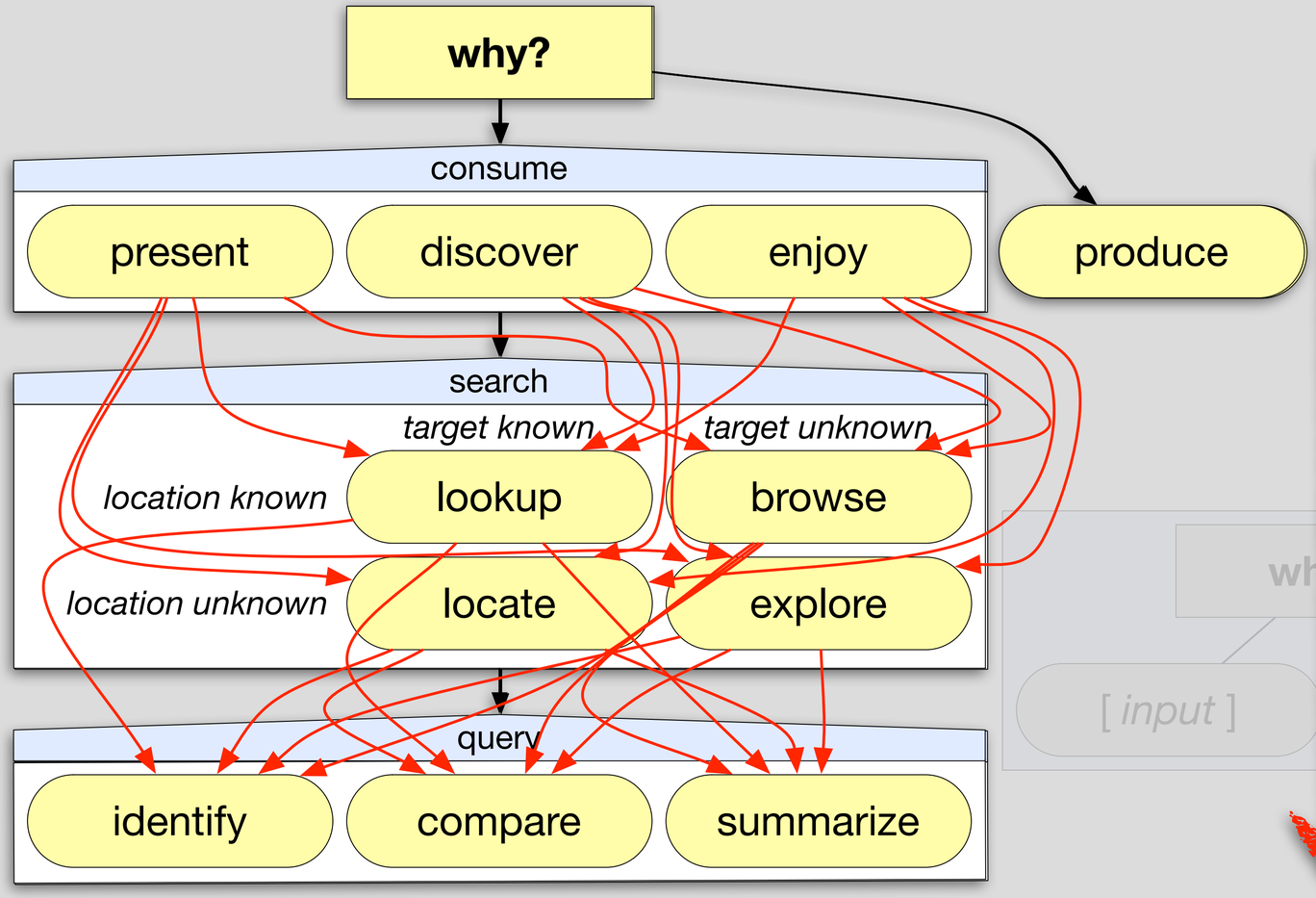
Multi-Level Typology of Abstract Visualization Tasks

{ *why* , *what* , *how* }



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Multi-Level Typology of Abstract Visualization Tasks

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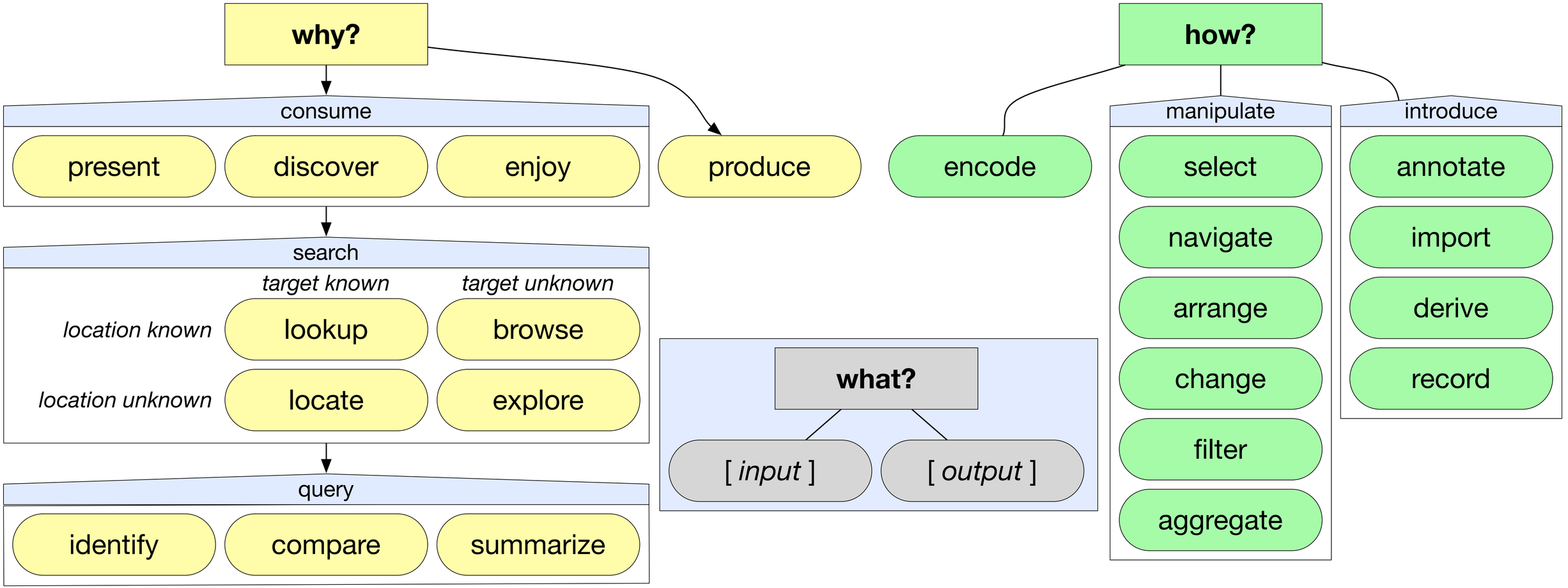
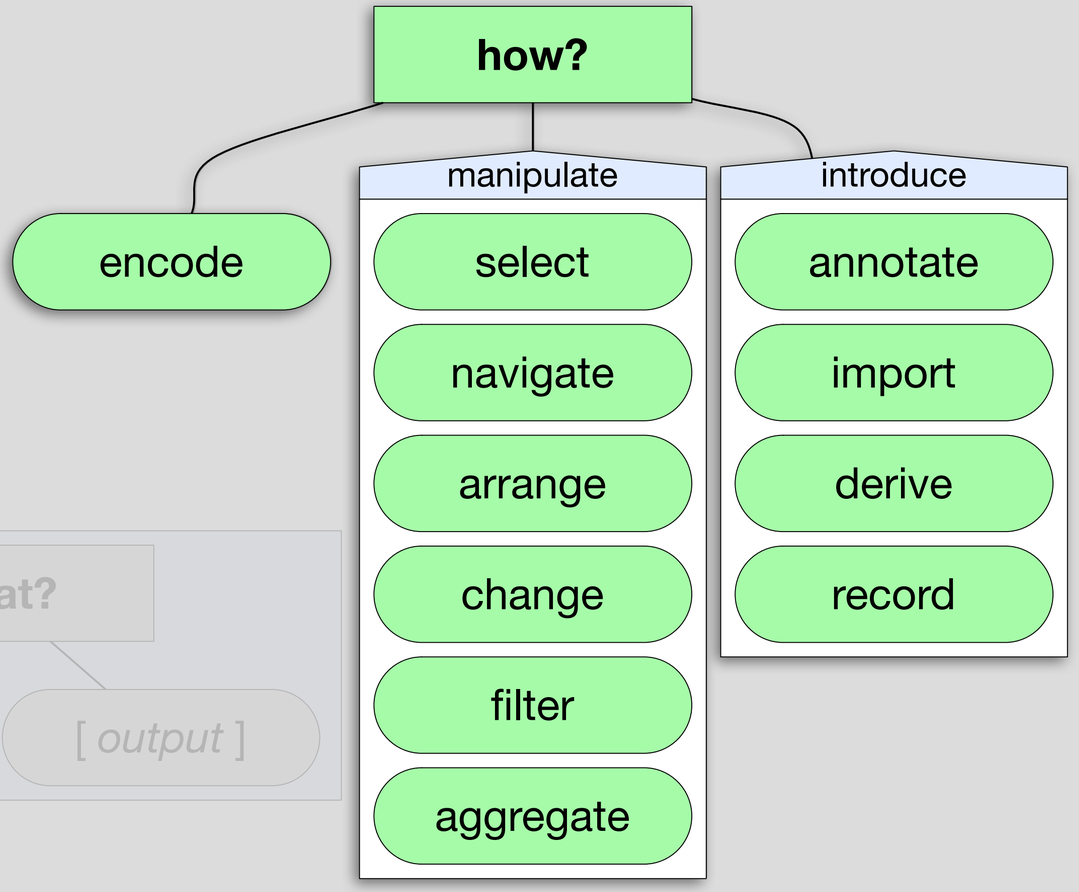


Multi-Level Typology of Abstract Visualization Tasks

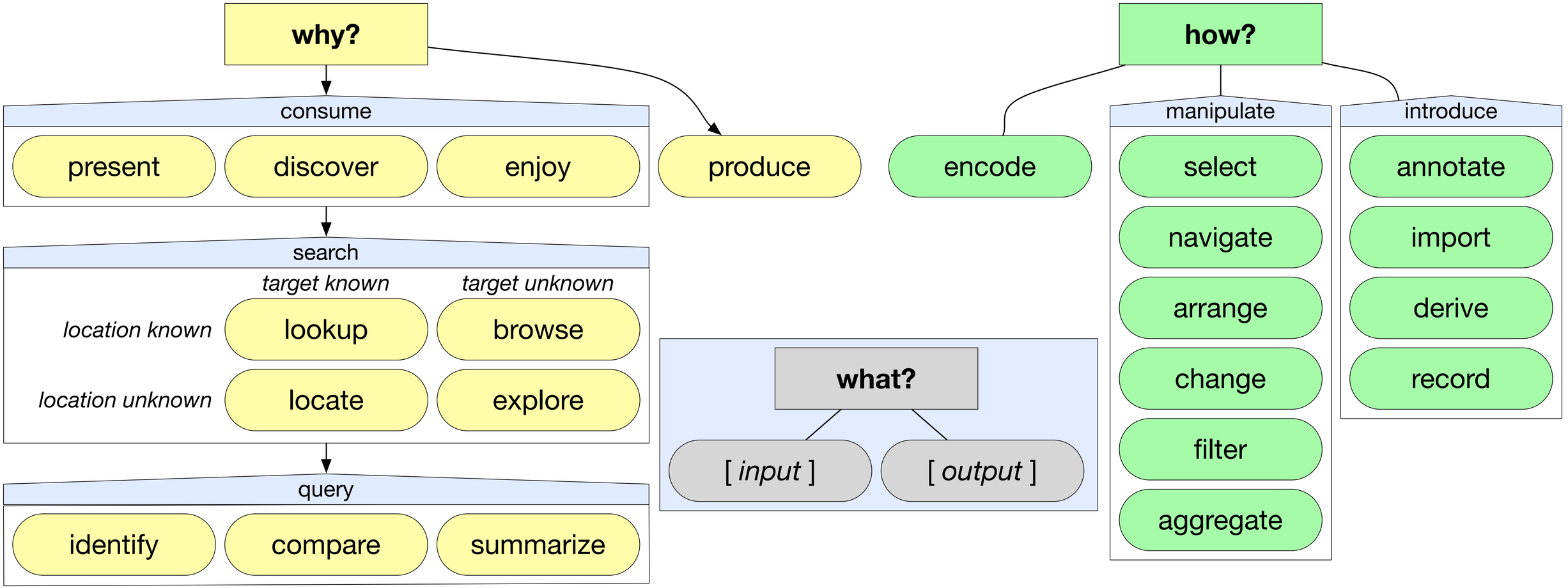
{ *why* , *how* , *what* }

2. Choose a combination of
   Encode and / or
   Manipulate and / or
   Introduce methods



Multi-Level Typology of Abstract Visualization Tasks

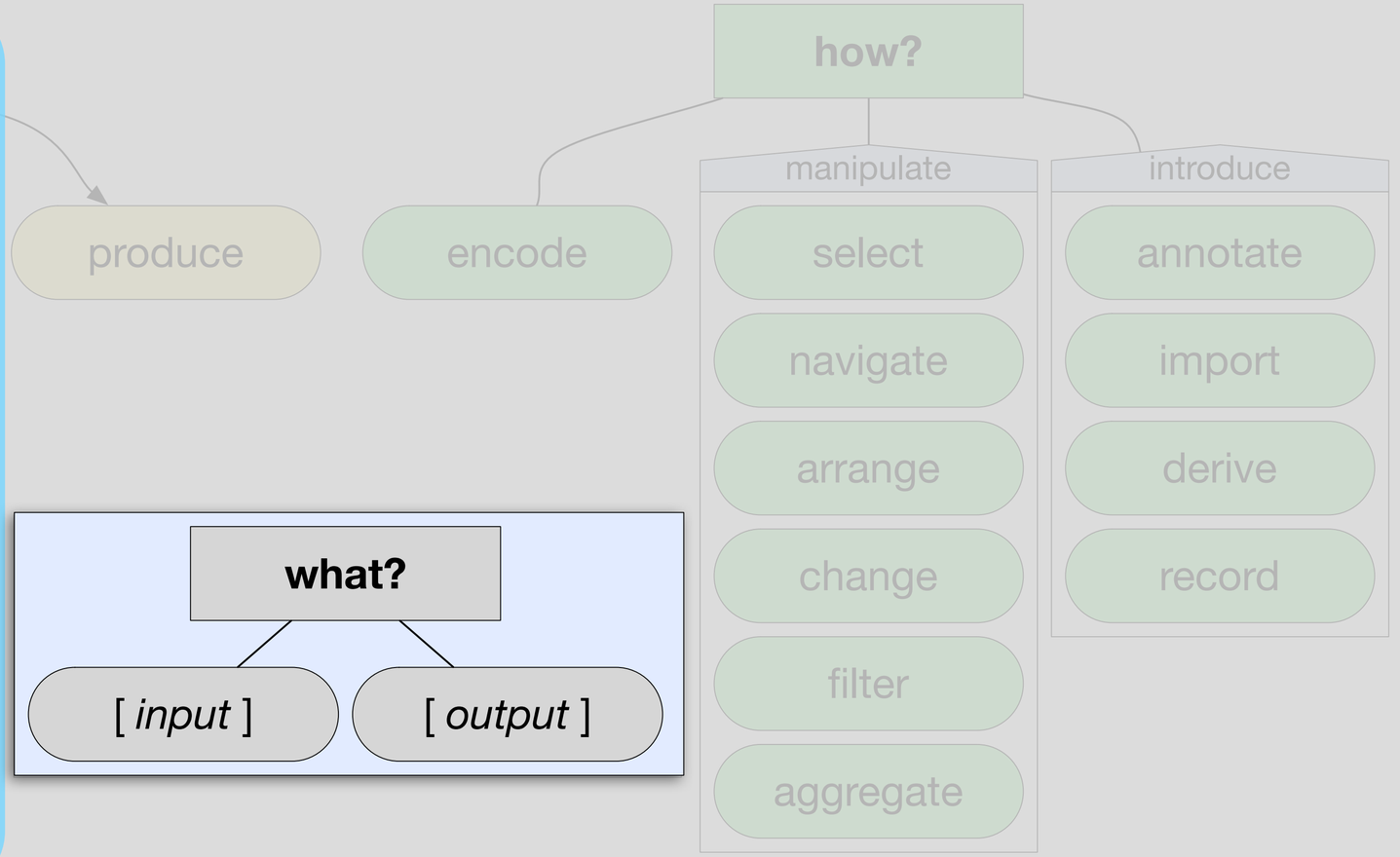
{ *why* , *how* , *what* }



Multi-Level Typology of Abstract Visualization Tasks

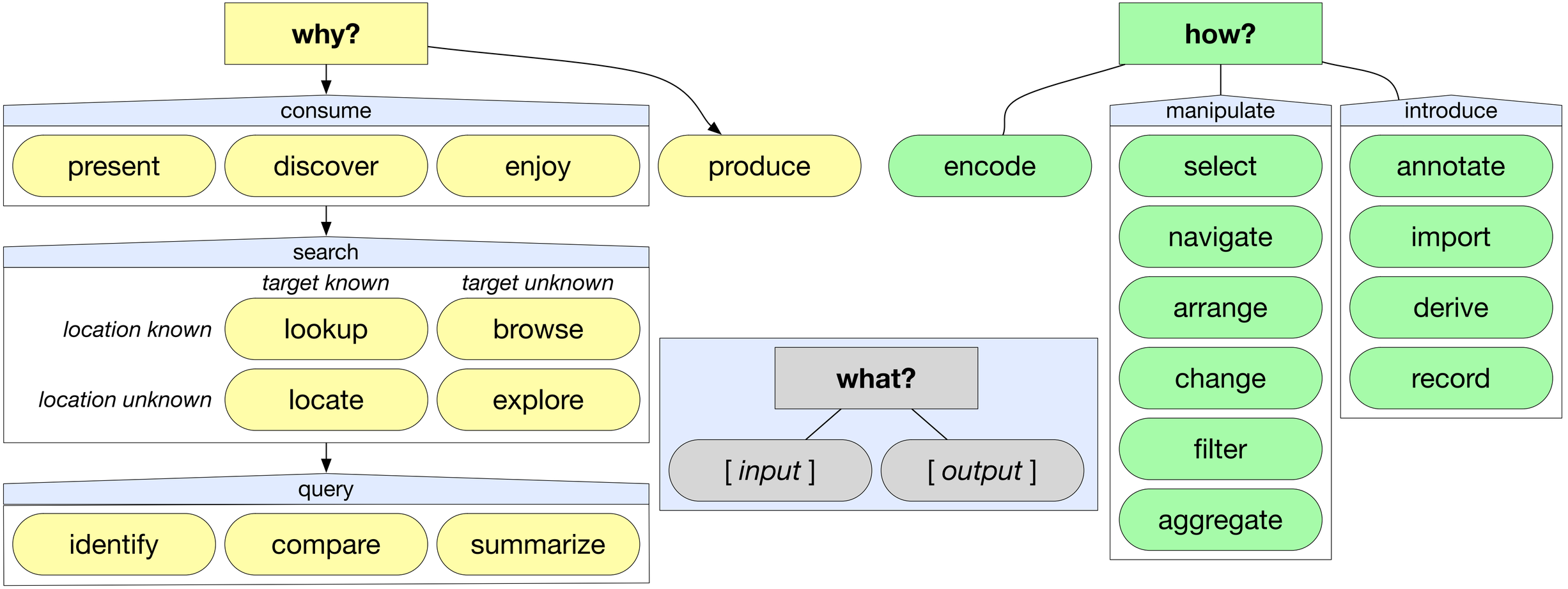
{ *why* , *how* , *what* }

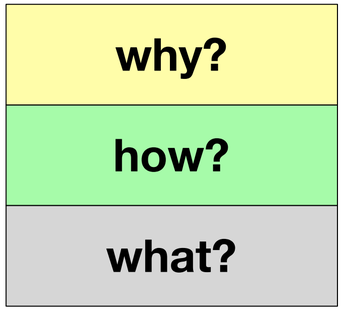
3. Fill in:
   Input and
   Output with
   nouns



Multi-Level Typology of Abstract Visualization Tasks

Why: choose from alternatives. **What**: fill in *Input* and *Output*. **How**: choose combination.





Example:

"presenting a path between nodes"

[1] Grosjean et al. (InfoVis 2002)

[2] Munzner et al. (SIGGRAPH 2003)

why?

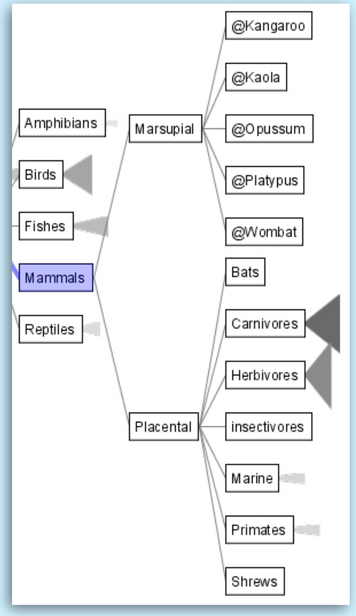
how?

what?

Example:

"presenting a path between nodes"

SpaceTree [1]



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how?

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Example:

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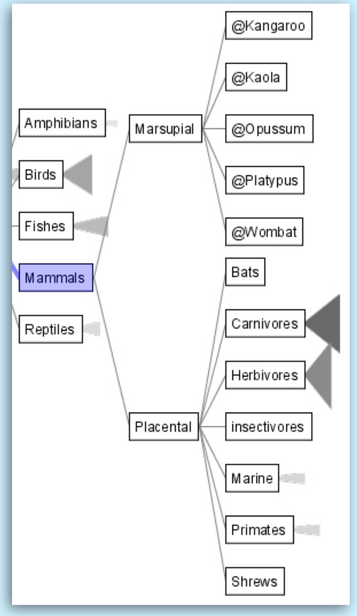

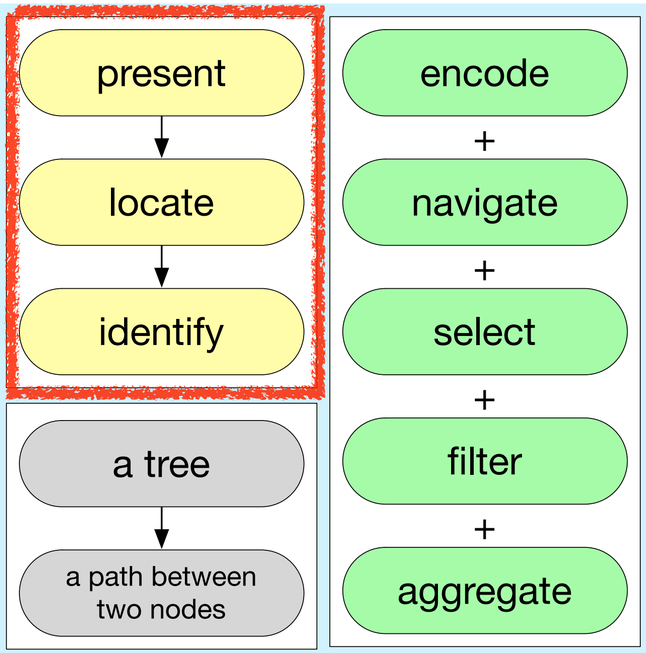

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Example:

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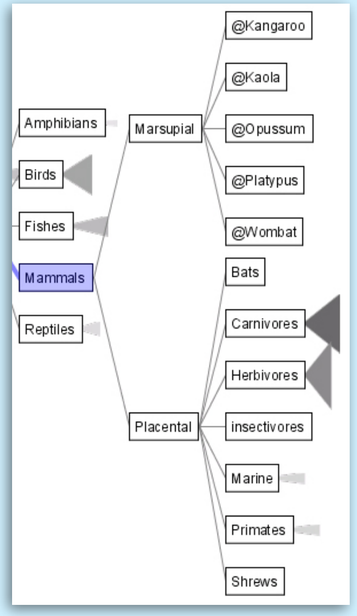

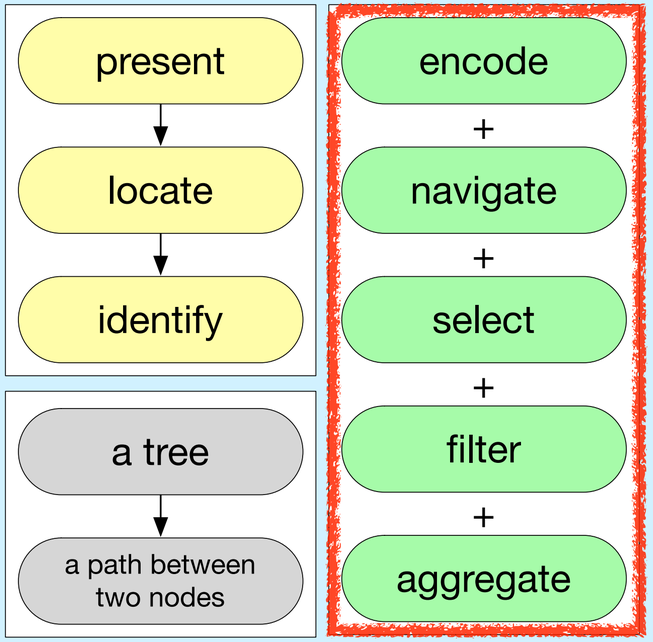

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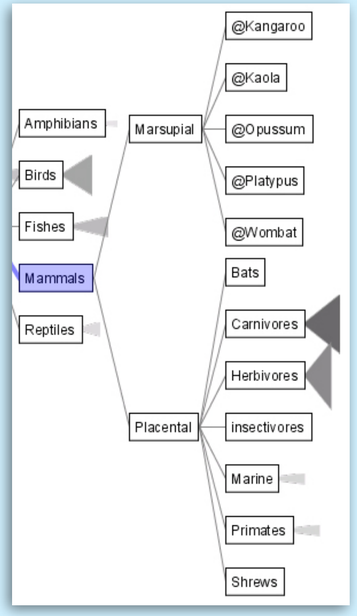
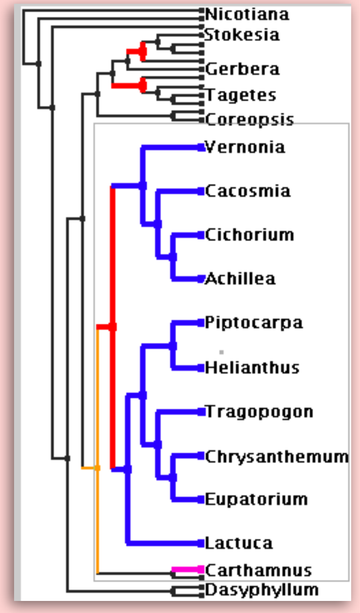


present → locate → identify

a tree → a path between two nodes

encode + navigate + select + filter + aggregate

TreeJuxtaposer [2]



present → locate → identify

a tree → a path between two nodes

encode + navigate + select + arrange

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Example:

Task Sequence

"verifying a hypothesis regarding the existence of clusters of items in a scatterplot of dimensionally reduced data, then labelling clusters of points."

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"verifying a hypothesis regarding the existence of clusters of items in a scatterplot of dimensionally reduced data, then labelling clusters of points."

	dim 1	dim 2	dim 3	…	dim m
Item 1					
Item 2					
…					
Item n					

	dim' 1	dim' 2
Item 1		
Item 2		
…		
Item n		

Dimensionality Reduction

Visual Encoding

Example:

Task Sequence

"verifying a hypothesis regarding the existence of clusters of items in a scatterplot of dimensionally reduced data, then labelling clusters of points."

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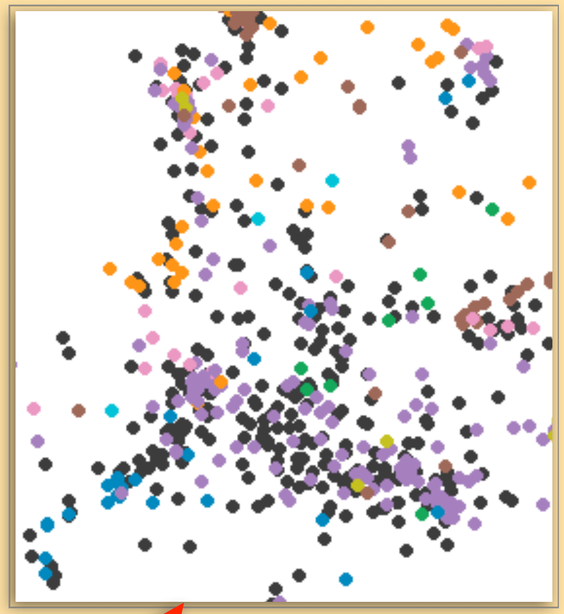

Dimensionality Reduction

Visual Encoding

Labelling

Example:

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"verifying a hypothesis regarding the existence of clusters of items in a scatterplot of dimensionally reduced data, then labelling clusters of points."

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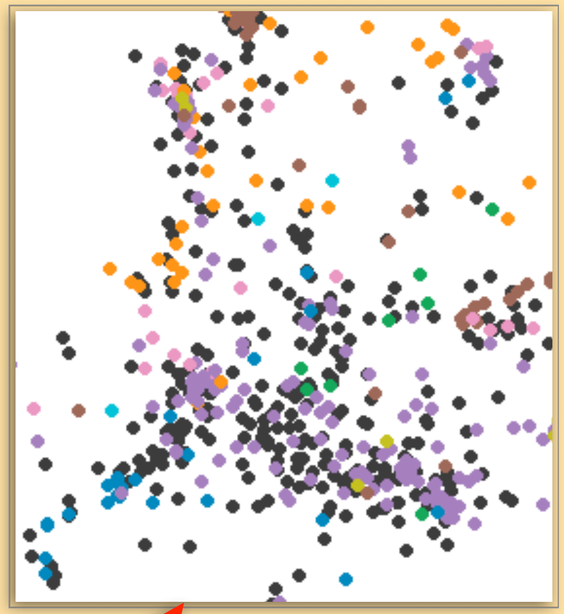

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Visual Encoding

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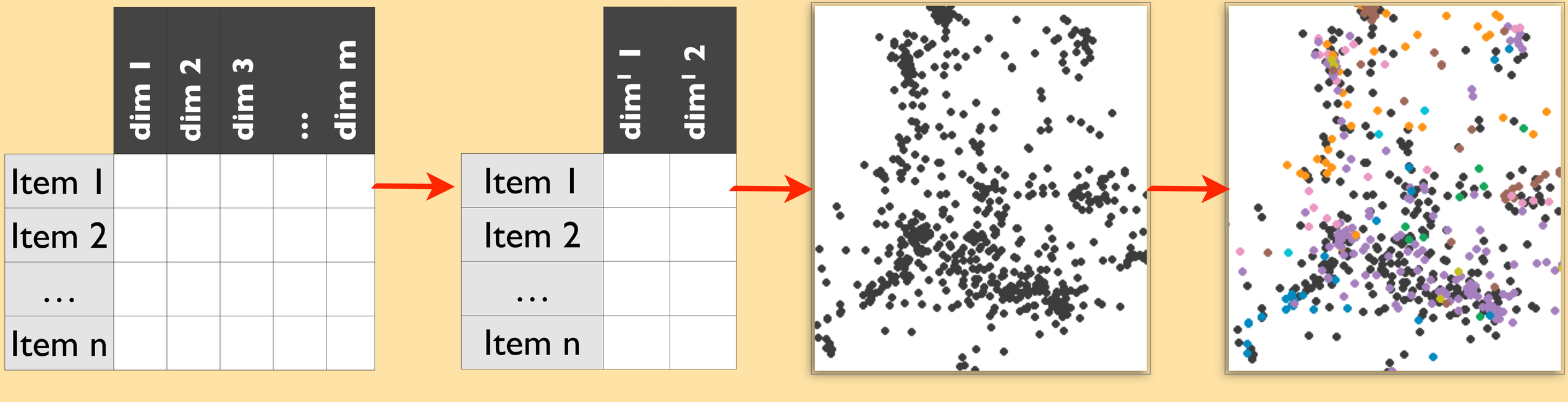
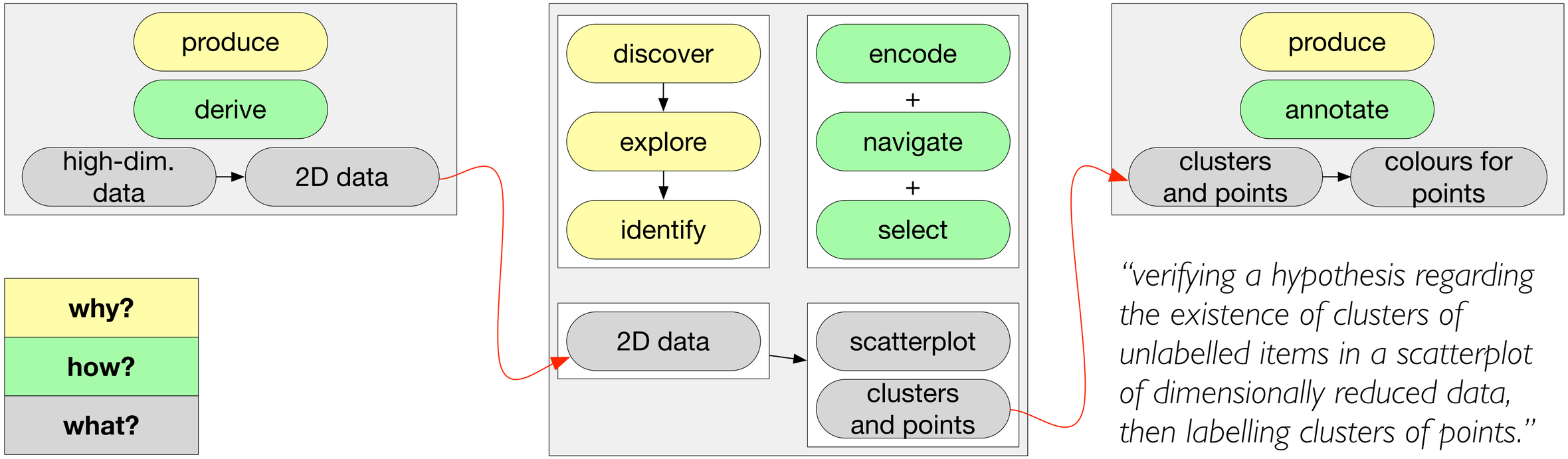
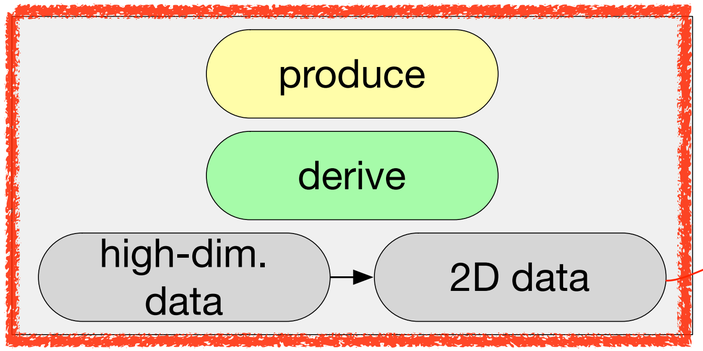


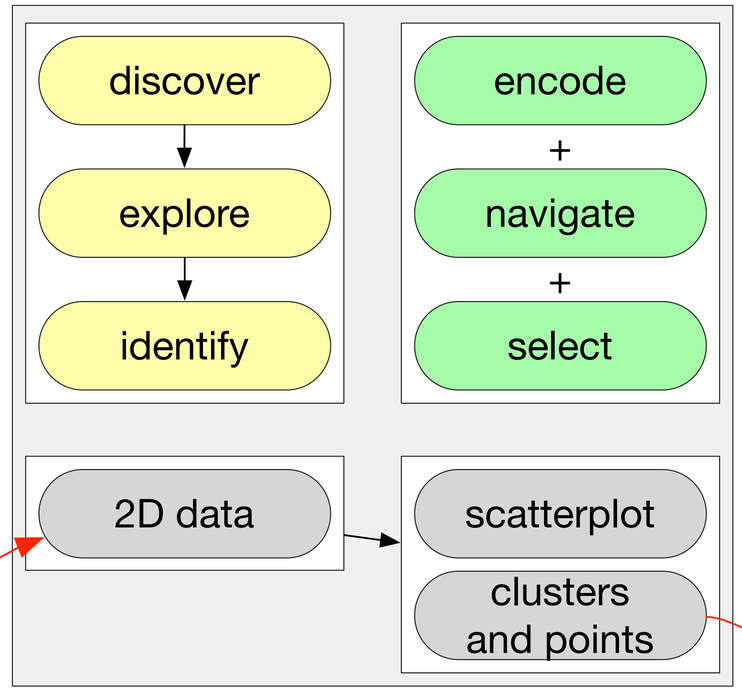


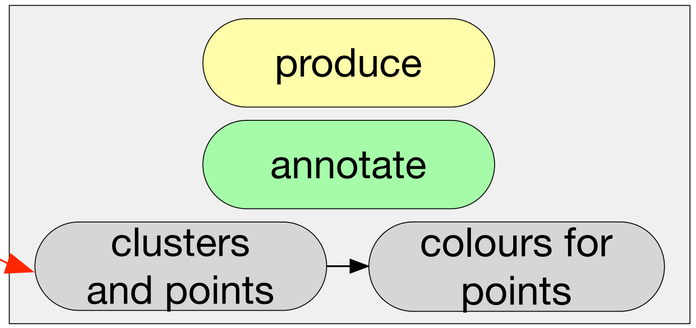
"verifying a hypothesis regarding the existence of clusters of unlabelled items in a scatterplot of dimensionally reduced data, then labelling clusters of points."

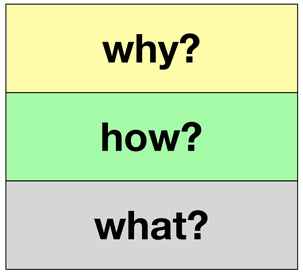
	dim 1	dim 2	dim 3	..	dim m
Item 1					
Item 2					
…					
Item n					

	dim' 1	dim' 2
Item 1		
Item 2		
…		
Item n		

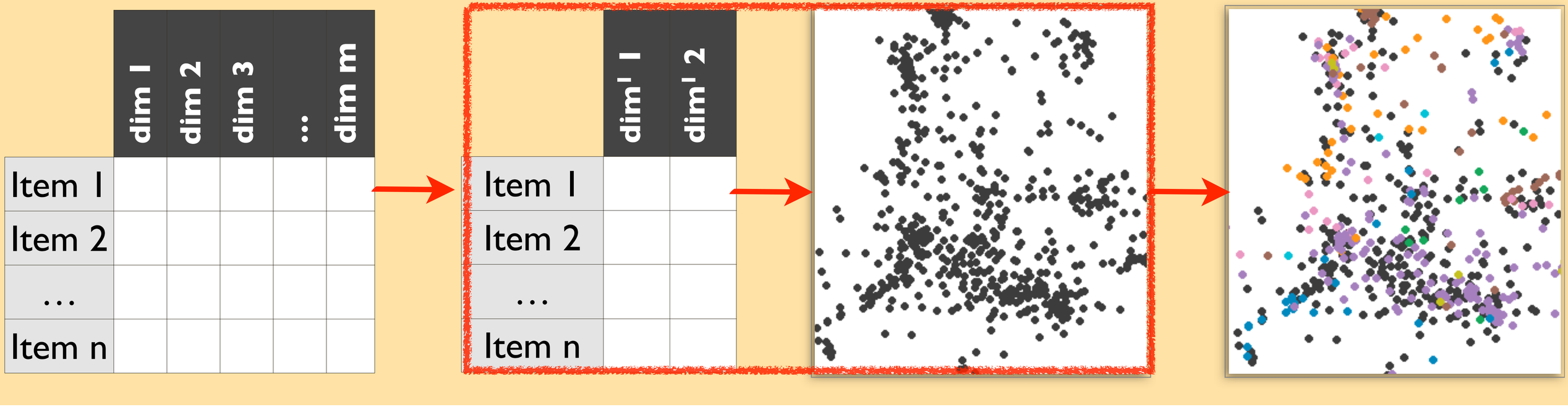


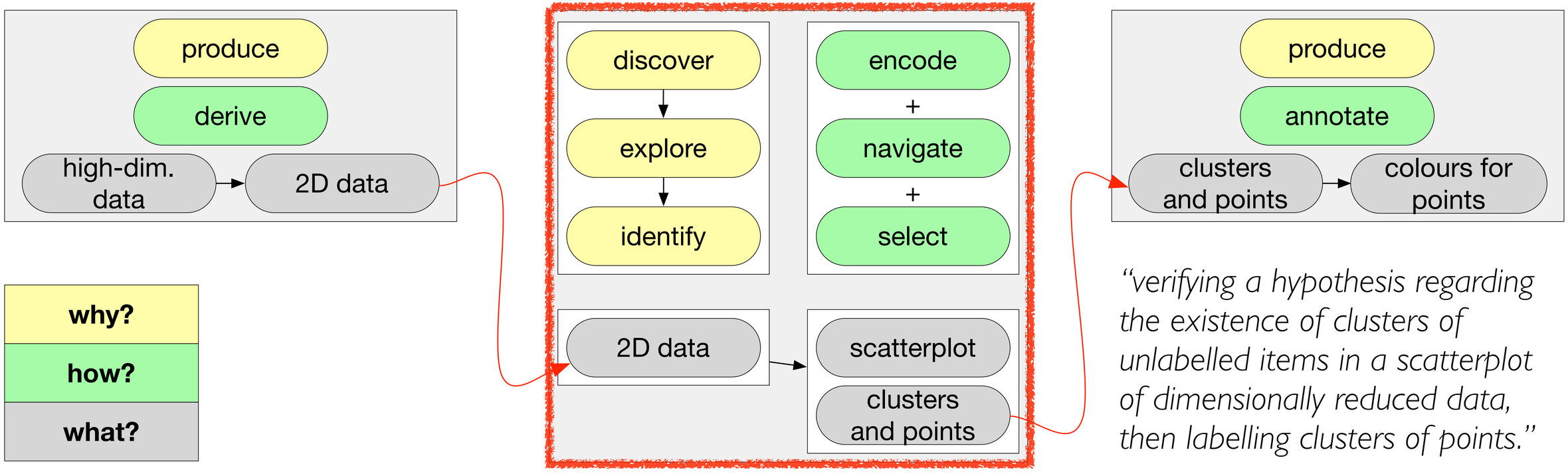






"verifying a hypothesis regarding the existence of clusters of unlabelled items in a scatterplot of dimensionally reduced data, then labelling clusters of points."





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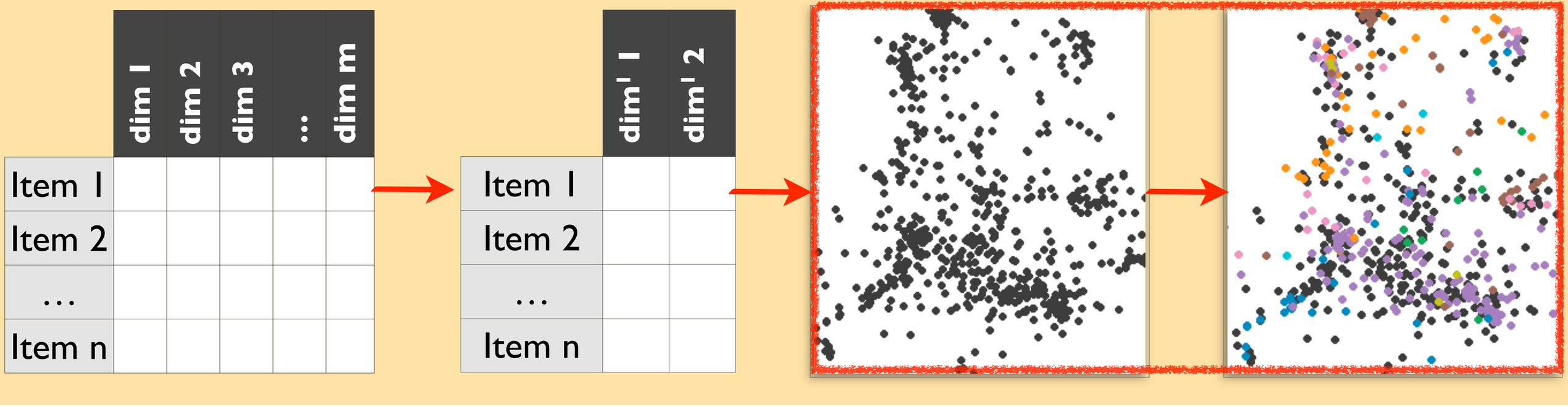

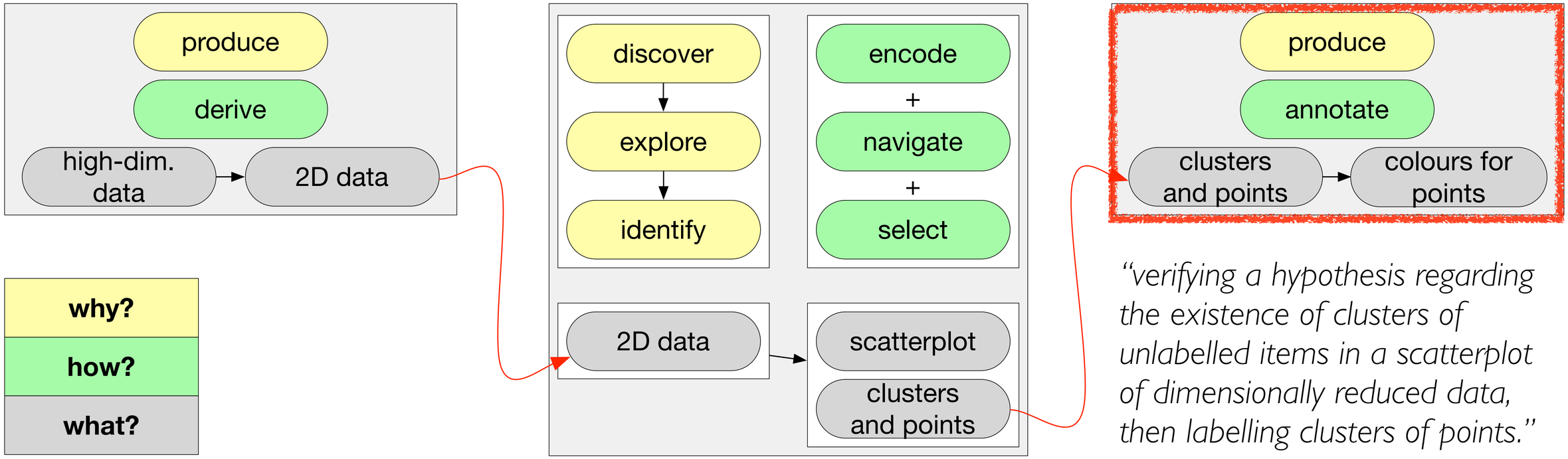

"verifying a hypothesis regarding the existence of clusters of unlabelled items in a scatterplot of dimensionally reduced data, then labelling clusters of points."

Similarities and **Differences** from Schulz et al., Roth (*InfoVis '13*)

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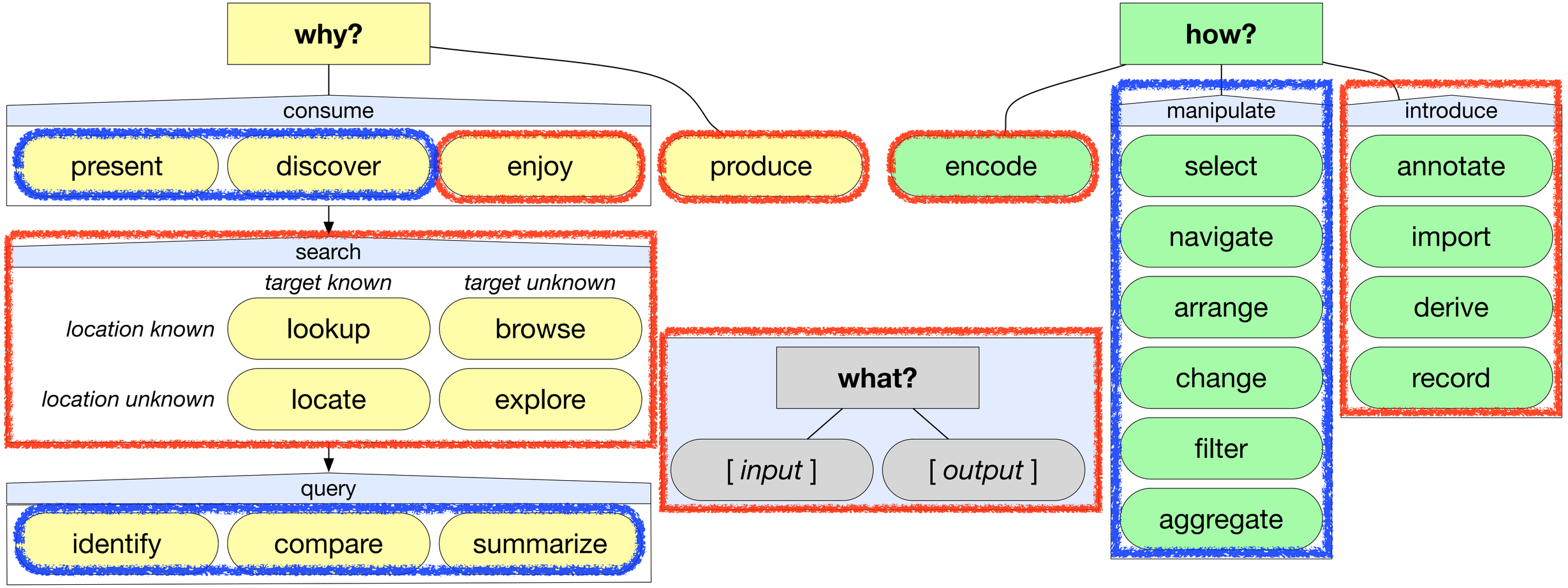
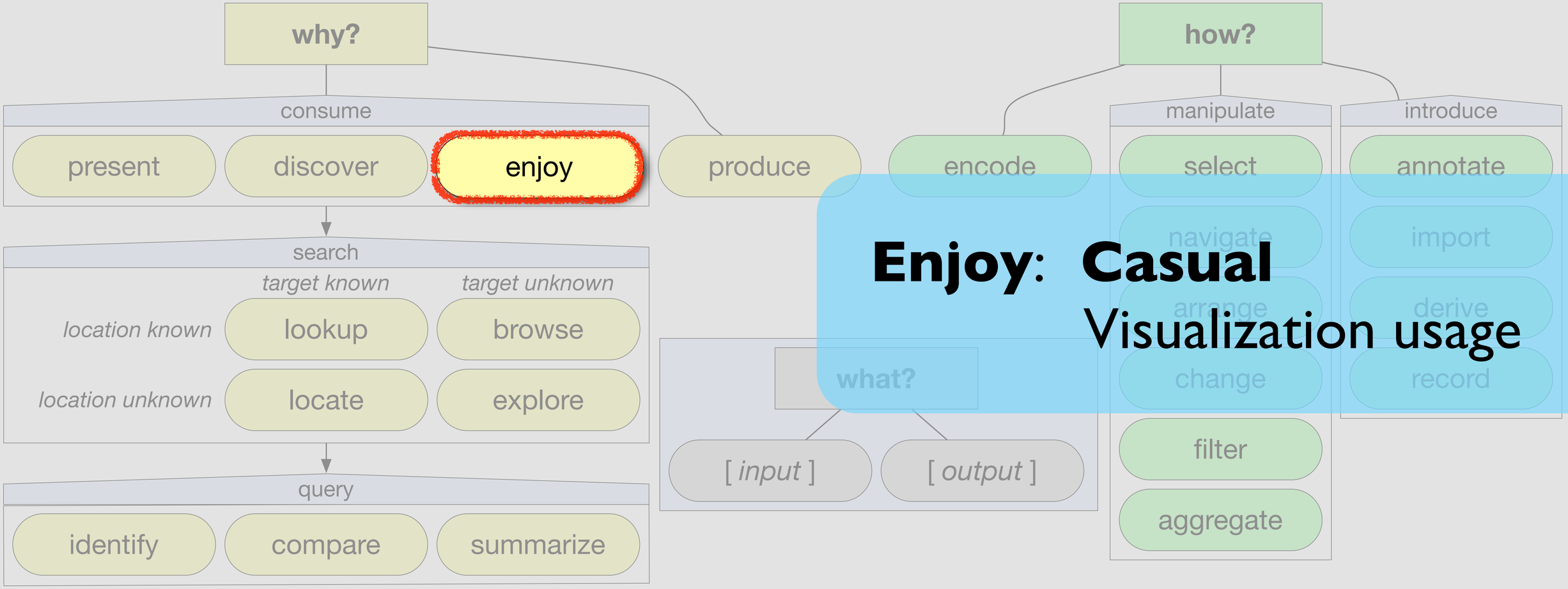


Similarities and **Differences** from Schulz et al., Roth (*InfoVis '13*)



Enjoy: **Casual** Visualization usage

Multi-Level Typology of Abstract Visualization Tasks

Brehmer & Munzner (2013)

Design Space of Visualization Tasks

Schulz et al. (2013)

Taxonomy of Cartographic Interaction Primitives

Roth (2013)

Multi-Level Typology of Abstract Visualization Tasks

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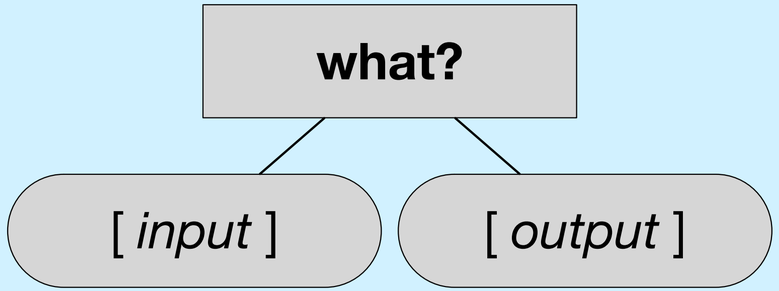

Design Space of Visualization Tasks

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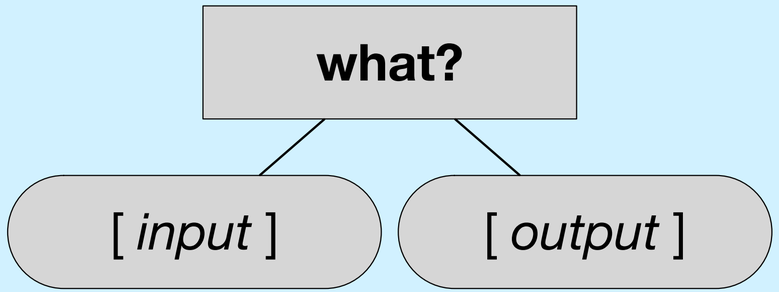
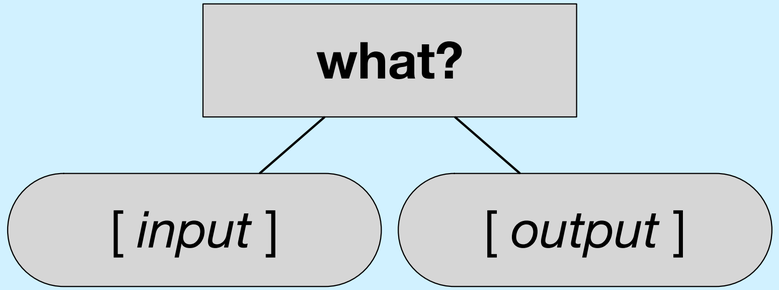


Bring Your Own " What ":

- *values, extremum, ranges, distributions, clusters, …*
  [Amar, Eagan, & Stasko (InfoVis 2005)]
- *nodes, links, paths, graphs, clusters, …*
  [Lee et al.'s *Graph-Specific Objects* (BELIV 2006)]
- *points, intervals, spans, patterns, sequences, …*
  [Aigner et al.'s *Time-Oriented Primitives* (2011)]
- *pixels, data values, attributes, vis. structures, …*
  [Ward and Yang's *Interaction Operands* (InfoVis 2004)]

Multi-Level Typology of Abstract Visualization Tasks

Brehmer & Munzner (2013)



Bring Your Own " What ":

- *values, extremum, ranges, distributions, clusters, …*
  [Amar, Eagan, & Stasko (InfoVis 2005)]
- *nodes, links, paths, graphs, clusters, …*
  [Lee et al.'s *Graph-Specific Objects* (BELIV 2006)]
- *points, intervals, spans, patterns, sequences, …*
  [Aigner et al.'s *Time-Oriented Primitives* (2011)]
- *pixels, data values, attributes, vis. structures, …*
  [Ward and Yang's *Interaction Operands* (InfoVis 2004)]

Design Space of Visualization Tasks

Schulz et al. (2013)

Characteristics

Low-Level

High-Level

Target

Attribute Relations

- *Temporal*
- *Spatial*

Structural Relations

Taxonomy of Cartographic Interaction Primitives

Roth (2013)

Operands

Space Alone

Attributes in Space

Space in Time

Multi-Level Typology of Abstract Visualization Tasks

Brehmer & Munzner (2013)

Design Space of Visualization Tasks

Schulz et al. (2013)

Taxonomy of Cartographic Interaction Primitives

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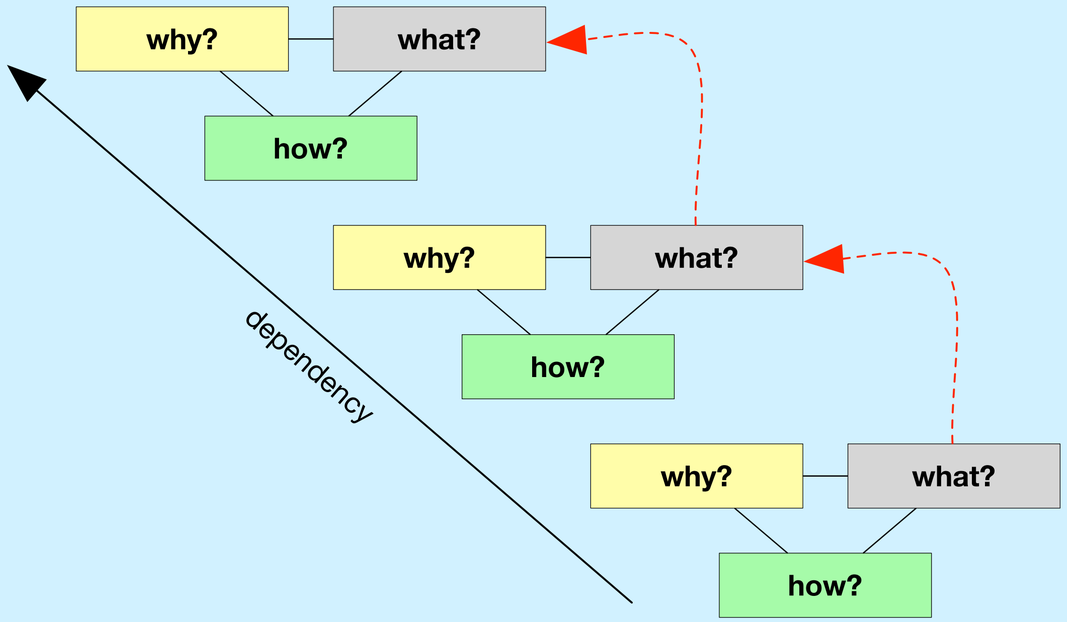

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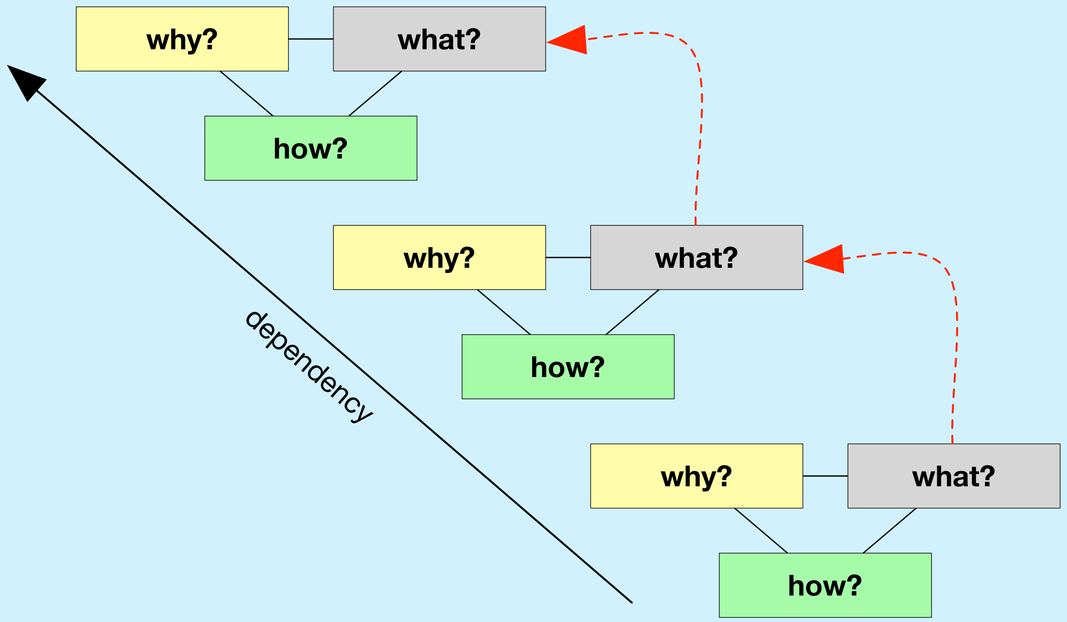

Design Space of Visualization Tasks

Schulz et al. (2013)

$$(exploratory,\ summarize,\ *,\ *,\ all) \Rightarrow$$
$$(exploratory,\ elaborate|filter,\ *,\ *,\ multiple)^{+} \Rightarrow$$
$$(exploratory|confirmatory,\ gather,\ look\text{-}up,\ *,\ single)$$

"Overview first, zoom and filter, details on demand"

legend:

(goal, means, characteristics, target, cardinality)

see Schulz et al. (2013) §3.3.3 on *Workflows*

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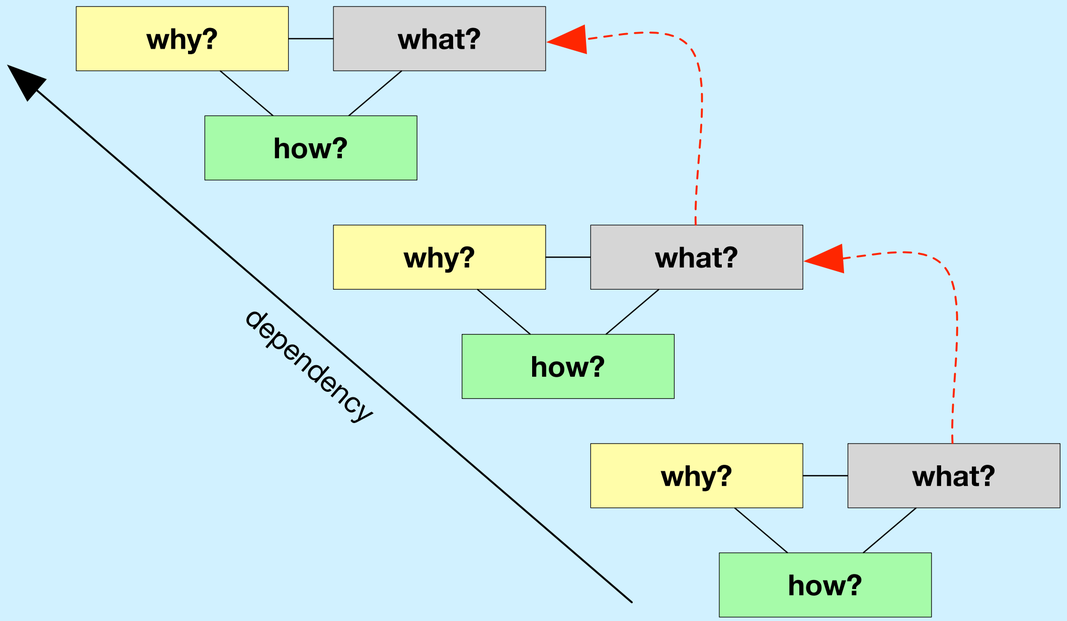

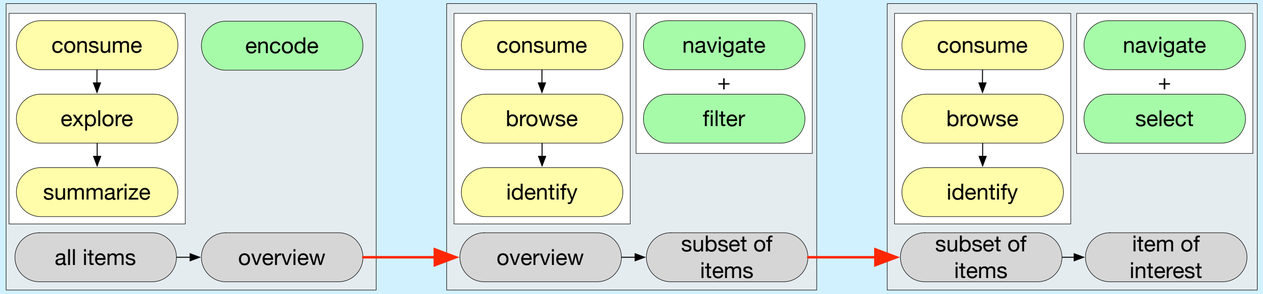

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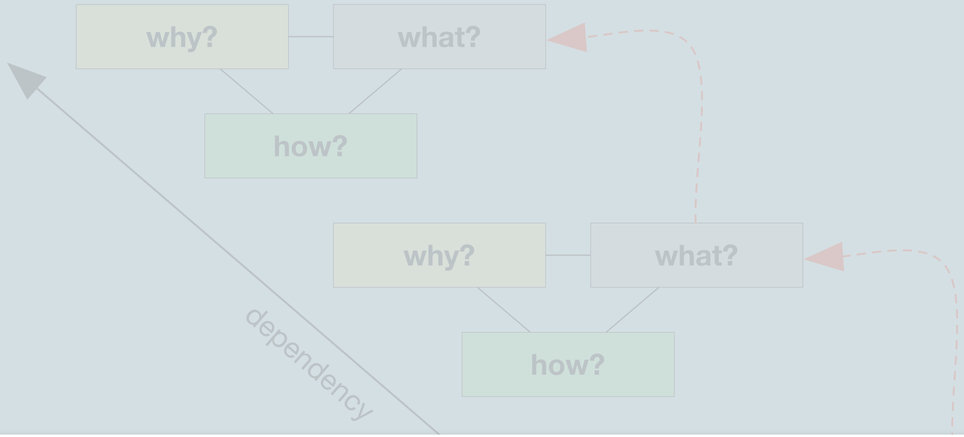

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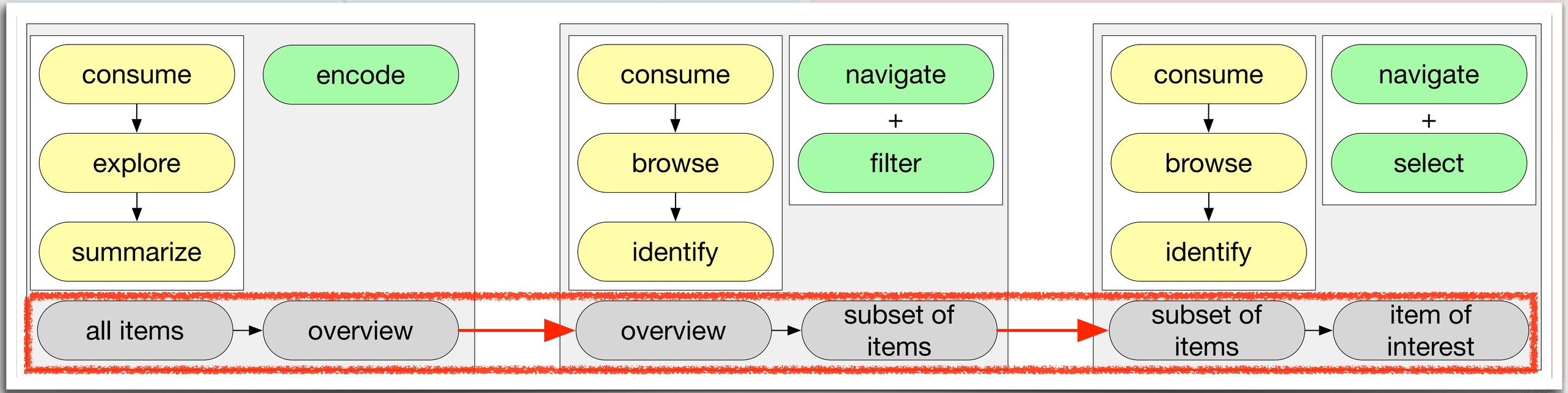


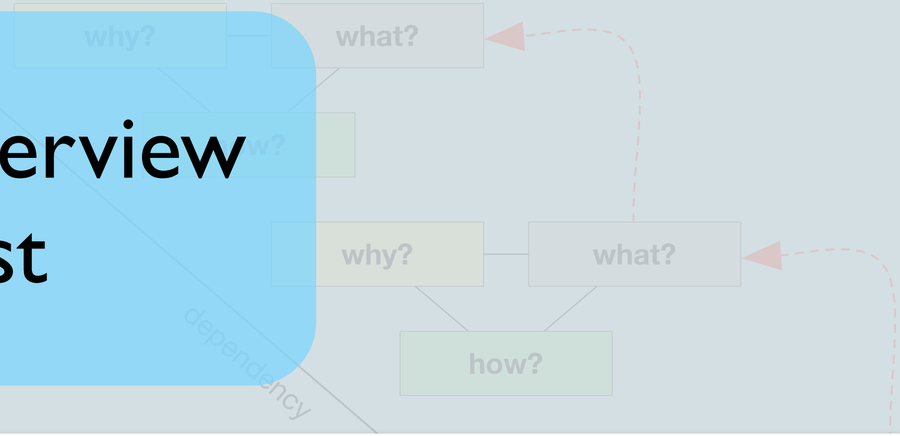
Multi-Level Typology of Abstract Visualization Tasks

Brehmer & Munzner (2013)

Design Space of Visualization Tasks

Schulz et al. (2013)

Overview First



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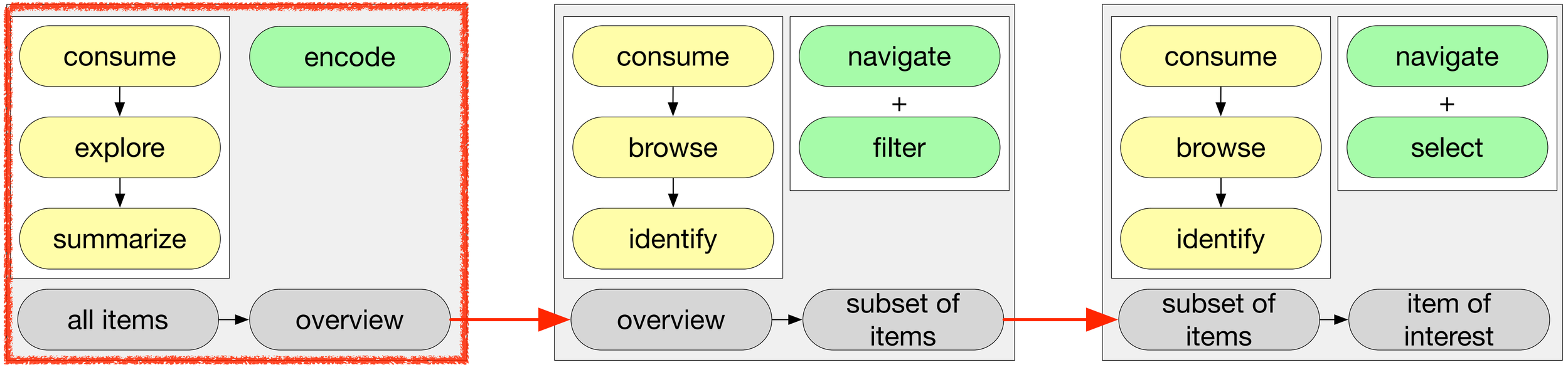

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Design Space of Visualization Tasks

Schulz et al. (2013)

Zoom and Filter

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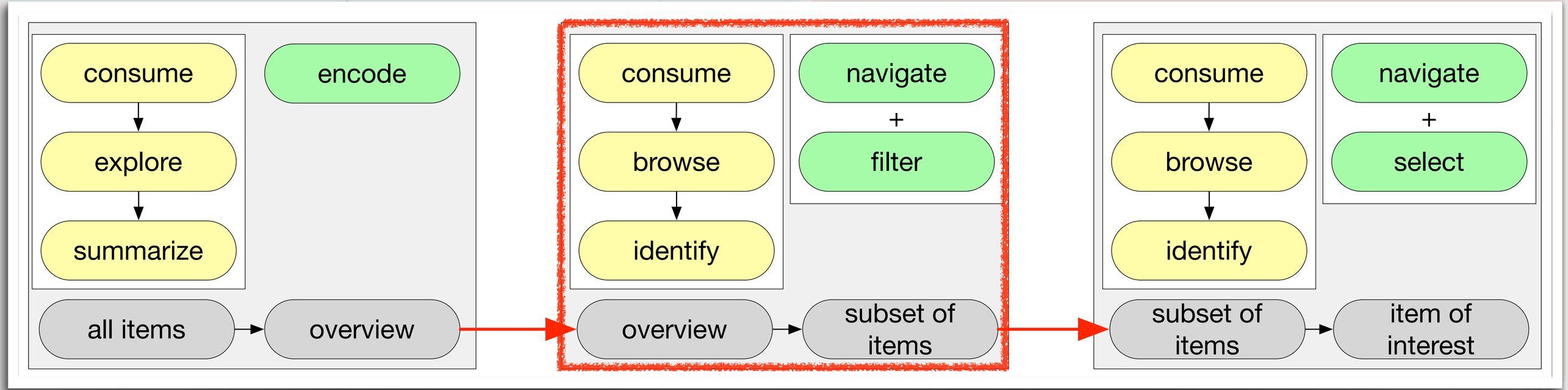

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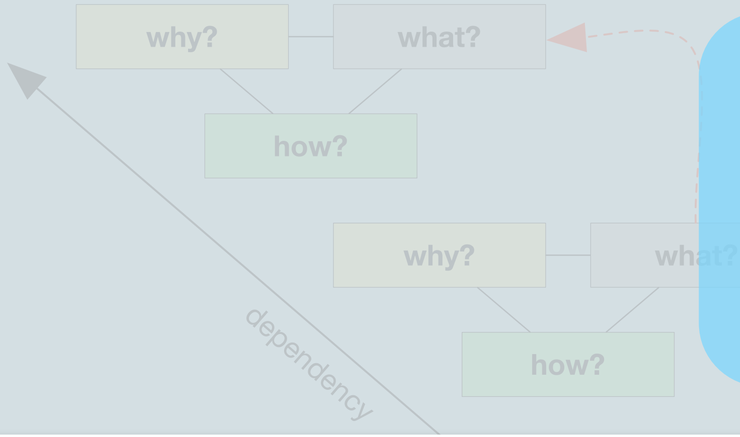

Details on Demand

$$(exploratory, summarize, *, *, all) \Rightarrow$$
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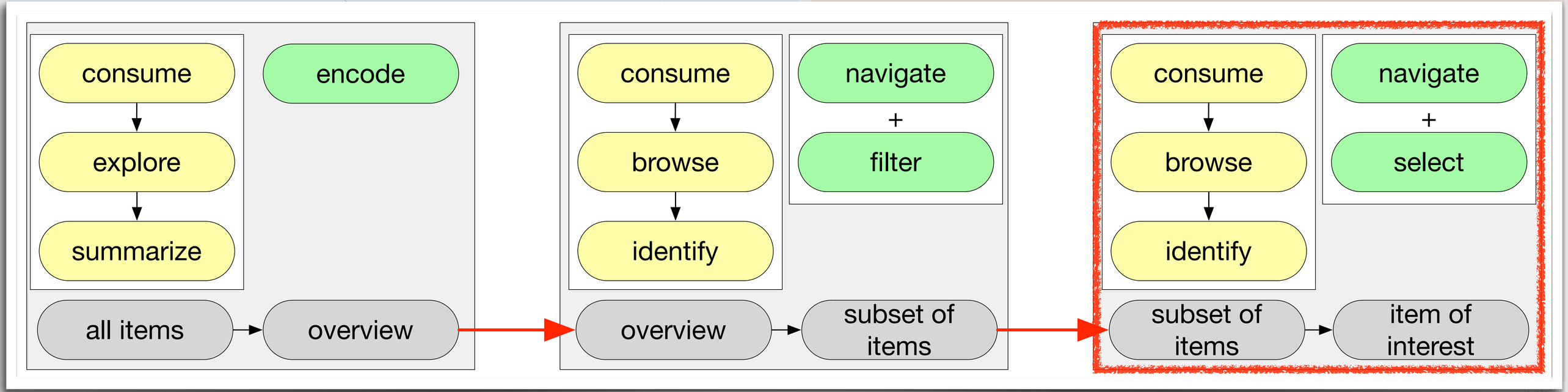
"Overview first, zoom and filter, details on demand"



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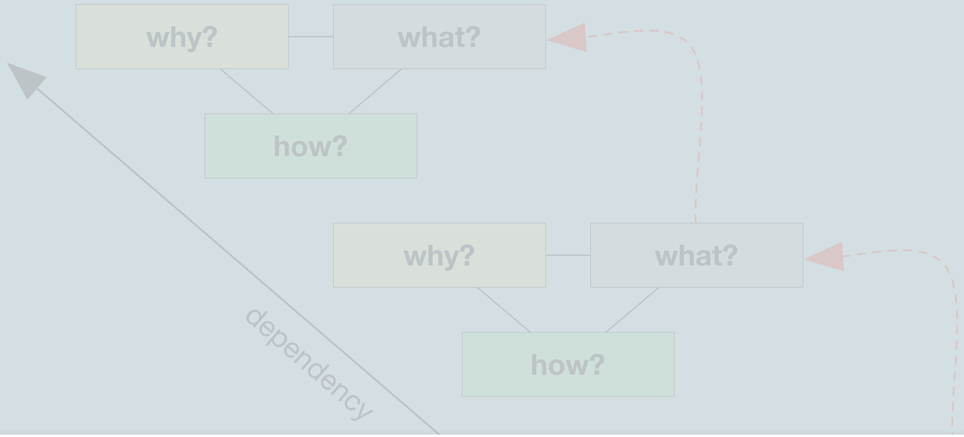

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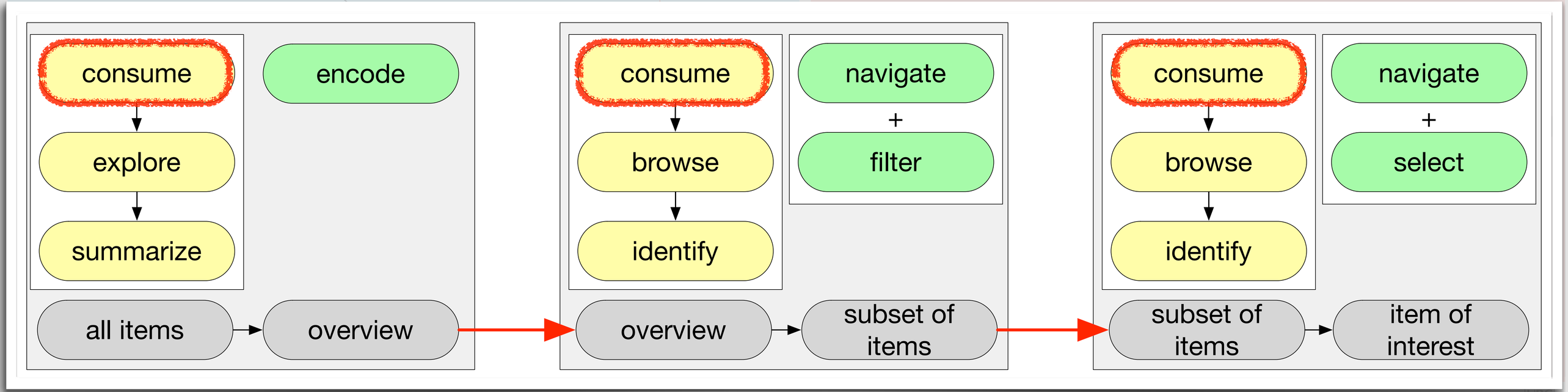

Take-Home Points:

Using the Typology [1]

[1] Beaudouin-Lafon (AVI 2004)

[2] Sedlmair, Meyer, & Munzner (TVCG 2012)

Take-Home Points:

Using the Typology [1]

Describe: analyze and compare task **sequences** at **multiple levels**, clarify ***means*** and ***ends***

[1] Beaudouin-Lafon (AVI 2004)

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Take-Home Points:
Using the Typology [1]

Describe: analyze and compare task **sequences** at **multiple levels**, clarify ***means*** and ***ends***

Generate: lens for requirements gathering and abstraction in **design studies** [2]

[1] Beaudouin-Lafon (AVI 2004)

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Take-Home Points:
Using the Typology [1]

Describe: analyze and compare task **sequences** at **multiple levels**, clarify ***means*** and ***ends***

Generate: lens for requirements gathering and abstraction in **design studies** [2]

Evaluate: a code set for field studies
+ external validity for lab study tasks

[1] Beaudouin-Lafon (AVI 2004)

[2] Sedlmair, Meyer, & Munzner (TVCG 2012)

A Multi-Level Typology of Abstract Visualization Tasks

cs.ubc.ca/labs/imager/tr/2013/MultiLevelTaskTypology/

Matthew Brehmer
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A Multi-Level Typology of Abstract Visualization Tasks

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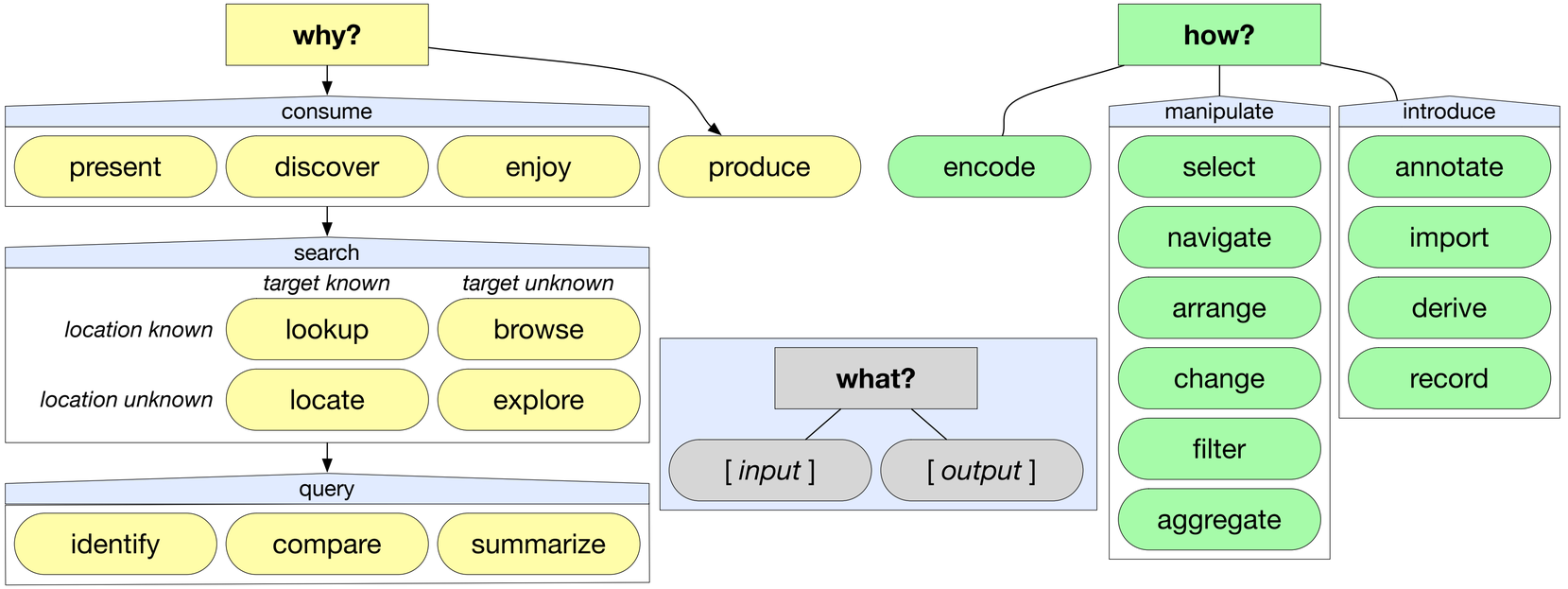


Thanks: Ron Rensink, François Guimbretière, Miriah Meyer, Michael Sedlmair, Colin Ware, Joanna McGrenere, Stephen Ingram, Jessica Dawson, Joel Ferstay

a place of mind
THE UNIVERSITY OF BRITISH COLUMBIA

NSERC CRSNG

Supplemental

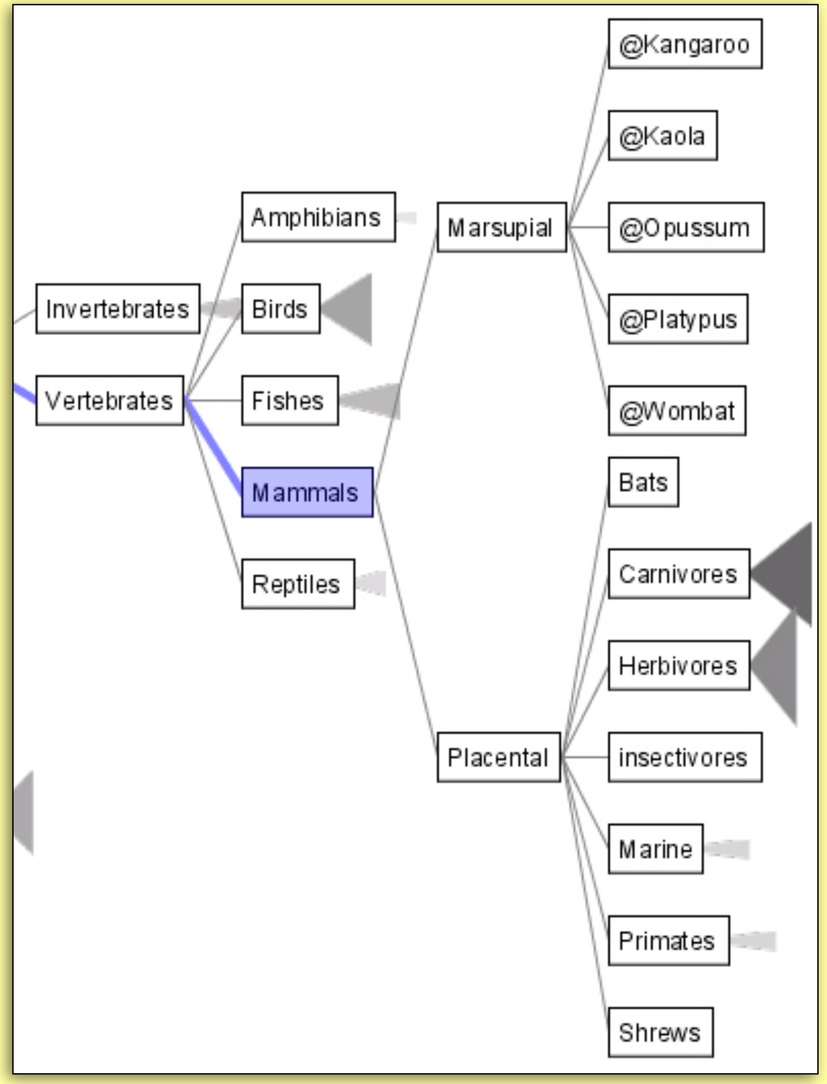
Example:

"presenting a path between nodes"

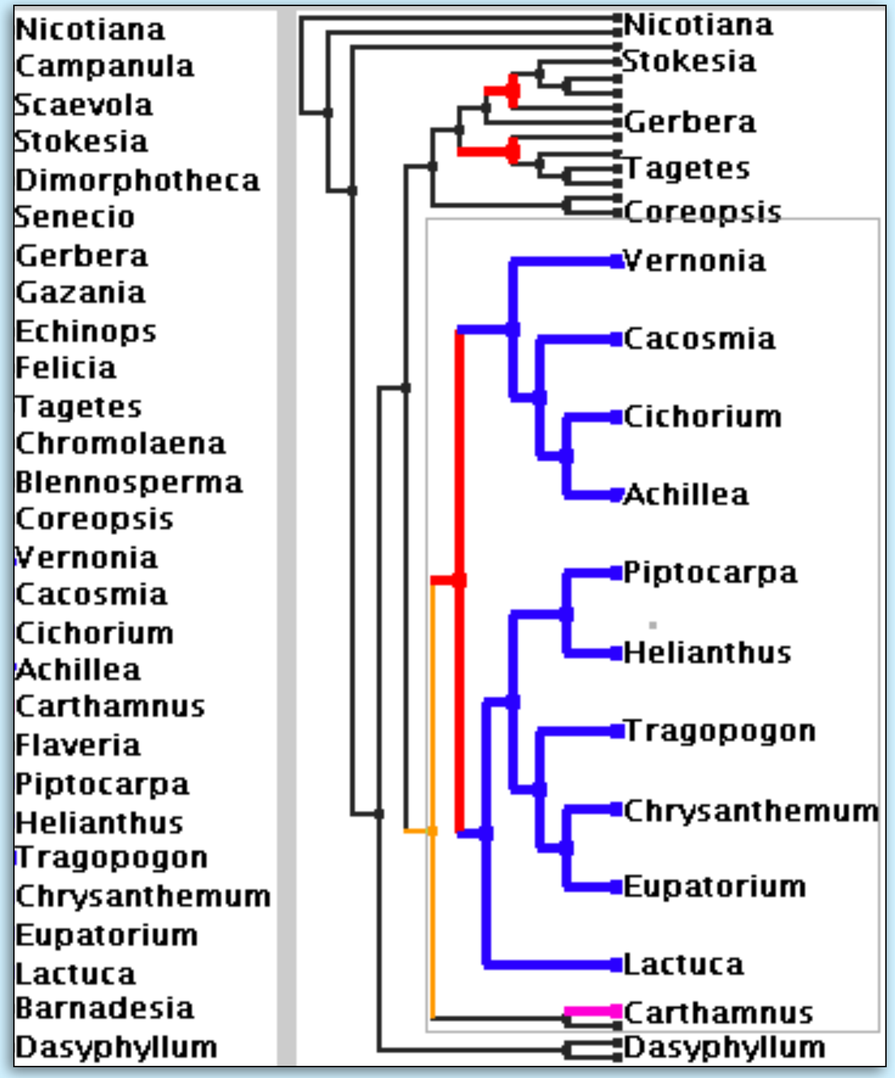
[1] Grosjean et al. (2002)

[2] Munzner et al. (2003)

SpaceTree [1]



TreeJuxtaposer [2]

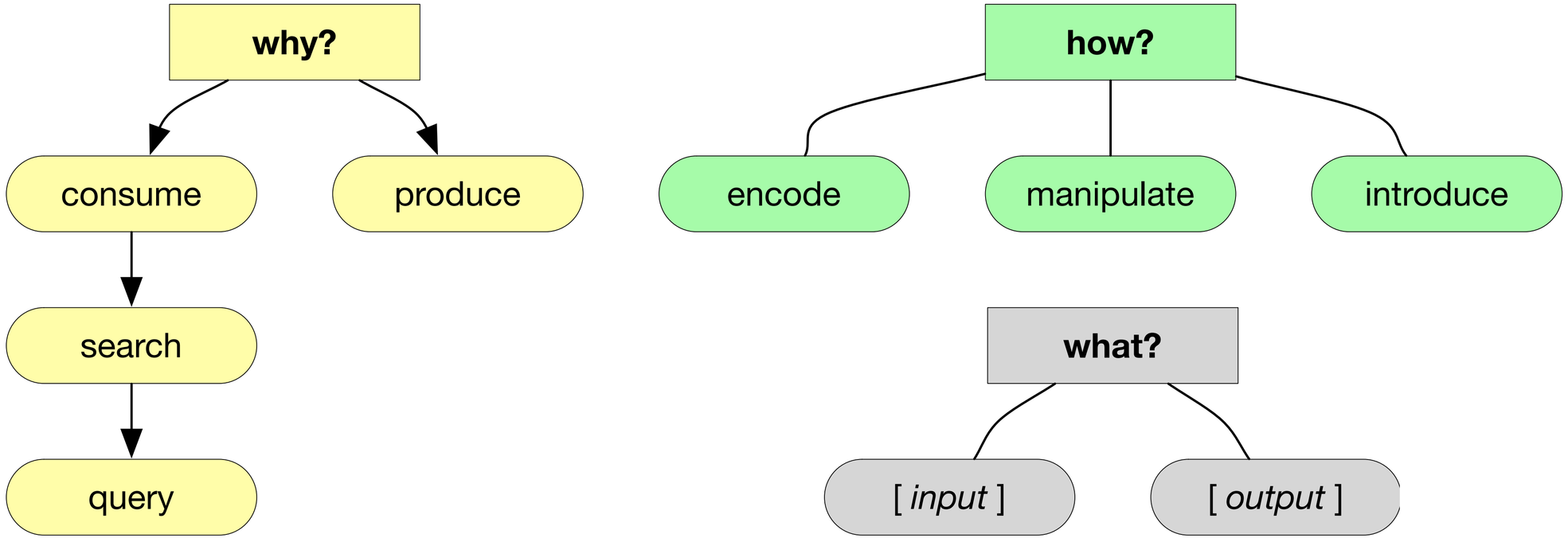


Multi-Level Typology of Abstract Visualization Tasks

{ ***why*** , ***how*** , ***what*** }

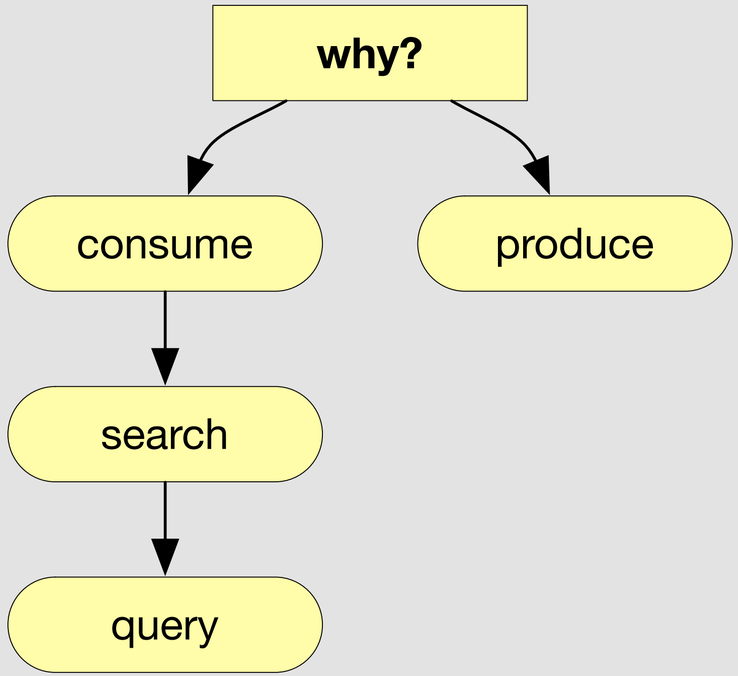
Multi-Level Typology of Abstract Visualization Tasks

{ *why* , *how* , *what* }



Multi-Level Typology of Abstract Visualization Tasks

{ ***why*** , ***how*** , ***what*** }

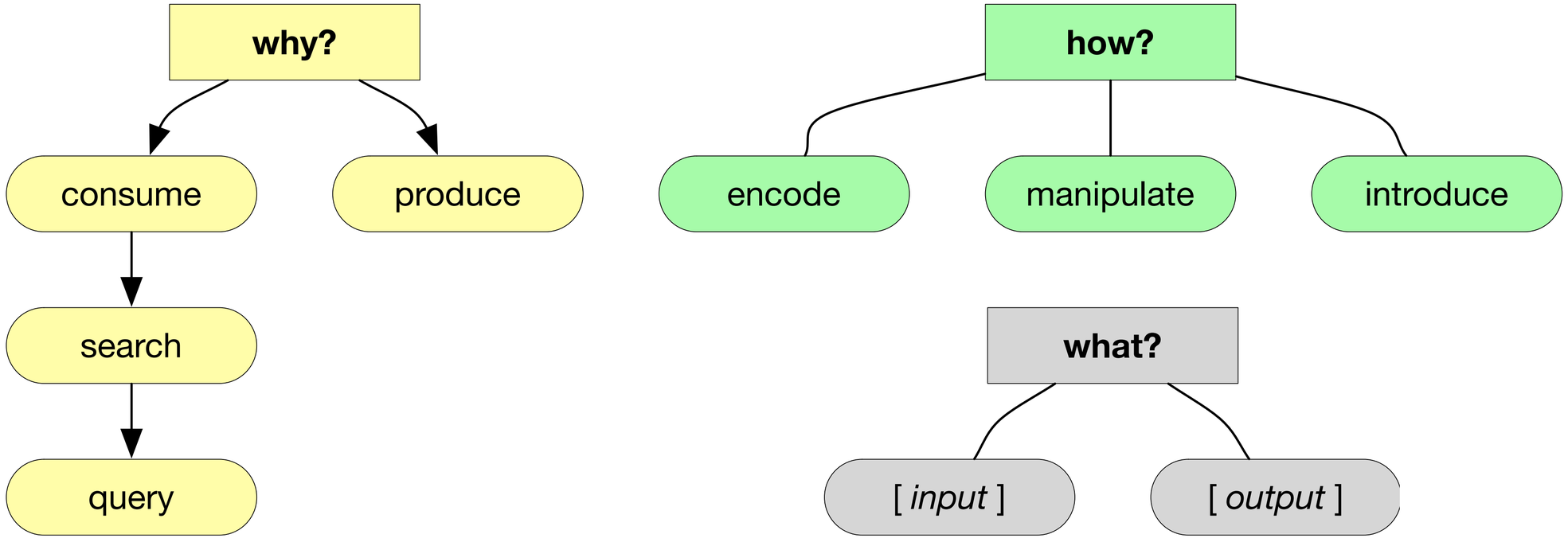


1. Choose either **Consume** or **Produce**

   a. If **Consume**, implies **Search**, **Query**

Multi-Level Typology of Abstract Visualization Tasks

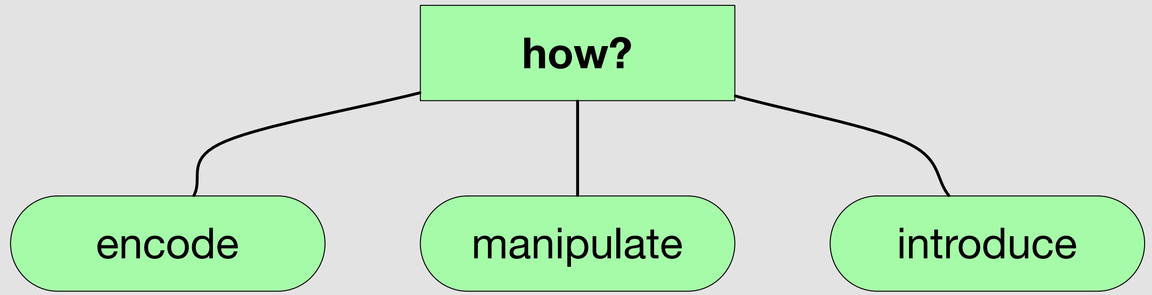
{ ***why*** , ***how*** , ***what*** }

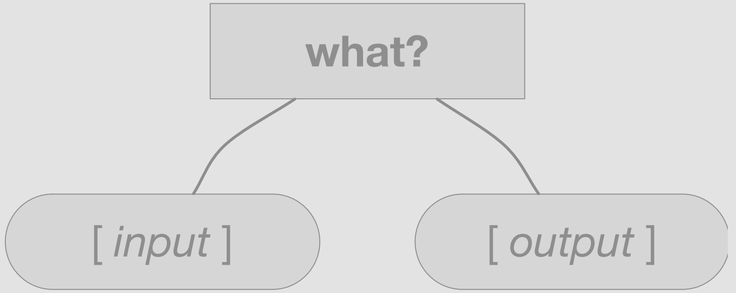


Multi-Level Typology of Abstract Visualization Tasks

{ ***why*** , ***how*** , ***what*** }

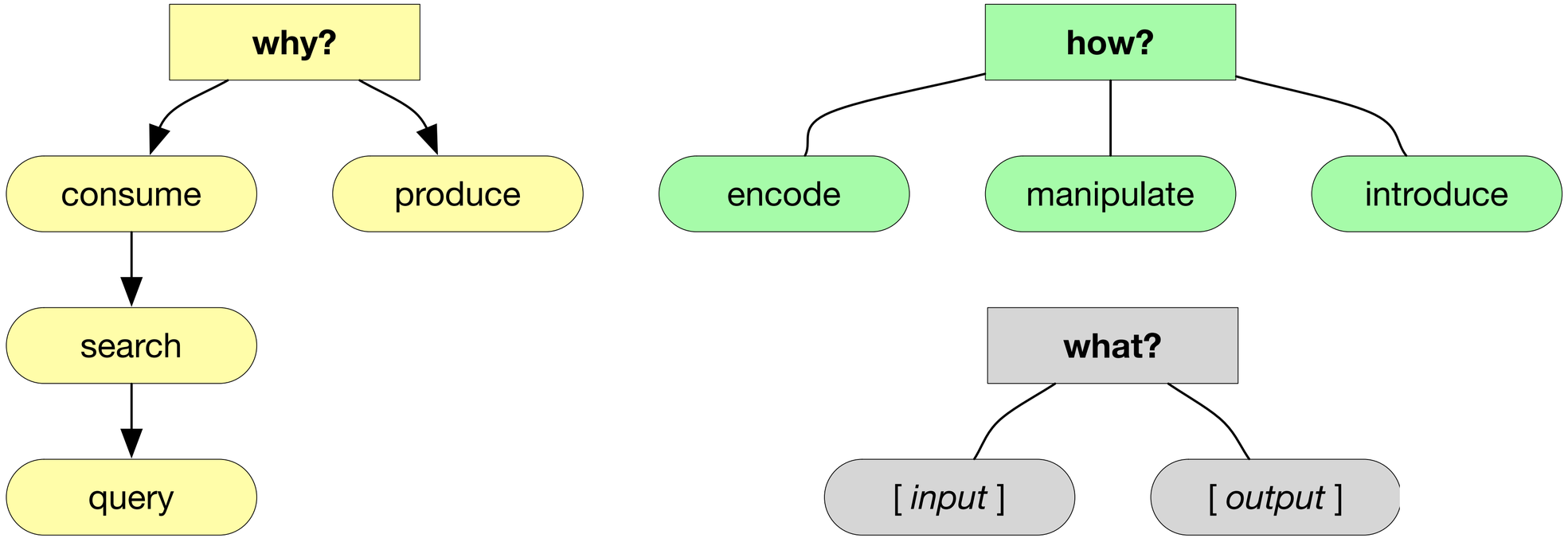
2. Choose a combination:
   Encode and / or
   Manipulate and / or
   Introduce





Multi-Level Typology of Abstract Visualization Tasks

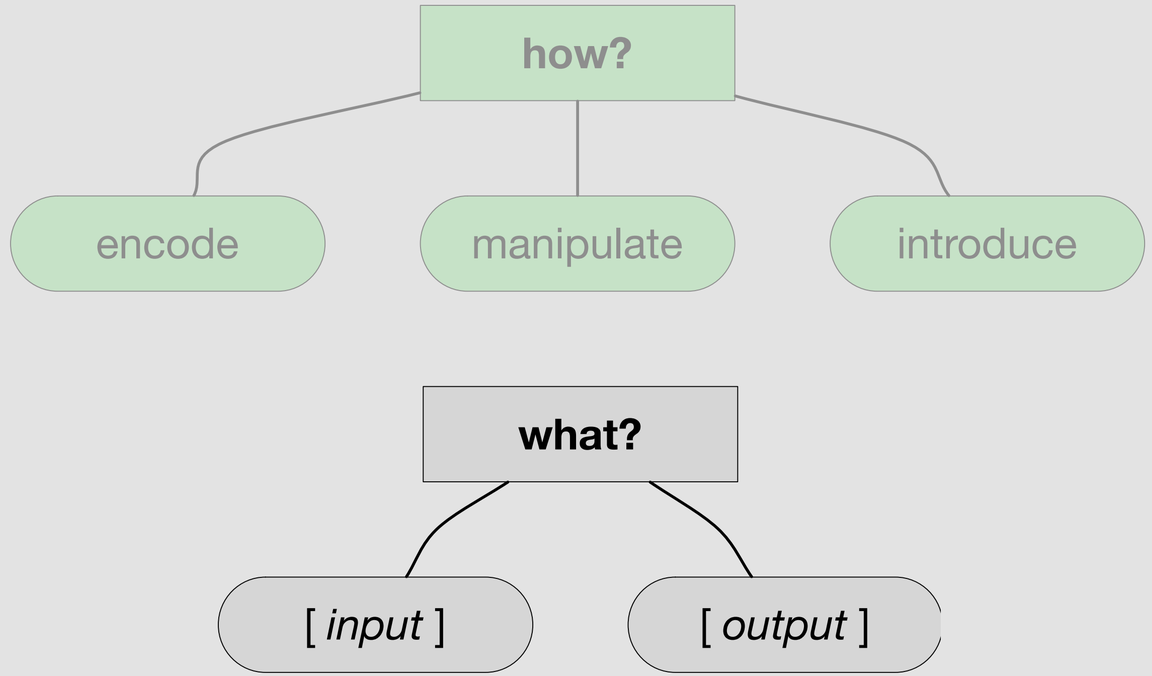
{ ***why*** , ***how*** , ***what*** }



Multi-Level Typology of Abstract Visualization Tasks

{ ***why*** , ***how*** , ***what*** }

3. Fill in:
   Input and
   Output



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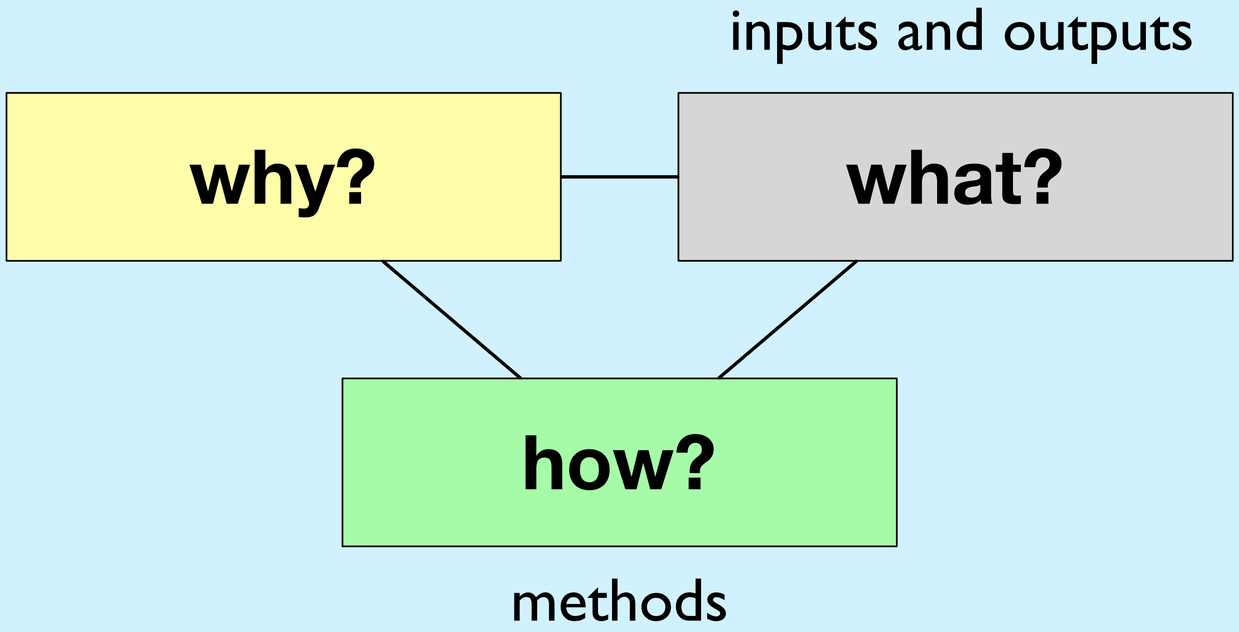

Design Space of Visualization Tasks

Schulz et al. (2013)

Goals

Means

Characteristics

Targets

Cardinality

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Objectives

Operators

Operands

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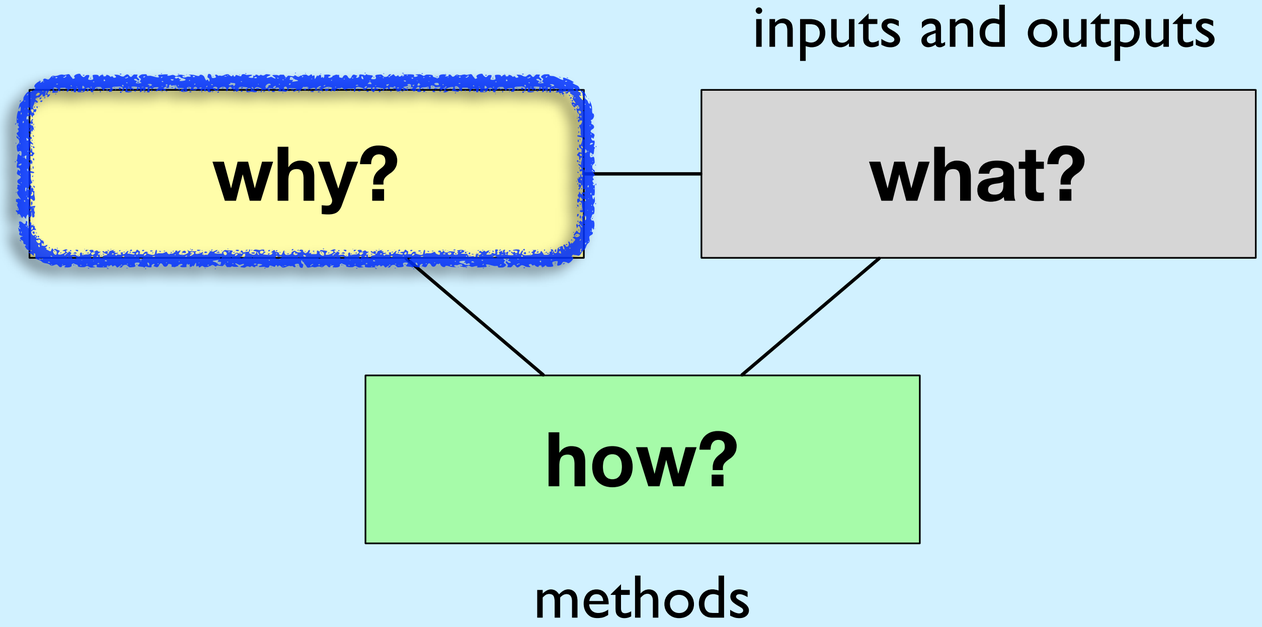

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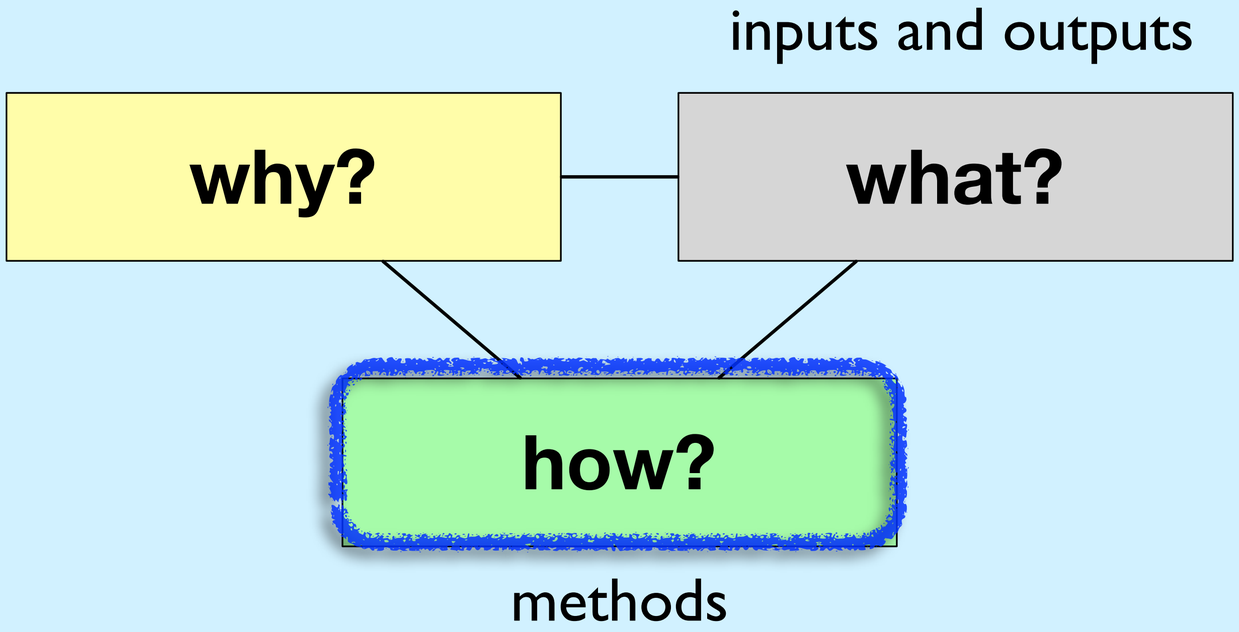

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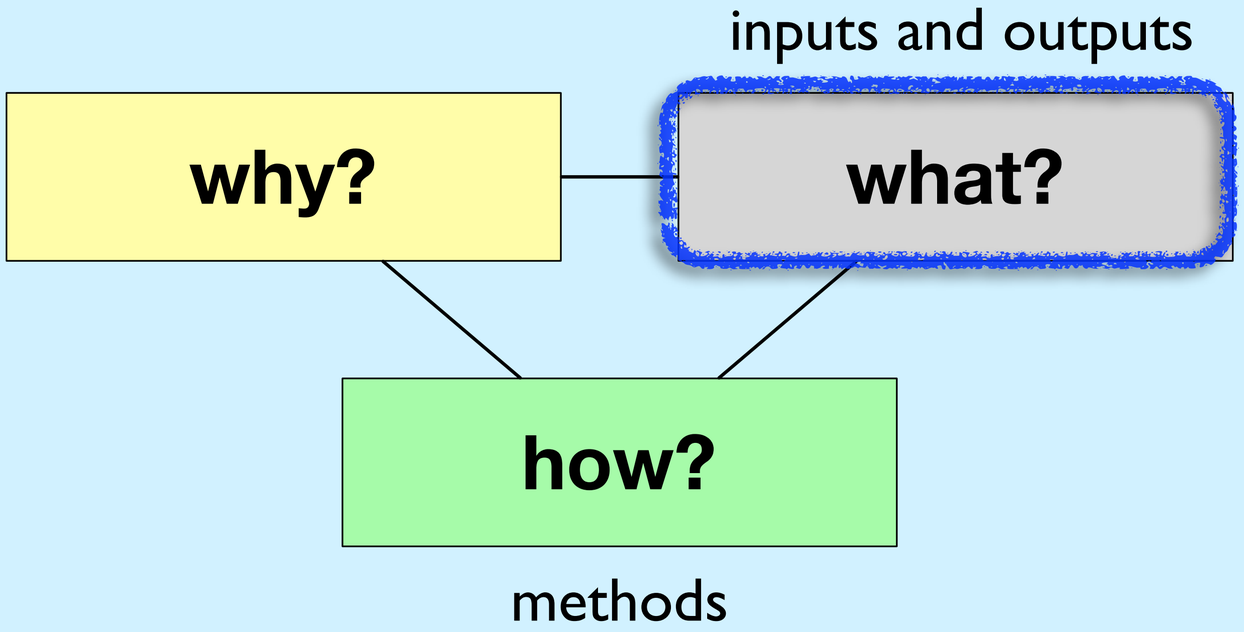

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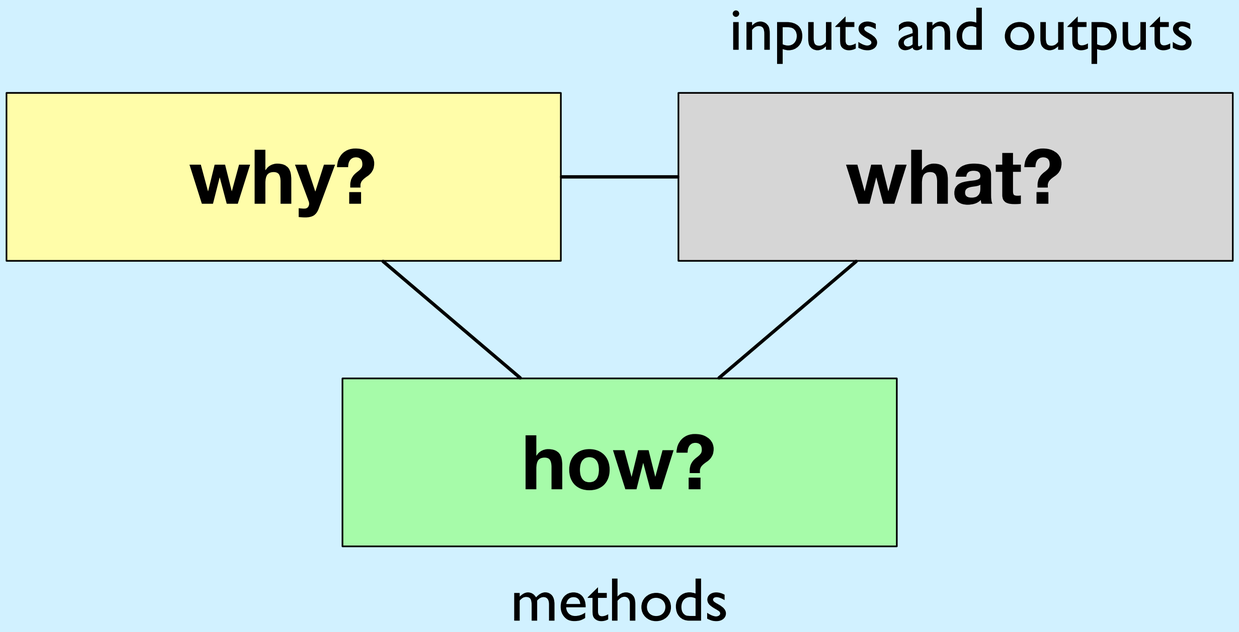

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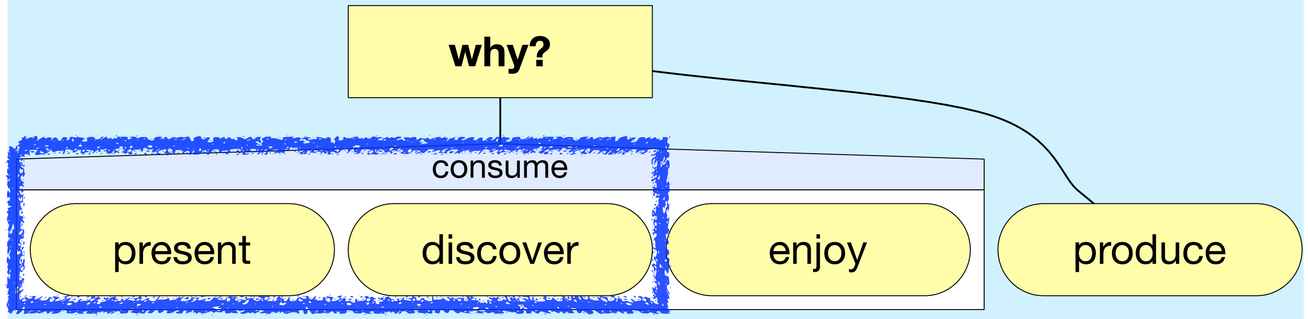

Design Space of Visualization Tasks

Schulz et al. (2013)

Goal

Exploratory Analysis

Confirmatory Analysis

Presentation

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Procure

Predict

Prescribe

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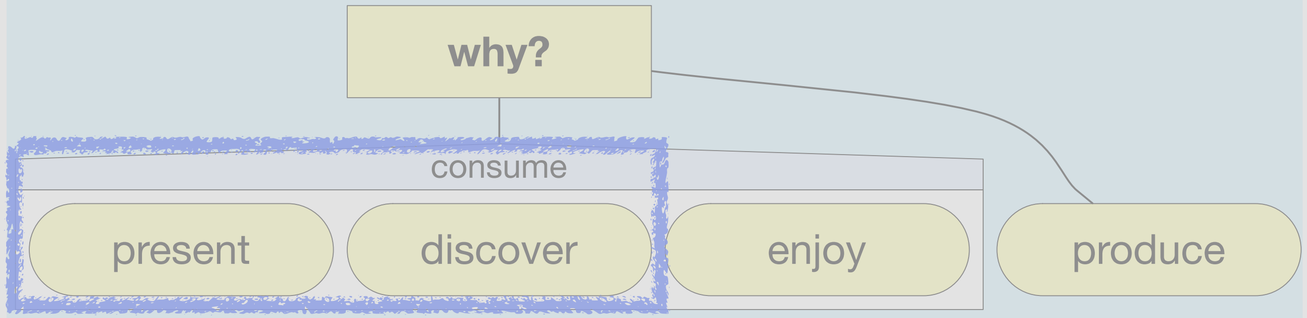

discover
generate / verify

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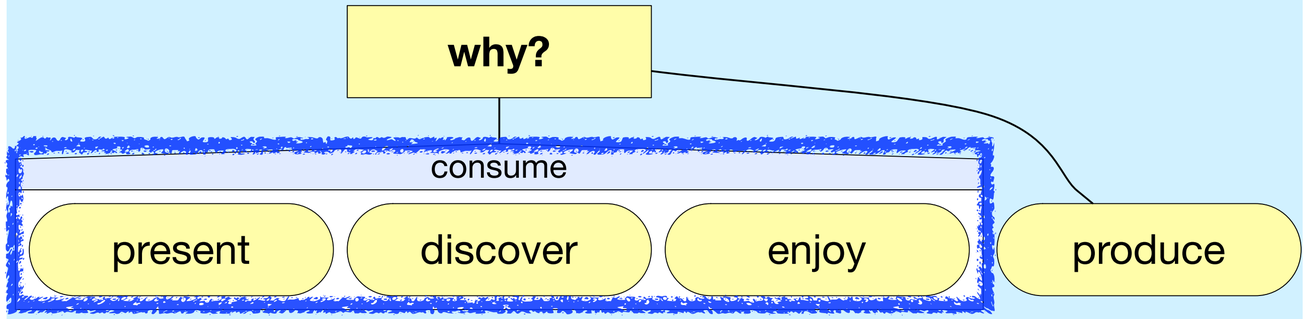

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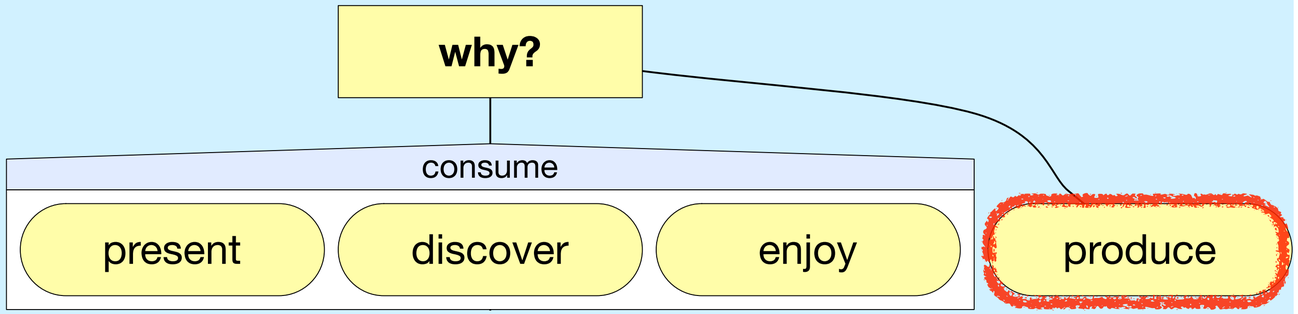

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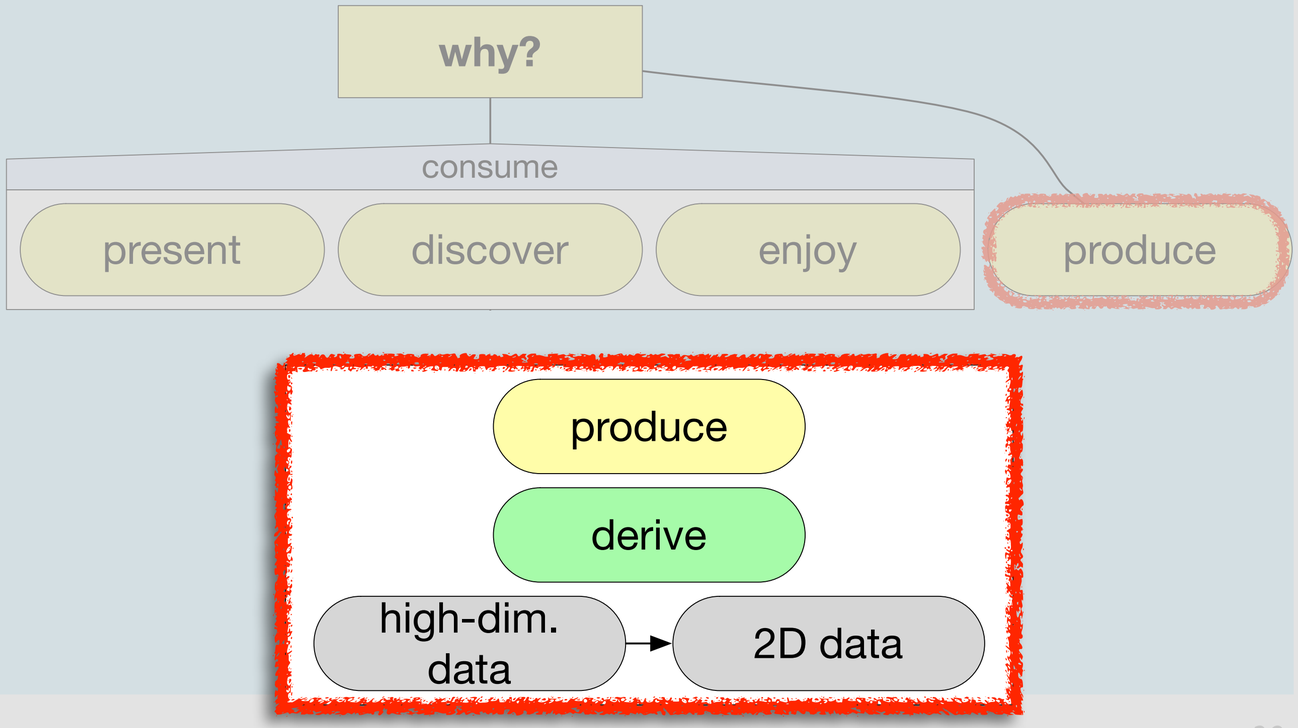

Design Space of Visualization Tasks

Schulz et al. (2013)

Goal

- *Exploratory Analysis*
- *Confirmatory Analysis*
- *Presentation*

Taxonomy of Cartographic Interaction Primitives

Roth (2013)

Goals

- *Procure*
- *Predict*
- *Prescribe*

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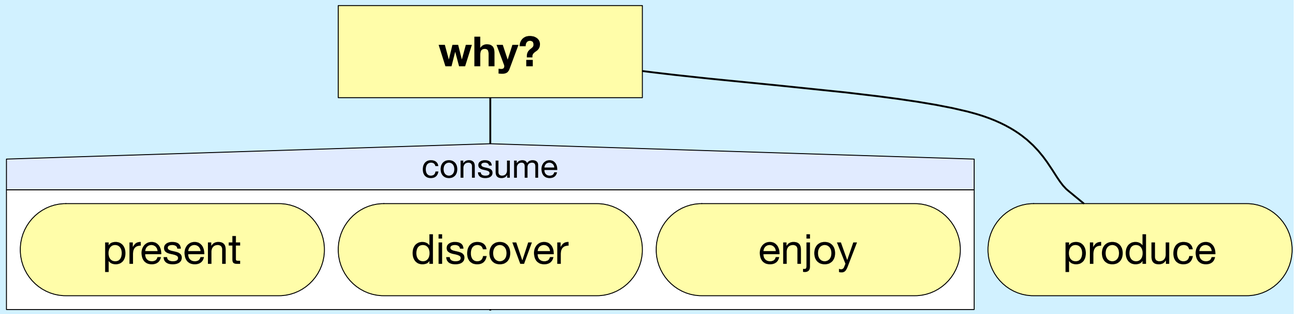

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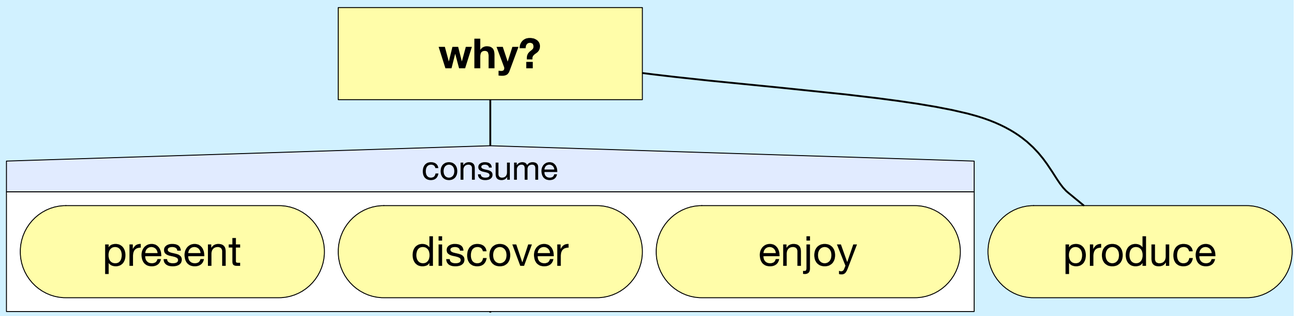
Multi-Level Typology of Abstract Visualization Tasks

Brehmer & Munzner (2013)



Design Space of Visualization Tasks

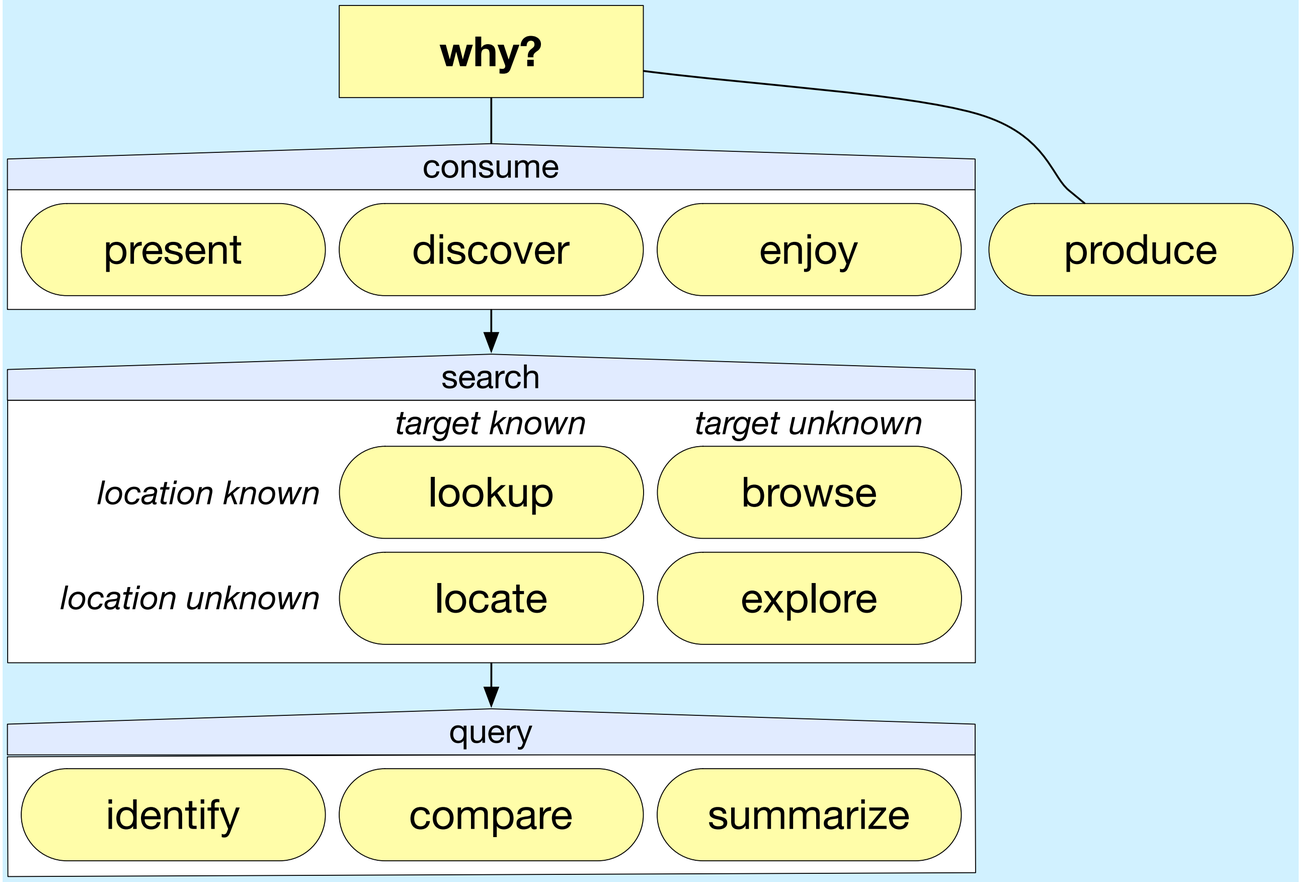
Schulz et al. (2013)

Taxonomy of Cartographic Interaction Primitives

Roth (2013)

Multi-Level Typology of Abstract Visualization Tasks

Brehmer & Munzner (2013)



Design Space of Visualization Tasks

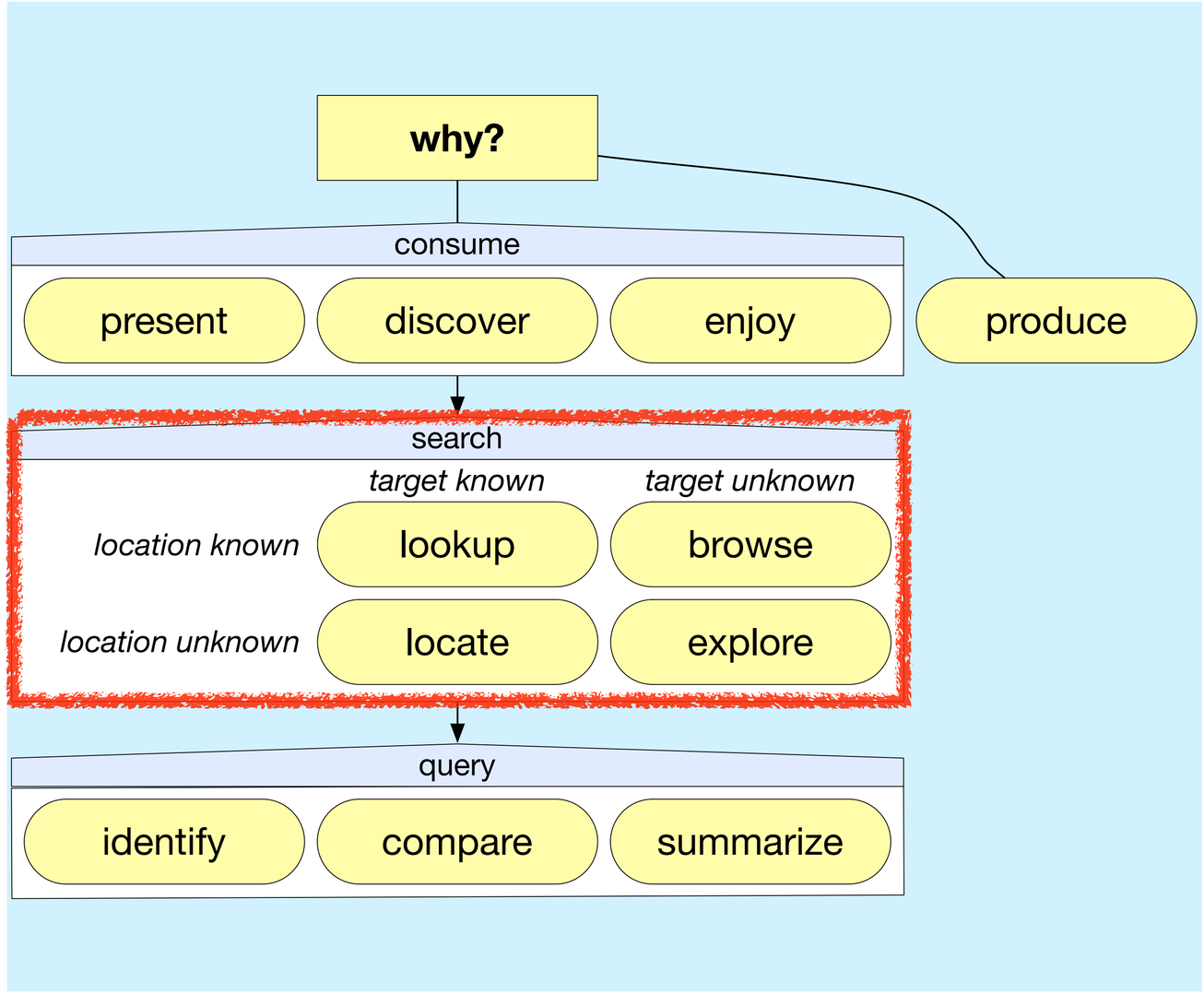
Schulz et al. (2013)

Taxonomy of Cartographic Interaction Primitives

Roth (2013)

Multi-Level Typology of Abstract Visualization Tasks

Brehmer & Munzner (2013)



Design Space of Visualization Tasks

Schulz et al. (2013)

Goal

Directed Search

Undirected Search

Means

Navigation

Taxonomy of Cartographic Interaction Primitives

Roth (2013)

Operators

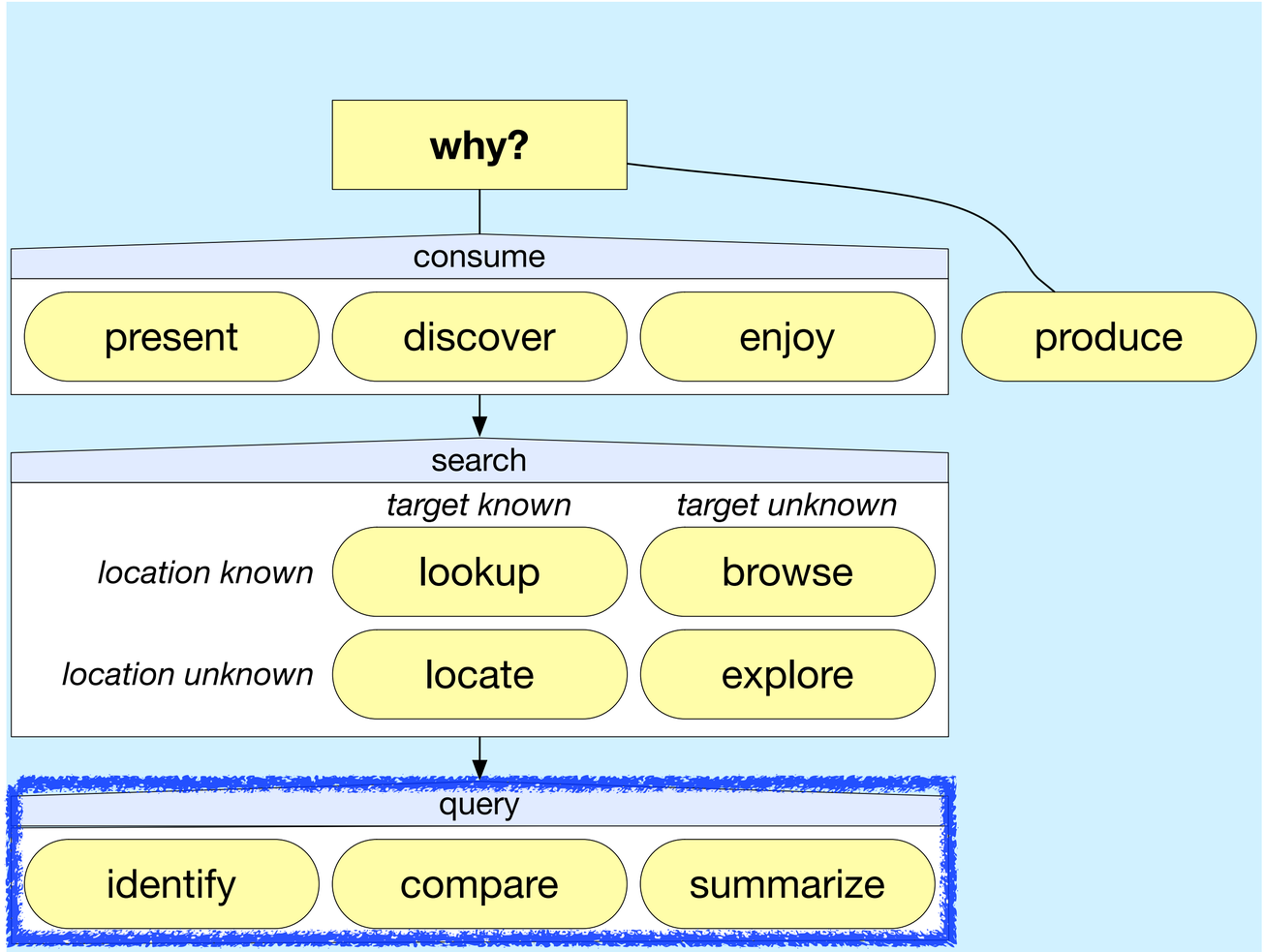
Search

Retrieve

Filter

Multi-Level Typology of Abstract Visualization Tasks

Brehmer & Munzner (2013)



Design Space of Visualization Tasks

Schulz et al. (2013)

Goal

Directed Search

Undirected Search

Means

Navigation

Relation

Cardinality

Single Instance

Multiple Instances

All Instances

Taxonomy of Cartographic Interaction Primitives

Roth (2013)

Operators

Search

Retrieve

Filter

Objectives

Identify

Compare

Associate

Delineate

Multi-Level Typology of Abstract Visualization Tasks

Brehmer & Munzner (2013)

Design Space of Visualization Tasks

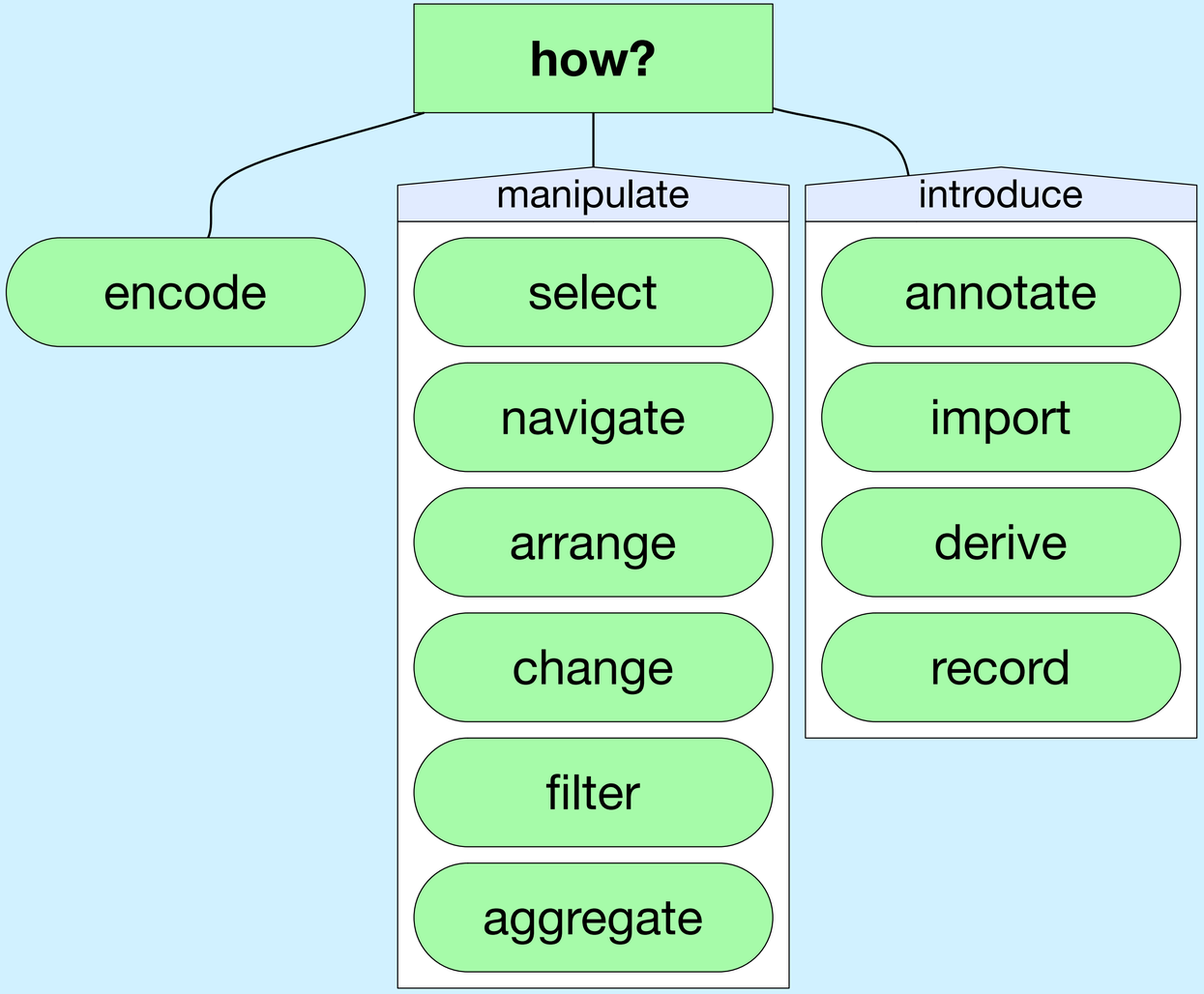
Schulz et al. (2013)

Taxonomy of Cartographic Interaction Primitives

Roth (2013)

Multi-Level Typology of Abstract Visualization Tasks

Brehmer & Munzner (2013)



Design Space of Visualization Tasks

Schulz et al. (2013)

Means

Navigation

(Re)-Organization

- *Extraction*
- *Abstraction*
- *Deriving*
- *Gathering*

(extend as needed)

Meta-Tasks

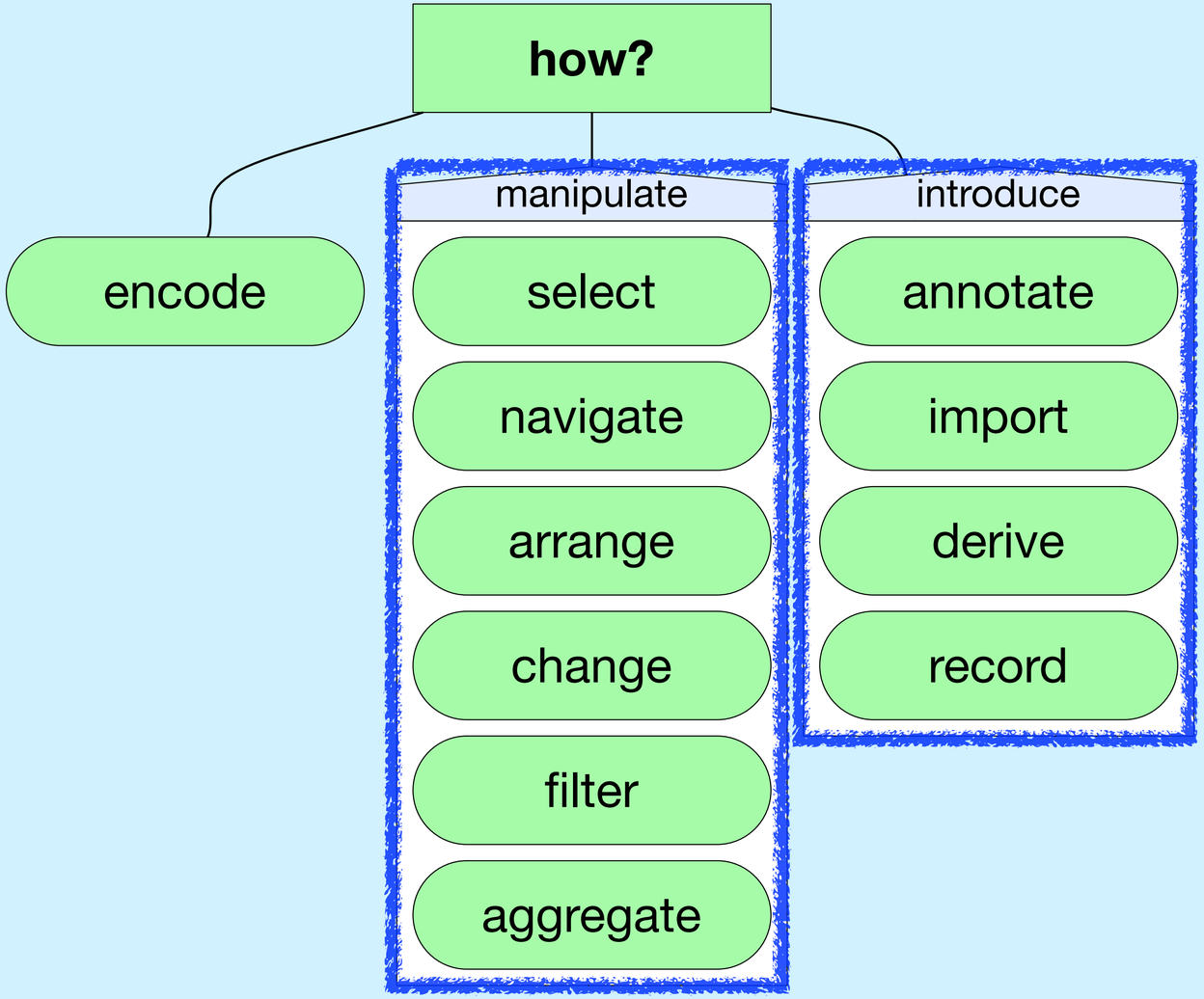
Annotate

Taxonomy of Cartographic Interaction Primitives

Roth (2013)

Multi-Level Typology of Abstract Visualization Tasks

Brehmer & Munzner (2013)



Design Space of Visualization Tasks

Schulz et al. (2013)

Means

Navigation

(Re)-Organization

- *Extraction*
- *Abstraction*
- *Deriving*
- *Gathering*

(extend as needed)

Meta-Tasks

Annotate

Taxonomy of Cartographic Interaction Primitives

Roth (2013)

Enabling Operators

Re-express

Re-symbolize

Re-project

Sequence

Arrange

Overlay

Pan

Zoom

Filter

Calculate

Work Operators

Import

Export

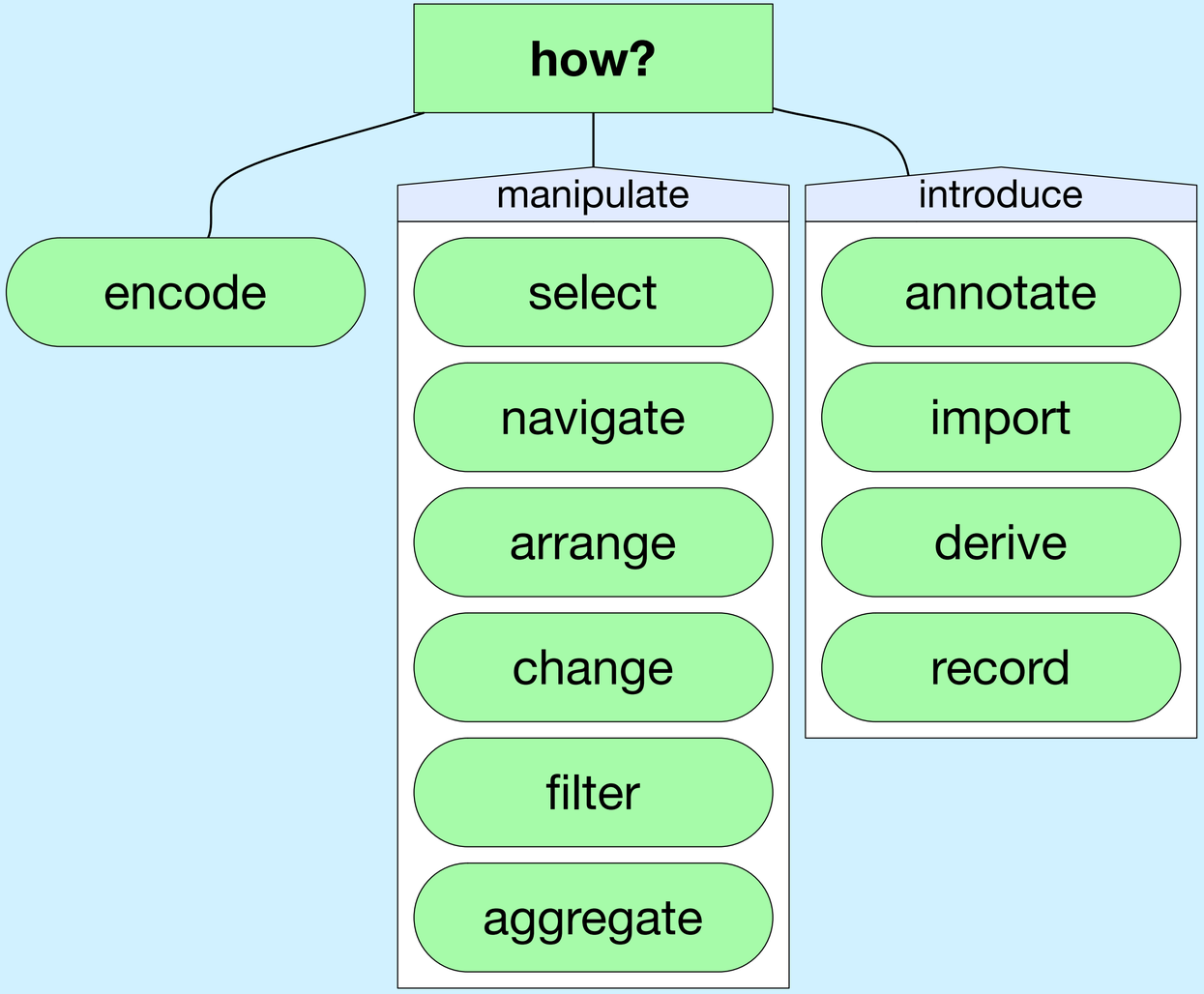
Save

Edit

Annotate

Multi-Level Typology of Abstract Visualization Tasks

Brehmer & Munzner (2013)



Design Space of Visualization Tasks

Schulz et al. (2013)

Means

Navigation

(Re)-Organization

- *Extraction*
- *Abstraction*
- *Deriving*
- *Gathering*

(extend as needed)

Meta-Tasks

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Taxonomy of Cartographic Interaction Primitives

Roth (2013)

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Re-symbolize

Re-project

Sequence

Arrange

Overlay

Pan

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Filter

Calculate

Work Operators

Import

Export

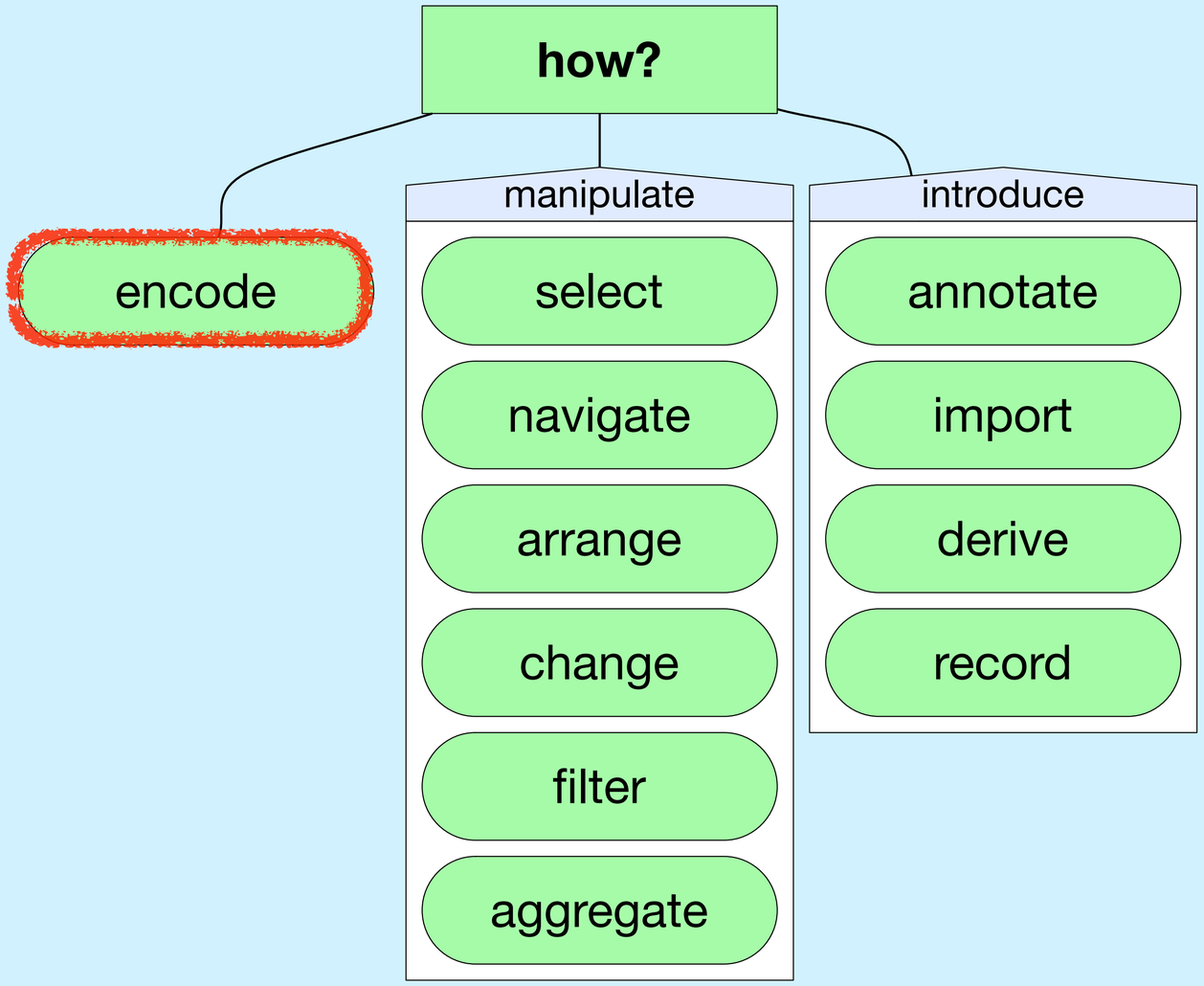
Save

Edit

Annotate

Multi-Level Typology of Abstract Visualization Tasks

Brehmer & Munzner (2013)



Design Space of Visualization Tasks

Schulz et al. (2013)

Means

Navigation

(Re)-Organization

- *Extraction*
- *Abstraction*
- *Deriving*
- *Gathering*

(extend as needed)

Meta-Tasks

Annotate

Taxonomy of Cartographic Interaction Primitives

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Re-symbolize

Re-project

Sequence

Arrange

Overlay

Pan

Zoom

Filter

Calculate

Work Operators

Import

Export

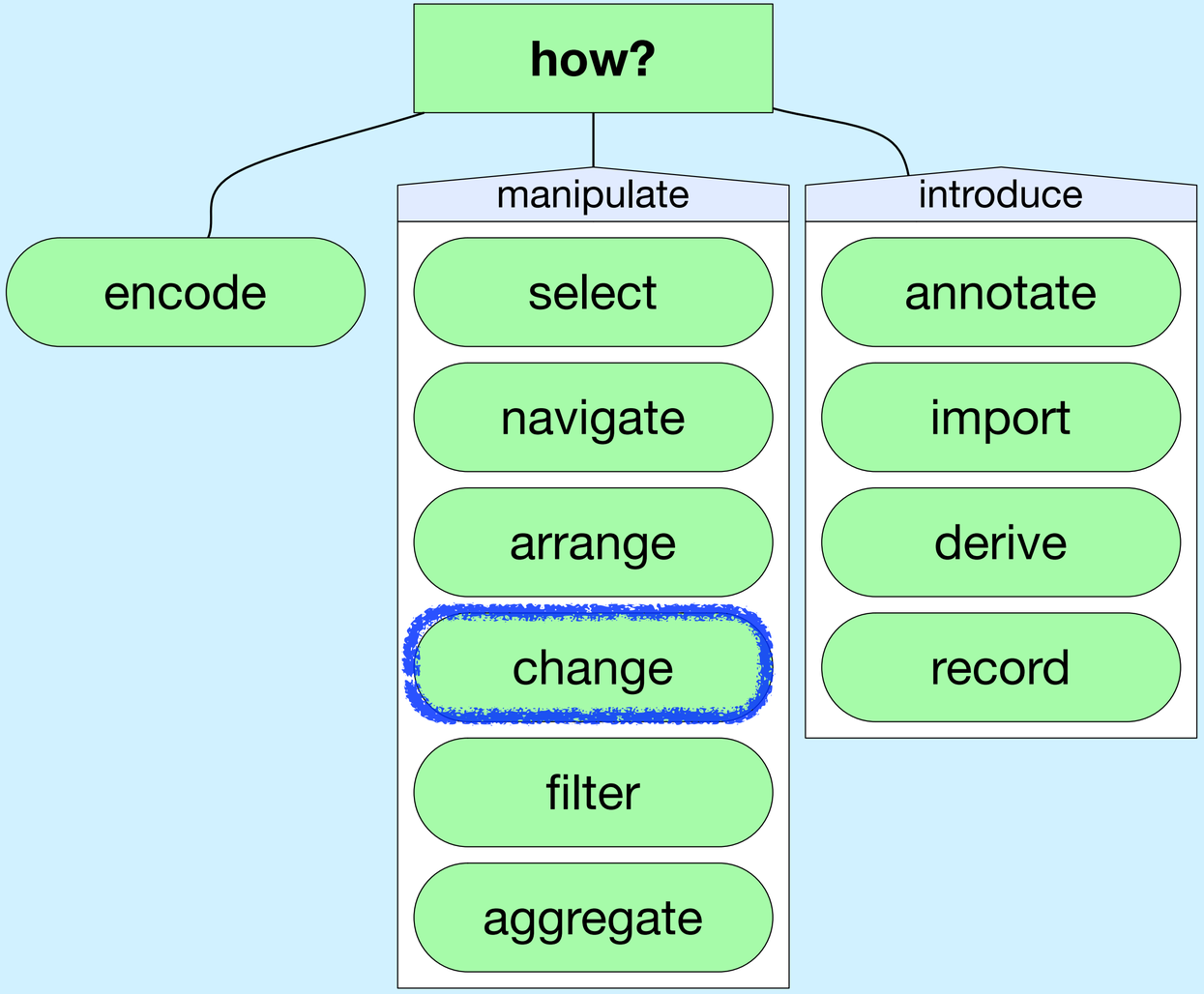
Save

Edit

Annotate

Multi-Level Typology of Abstract Visualization Tasks

Brehmer & Munzner (2013)



Design Space of Visualization Tasks

Schulz et al. (2013)

Means

Navigation

(Re)-Organization

- *Extraction*
- *Abstraction*
- *Deriving*
- *Gathering*

(extend as needed)

Meta-Tasks

Annotate

Taxonomy of Cartographic Interaction Primitives

Roth (2013)

Enabling Operators

Re-express

Re-symbolize

Re-project

Sequence

Arrange

Overlay

Pan

Zoom

Filter

Calculate

Work Operators

Import

Export

Save

Edit

Annotate

Multi-Level Typology of Abstract Visualization Tasks

Brehmer & Munzner (2013)

encode

select

navigate

arrange

change

filter

aggregate

annotate

import

derive

record

Design Space of Visualization Tasks

Schulz et al. (2013)

(Re)-Organization

- Ext
- Abs
- Der
- Gat

(extenc

Meta-

Annotate

Taxonomy of Cartographic Interaction Primitives

Roth (2013)

Zoom

Filter

Calculate

rs

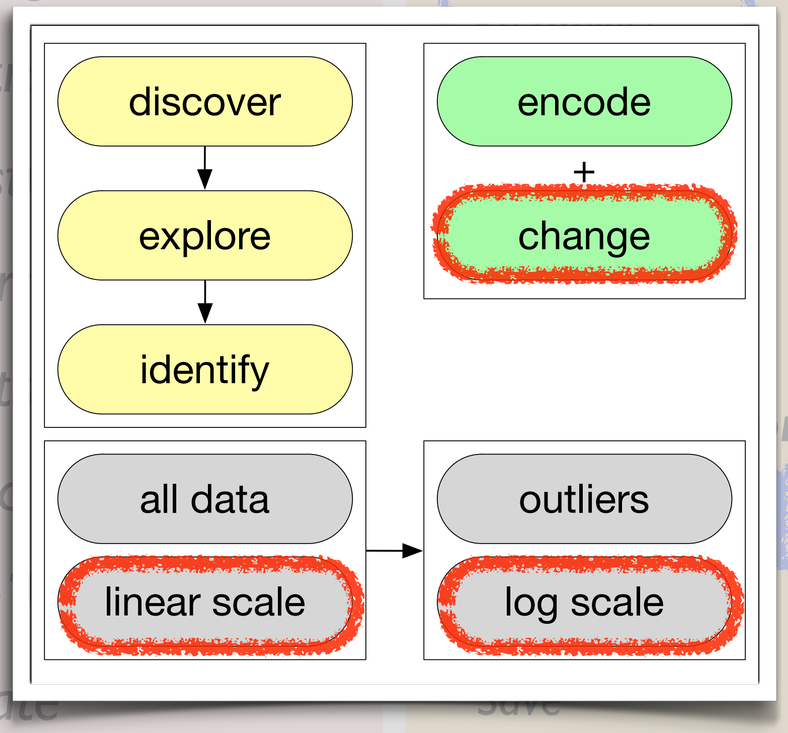
Edit

Annotate

save

→ change

change (parameters) [15]* [13], *change (metaphor)* [19]*, *change (representation)* [15]*, *change (vis. encoding)* [44], *transform* [56]*[40, 80], *transform (mapping), shift, scale, set (graphical value)* [14]*, *rotate, scale* [13], *configure* [73]*, *animate* [13, 80], *distort* [29, 75]* [13], *orient / transform* [66]*, *(object) manipulation: transform, stretch, shape* [42]*, *re-express*, *re-symbolize*, *re-project* [57]*, *edit* [42, 57]*, *activate* [56]*



Multi-Level Typology of Abstract Visualization Tasks

Brehmer & Munzner (2013) [1]

1. **Amar, Eagan, Stasko (2005)**
2. **Amar, Stasko (2004)**
3. **Andrienko, Andrienko (2006)**
4. **Buja, Cook, Swayne (1996)**
5. **Card, Mackinlay, Shneiderman (1999)**
6. **Casner (1991)**
7. **Chi, Riedl (1998)**
8. **Chuah, Roth (1996)**
9. **Dix, Ellis (1998)**
10. **Gotz, Zhou (2008)**
11. **Heer, Shneiderman (2012)**
12. **Keim (2002)**
13. **Klein, Moon, Hoffman (2006)**
14. **Lee, Plaisant, Parr, Fekete, Henry (2006)**
15. **Liu, Stasko (2010)**
16. **Mullins, Treu (1993)**
17. **Pike, Stasko, Chang, O'Connell (2009)**
18. **Pirolli, Card (2005)**
19. **Raskin (2000)**
20. **Roth (2012/2013)**
21. **Roth, Mattis (1990)**
22. **Shneiderman (1996)**
23. **Spence (2007)**
24. **Springmeyer, Blattner, Max (1992)**
25. **Tweedie (1997)**
26. **Valiati, Pimenta, Freitas (2006)**
27. **Ward, Yang (2004)**
28. **Wehrend, Lewis (1990)**
29. **Yi, Kang, Stasko, Jacko (2007)**
30. **Zhou, Feiner (1998)**

1. **Aigner, Miksch, Schumann, Tominski (2011)**
2. **Andre, Teevan, Dumais (2009)**
3. **Dörk, Carpendale, Williamson (2011)**
4. **Dörk, Riche, Ramos, Dumais (2012)**
5. **Friel, Curcio, Bright (2001)**
6. **Kandel, Paepcke, Hellerstein, Heer (2012)**
7. **Marchionini (2006)**
8. **Munzner (2009)**
9. **Plaisant, Carr, Shneiderman (1995)**
10. **Pousman, Stasko, Mateas (2007)**
11. **Roth (2012)**
12. **Shrinivasan, van Wijk (2008)**
13. **Sprague, Tory (2012)**
14. **Stephenson (1967)**
15. **Toms (2000)**
16. **Tory, Möller (2004)**
17. **Tukey (1977)**
18. **Ware (2012)**
19. **van Wijk (2006)**
20. **Wilkinson (2005)**

1. **Kirsh, Maglio (1994)**
2. **Lam (2008)**
3. **Liu, Nersessian, Stasko (2008)**
4. **Norman (1988)**
5. **Thomas, Cook (2005)**

[1] References from §5
[2] References from §2 † = §2.1 on classification systems
[3] References from §2:
OBJ = objective, OPR = operator, ORD = operand

7 references cited by all 3
12 references in common with Schulz et al., 22 cited by Schulz et al., not by us
12 references in common with Roth + Roth (2012/2013), 19 cited by Roth, not by us
8 References in common between Schulz et al. and Roth, **1 of these** not cited by us
23 references cited only by us

Design Space of Visualization Tasks

Schulz et al. (2013) [2]

1. Ahn, Plaisant, Shneiderman (2012)
2. **Aigner, Miksch, Schumann, Tominski (2011)**
3. **Amar, Eagan, Stasko (2005)** †
4. **Amar, Stasko (2004, 2005)** †
5. **Andrienko, Andrienko (2006)** †
6. Becks, Seeling (2001) †
7. Belkin, Cool, Stein, Thiel (1995) †
8. Beshers, Feiner (1993) †
9. Blackwell, Engelhardt (2002) †
10. Bugajska (2005) †
11. Card, Mackinlay (1997)
12. **Casner (1991)** †
13. **Chi (2000)**
14. **Chuah, Roth (1996)**
15. Engelhardt (2002)
16. Fujishiro, Furuhata, Ichikawa, Takeshima (2000) †
17. **Gotz, Zhiou (2008)** †
18. **Heer, Shneiderman (2012)** †
19. Hibino (1999) †
20. Ignatius, Senay, Favre (1994) †
21. Keller, Keller (1993)
22. Kosara, Hauser, Gresh (2003)
23. **Lee, Plaisant, Parr, Fekete, Henry (2006)** †
24. Morse, Lewis, Olson (2000)
25. Nazemi, Breyer, Kuijper (2011)
26. Nocke, Schumann (2004) †
27. Pfistzner, Hobbs, Powers (2003) †
28. **Pirolli, Card (2005)** †
29. **Roth, Mattis (1990)**
30. **Shneiderman (1996)** †
31. **Springmeyer, Blattner, Max (1992)** †
32. Stary (2000) †
33. Streit, Schulz, Lex, Schmalsteig, Schumann (2012) †
34. **Tory, Möller (2004)**
35. Tweedie (1995)
36. **Tweedie (1997)**
37. **Valiaiti, Pimenta, Freitas (2006)**
38. von Landesberger, Feibig, Bremm, Kuijper, Fellner (2013)
39. **Wehrend, Lewis (1990)** †
40. **Yi, Kang, Stasko, Jacko (2007)**
41. **Zhou, Feiner (1998)**

Taxonomy of Cartographic Interaction Primitives

Roth (2013) [3]

1. **Amar, Eagan, Stasko (2005)** [OBJ]
2. Andrienko, Andrienko, Gatalsky (2003) [OBJ, ORD]
3. Arnheim (1969)
4. Becker, Cleveland (1987) [OPR]
5. Blok (2000) [OBJ]
6. Blok, Kobben, Cheng, Kuterema (1999) [OBJ]
7. **Buja, Cook, Swayne (1996)** [OPR]
8. **Card, Mackinlay, Shneiderman (1999)**
9. **Chi (2000)** [ORD]
10. **Chi, Riedl (1998)** [ORD]
11. **Chuah, Roth (1996)** [OP]
12. Crampton (2002) [OBJ, OD]
13. DiBiase (1990)
14. **Dix, Ellis (1998)** [OPR]
15. Dou, Ziemciewicz, Harrison, Jeong, Ryan, Ribarsky, Wang, Chang (2010)
16. Dykes (1997) [OPR]
17. Edsall, Andrienko, Andrienko, Buttenfield (2008) [OPR]
18. Haber, McNabb (1990) [ORD]
19. Hutchins (1995)
20. **Keim (2002)** [OPR ORD]
21. MachEachren, Wachowicz, Edsall, Haug, Masters (1999) [OBJ, OPR]
22. Masters, Edsall (2000) [OPR]
23. **Norman (1988)**
24. Peuquet (1994) [ORD]
25. **Pike, Stasko, Chang, O'Connell (2009)**
26. **Pirolli, Card, (2005)**
27. **Roth (2012)**
28. Shepherd (1995) [OPR]
29. **Shneiderman (1996)** [OPR, ORD]
30. **Thomas, Cook (2005)**
31. **Tukey (1977)**
32. **Ward, Yang (2004)** [OPR, ORD]
33. **Ware (2004)**
34. **Wehrend, Lewis (1990)** [OBJ]
35. Wehrend (1993) [OBJ, ORD]
36. Whitefield, Escgate, Denley, Byerley (1993)
37. **Yi, Kang, Stasko, Jacko (2007)** [OBJ]
38. **Zhou, Feiner (1998)** [OBJ]

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