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Perceptual Issues in Dynamic Graph Drawing:

Animation, Small Multiples and Drawing Stability

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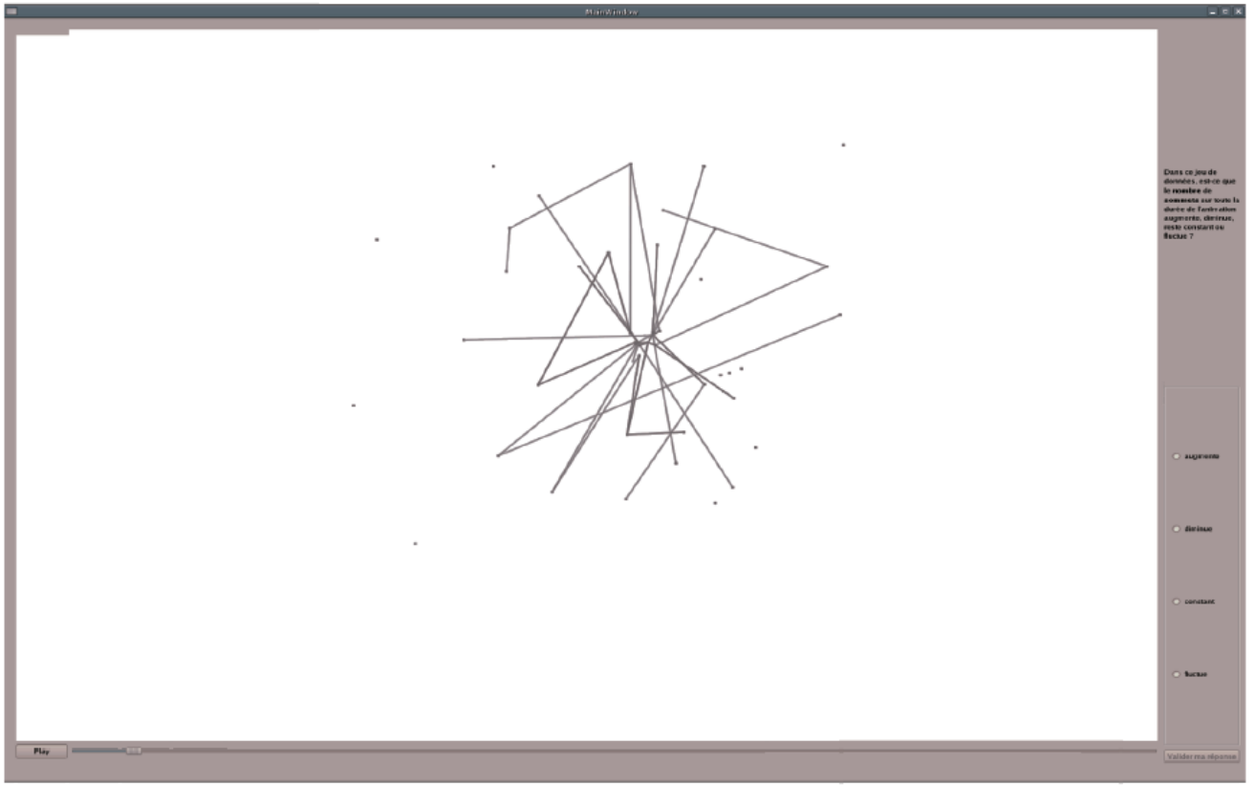
Outline

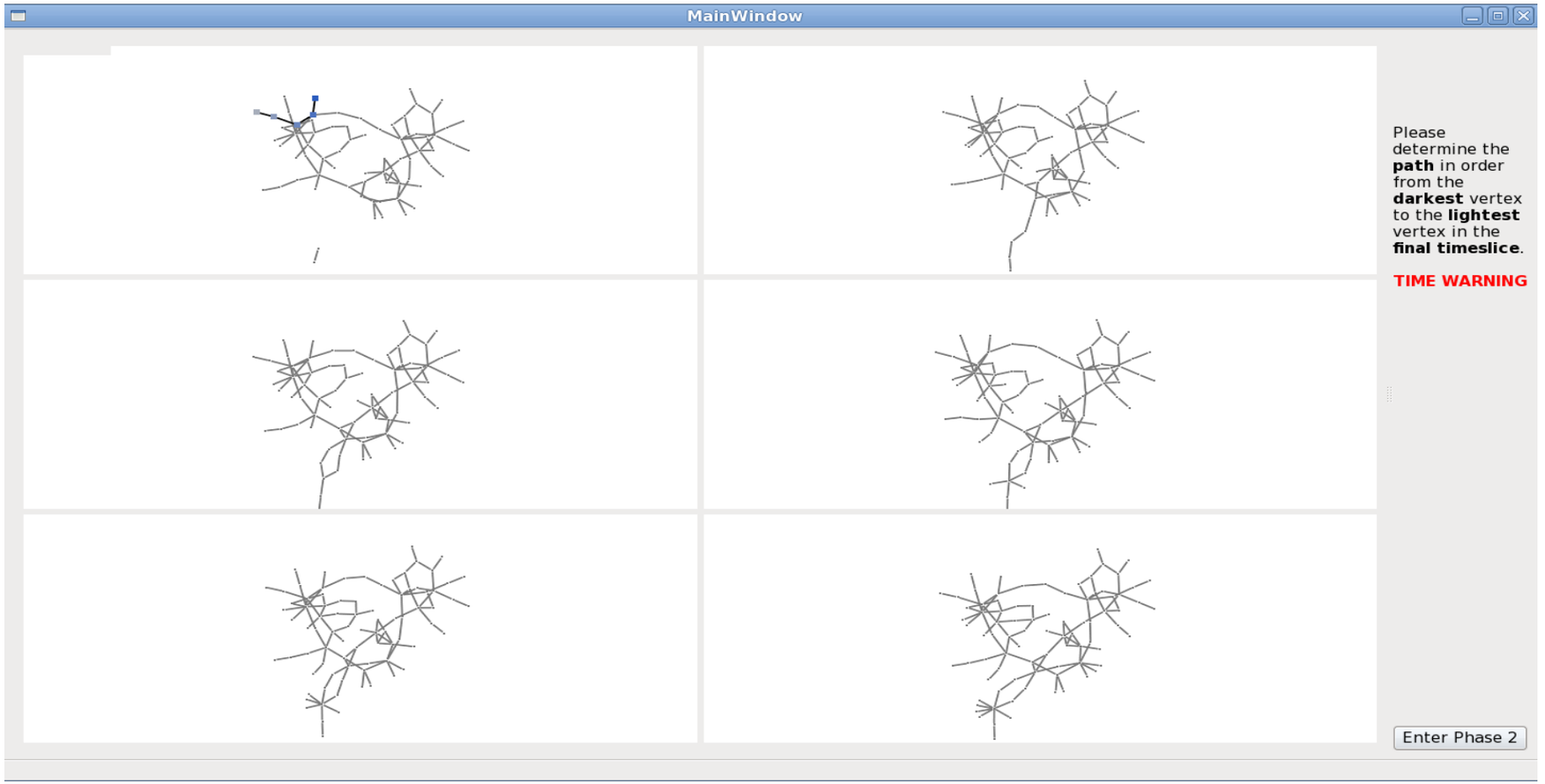
- Introduction and Definitions
- Experiments
  - Animation, Small Multiples, and the Mental Map
  - Memorability
  - Orientation and the Mental Map
- Conclusions
- Follow on Studies

What are Dynamic Graphs?



- Graph that evolves over time
- Snapshot of graph at a given time is a **timeslice**
- Quite frequently shown as an **animation** in graph drawing

What is small multiples?



- Each timeslice in its own window and scan windows for evolution
- Less prevalent for dynamic graph drawing

What is the mental map?

- Drawing stability is important
  - First definition Misue, Eades, Lai, and Sugiyama (1991,1995)

    placement of existing nodes and edges should change as little as possible when a change is made to the graph – Colman & Parker (1996)

- Many undirected dynamic graph drawing algorithms use this definition for the mental map
- No mental map -- each timeslice independent

Focus of Talk

- Experiments that provide evidence for:
  - When to use animation?
  - When to use small multiples?
  - When is drawing stability useful?

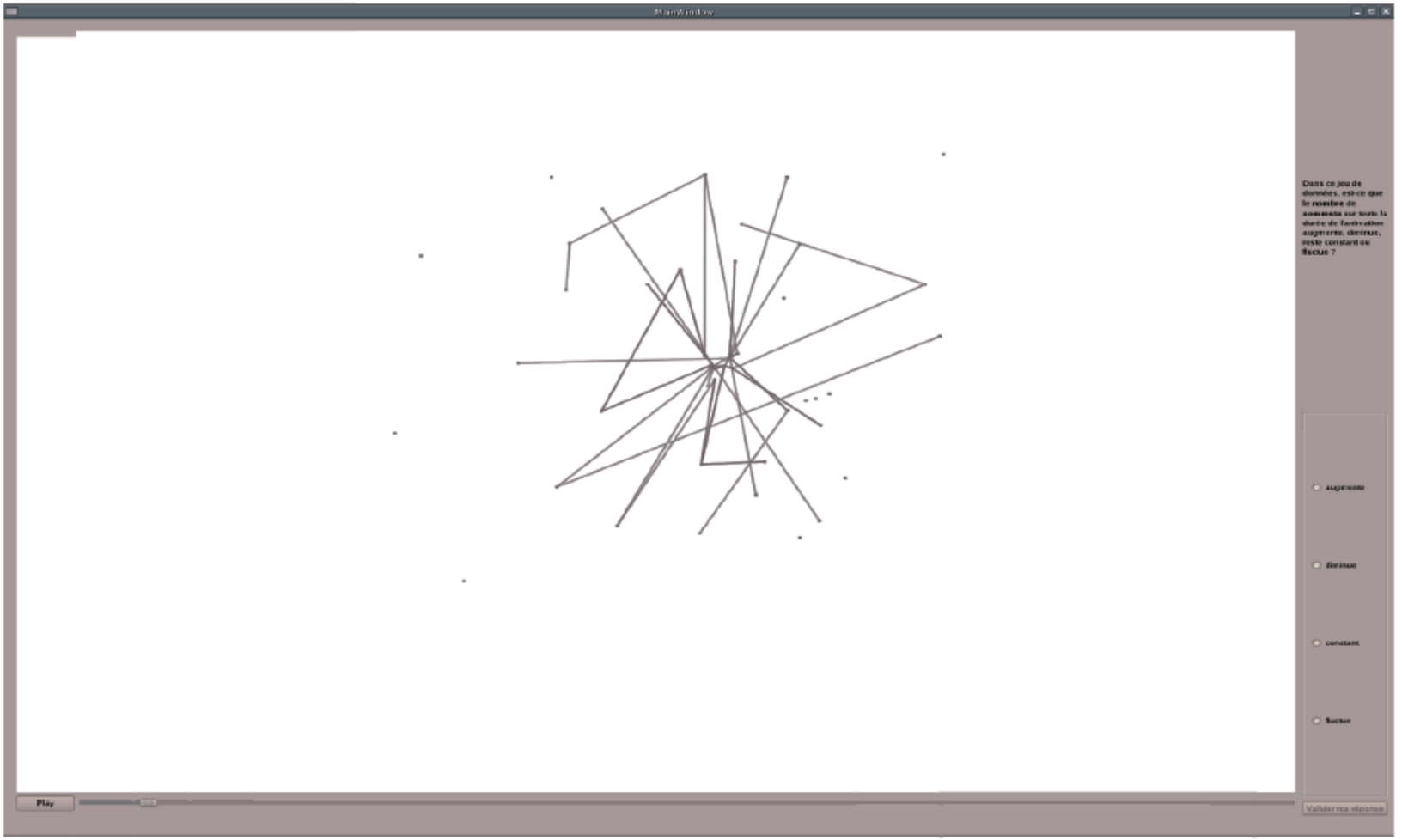
- Context of these experiments
  - Undirected graphs
  - Nodes/edges inserted and removed

First Experiment

- Small multiples, on many types of data, has been shown to be more effective in information visualisation
- What about dynamic graphs?
- Does the mental map influence the results?

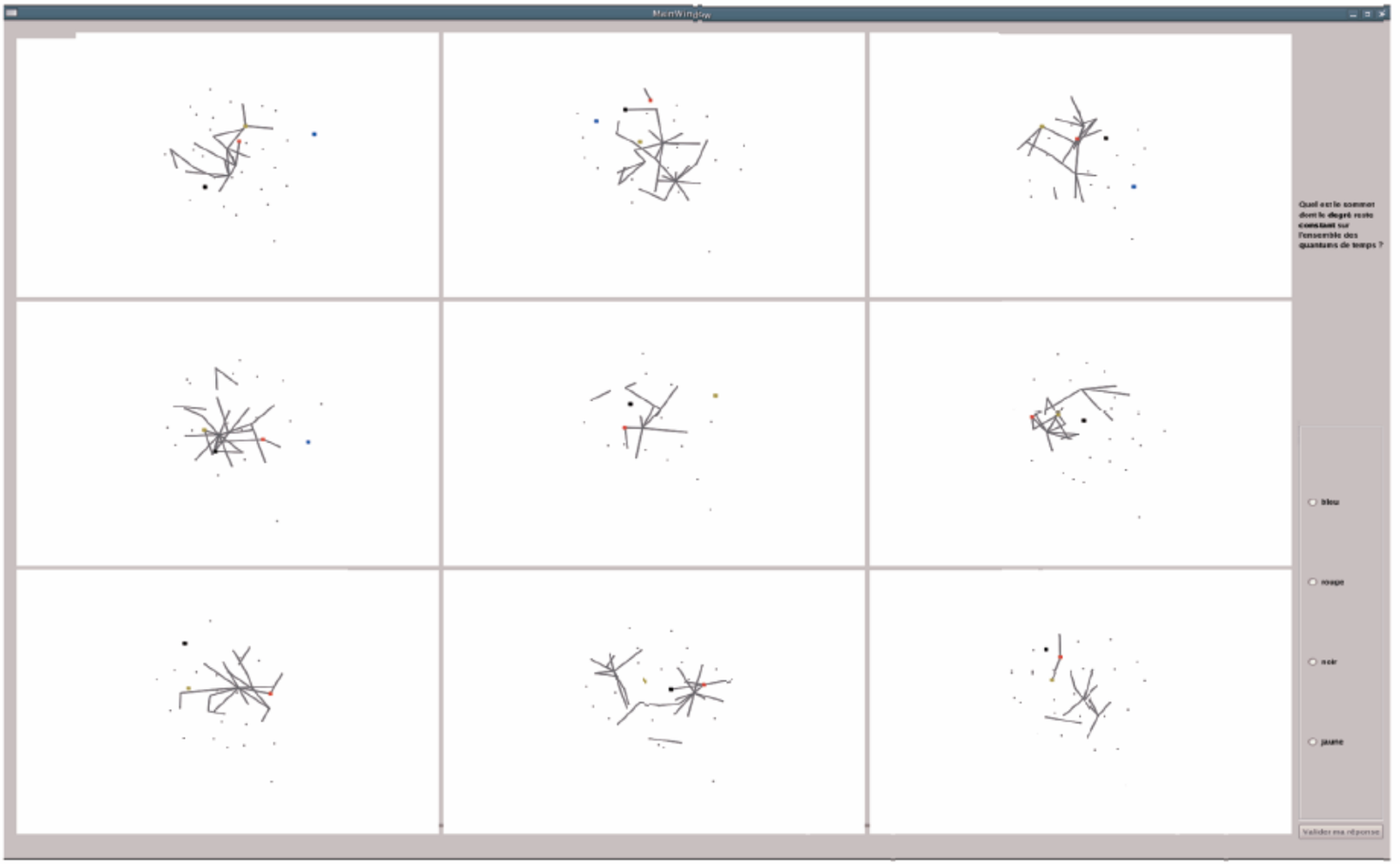
Daniel Archambault, Helen C. Purchase, and Bruno Pinaud. Animation, Small Multiples, and the Effect of Mental Map Preservation in Dynamic Graphs. IEEE Transactions on Visualization and Computer Graphics, 17(4):539-552, 2011.

Animation



- Similar to your standard movie player
- Node positions linearly interpolated
- Additions/deletions faded in/out

Small Multiples



- Each timeslice in its own window
- No interaction permitted for each time

Data Sets

- *threads2*, Frishman and Tal 2008
  - network of users on newsgroup
  - edge if one replies to a post

- *VAST*, 2008 Contest
  - nodes are cell phones
  - edge if one phone calls another on a particular day

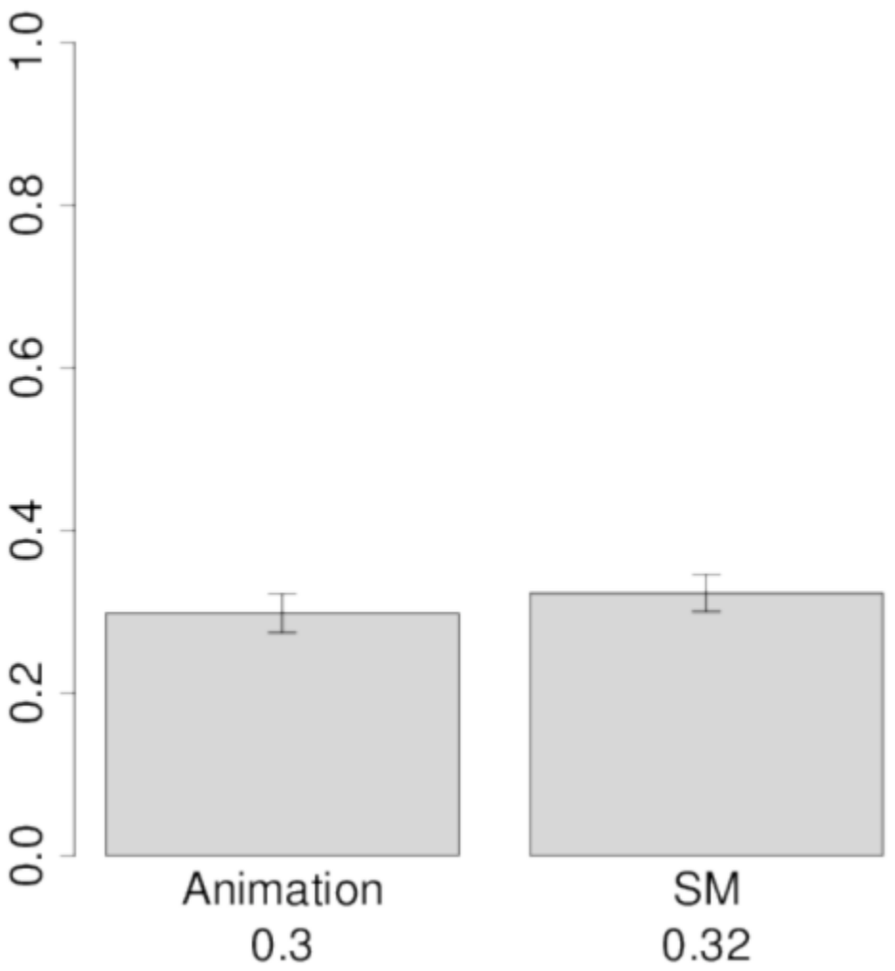
Tasks

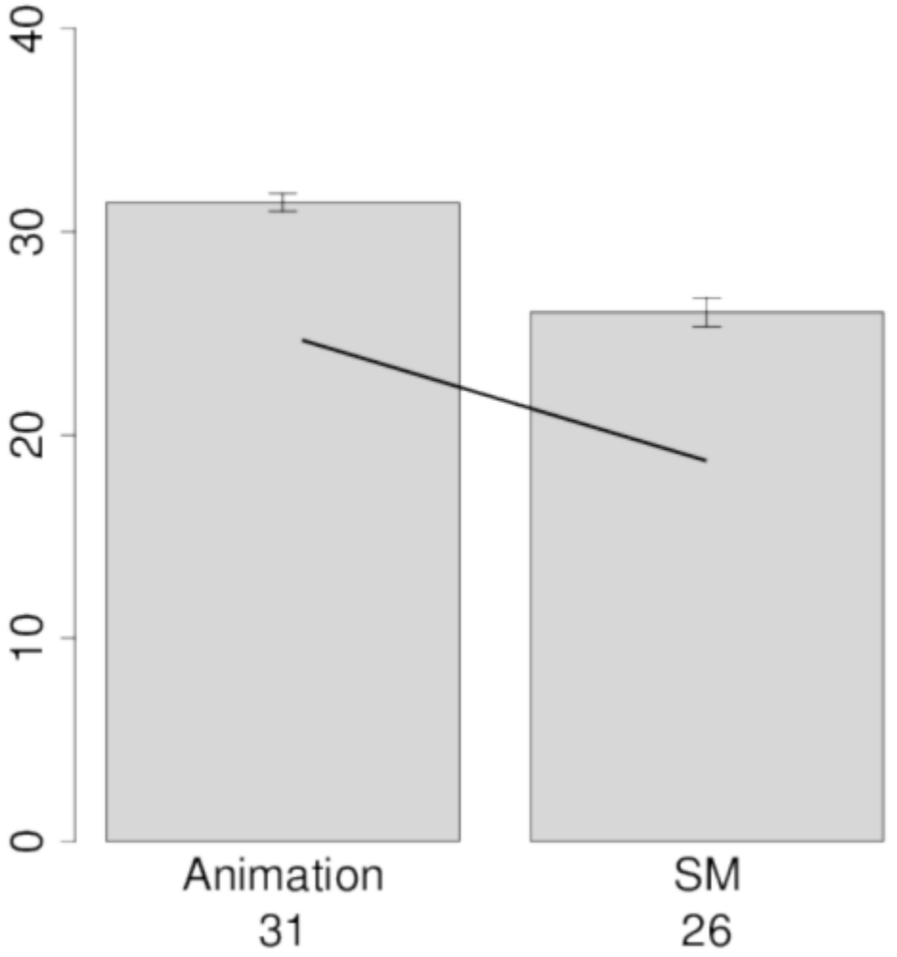
- Experiment conducted in French (translations):
  - Node degree changes:
    - increase, decrease, constant
  - Node appearance
    - Simultaneous appearance, continuous presence
  - Edge appearance
    - Simultaneous appearance
  - Does the graph grow or shrink?
  - Which shortest path gets shorter?

- Tasks similar to formal experiments on static graphs

Animation vs Small Multiples

- Small multiples significantly faster
- No difference in error rate





Results by Question

- Small multiples significantly faster
- No difference in error rate

- **Exception:**
  - Simultaneous appearance of Nodes/Edges
  - Animation slower but more error prone
  - Response time/error correlation indicates slower way to get to a more correct answer

Drawing Stability

- Animation condition
  - response time: no significant difference of notable magnitude
  - error rate no significant difference
- Small multiples
  - no significant difference in response time or error rate
- In this experiment, a stable drawing does not improve performance! Why?

Mental Map and Memorability

- Okay, does it help users remember if they have seen that data before?

- Ran an experiment to test recall of dynamic graphs.

The Mental Map and Memorability in Dynamic Graphs. Proceedings of IEEE PacificVis 2012, 89-96.

Experimental Design

- Tasks consisted of two phases
- **Memorisation Phase:** block of three graphs shown for memorisation
- **Recall Phase:** twelve graph sequences asked some modified/some not
- yes/no answer if you have seen it before
- In altered graphs, 8% of nodes removed

Results

- No significant difference in terms of response time or error rate
- When divided by data set
  - no significant difference in terms of response time and error rate
- A stable drawing does not seem to help with recall of a dynamic graph

Possible Explanation

- Qualitative data seems to indicate users used two features of the data to do the task
- **Static Features:** static patterns in the interconnections between nodes
- **Motion Features:** patterns of movement in the graph.

Previous Study Limitations

- Many experiments highlight targets using colour
- Colour disambiguates nodes/edges
- Drawing Stability is probably not as important in this scenario
- The red node is still the only red node on the screen – it does not matter where it is.

Related Work in Psycology

- Pylyshyn and Storm (1988)
  - participants track up to five randomly moving targets simultaneously against field of distractors
- Yantis (1992)
  - perceived coordinated movement of targets increases accuracy
- Liu *et al.* (2005)
  - replicated many of the results in an air traffic control scenario

Stability for Identification?

- Maybe the stability helps with node/edge identification?

- Does mental map preservation help with user orientation in dynamic graphs?
  - Does the number of targets influence performance?
  - Does animation or small multiples influence performance?

Daniel Archambault and Helen C. Purchase. Mental Map Preservation Helps User Orientation in Dynamic Graphs. Graph Drawing 2012, LNCS 7704, 475-486.

Experimental Design

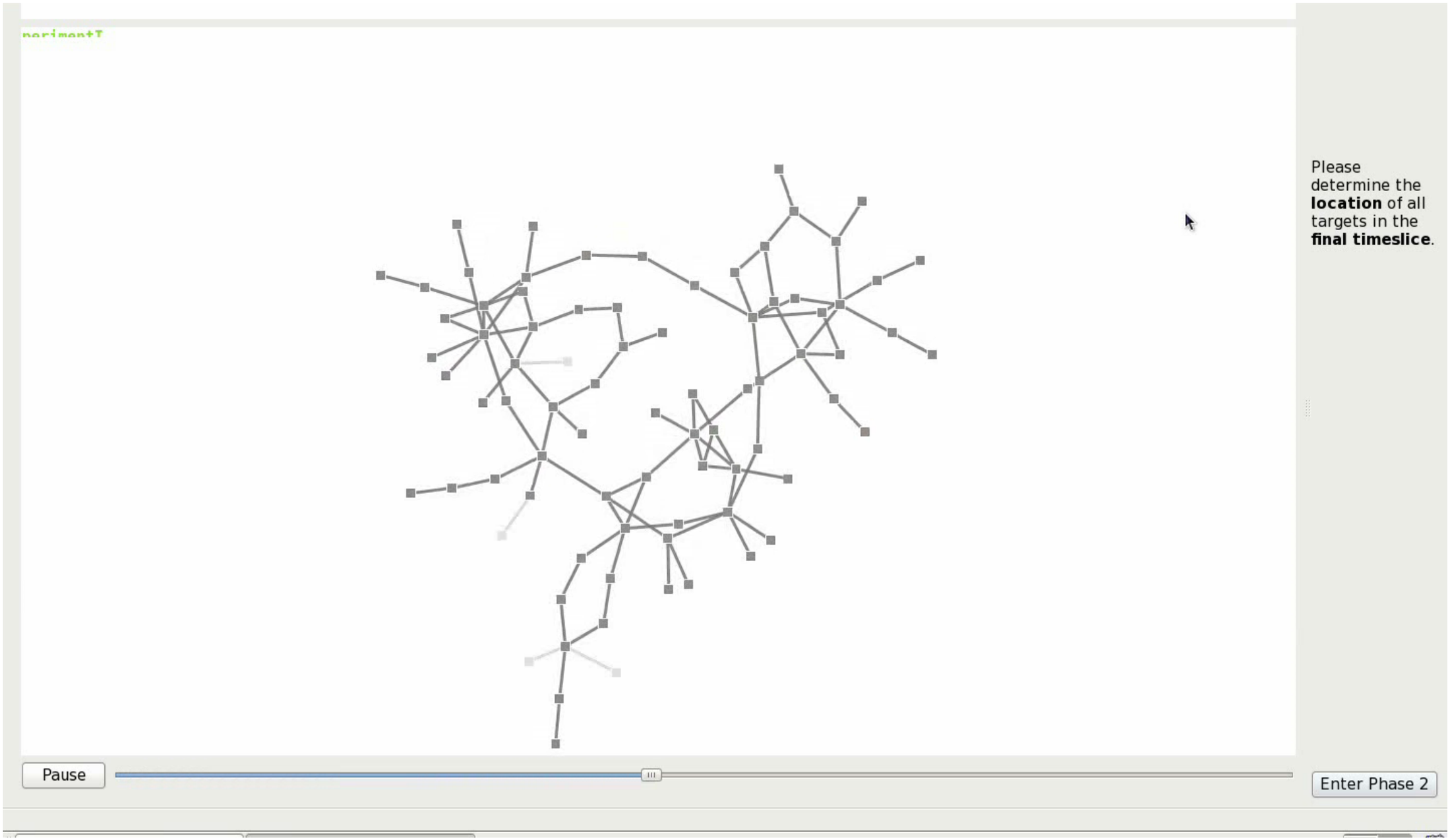
- Data: Two subsets of Threads2

- **Locate** nodes in graph during evolution
- Read long **paths** through the data

- **Target levels** for task complexity
  - 1, 3, or 5 locations
  - 3, 5, or 7 node long paths

- Target levels based on psychology results

Stimuli and Tasks



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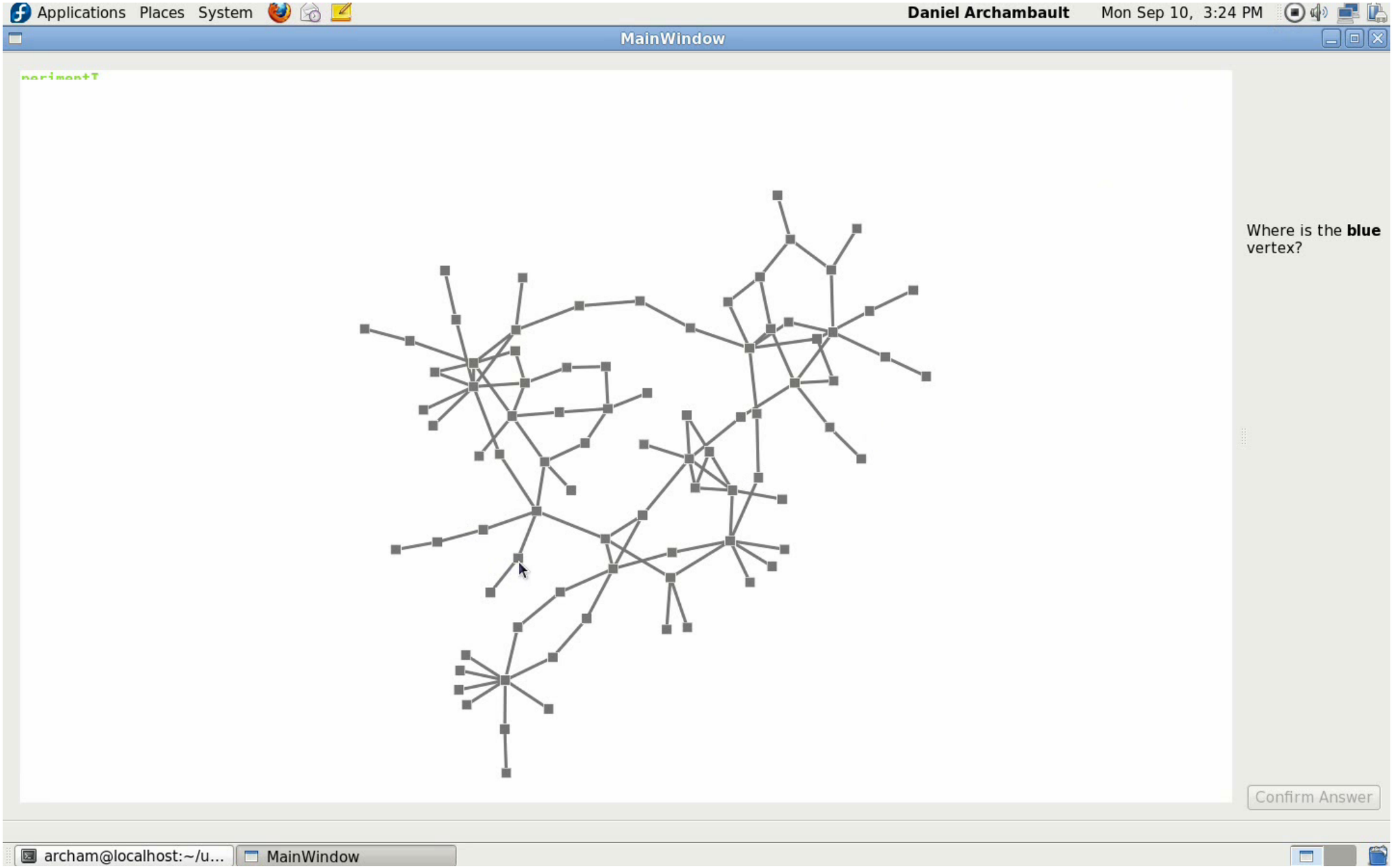

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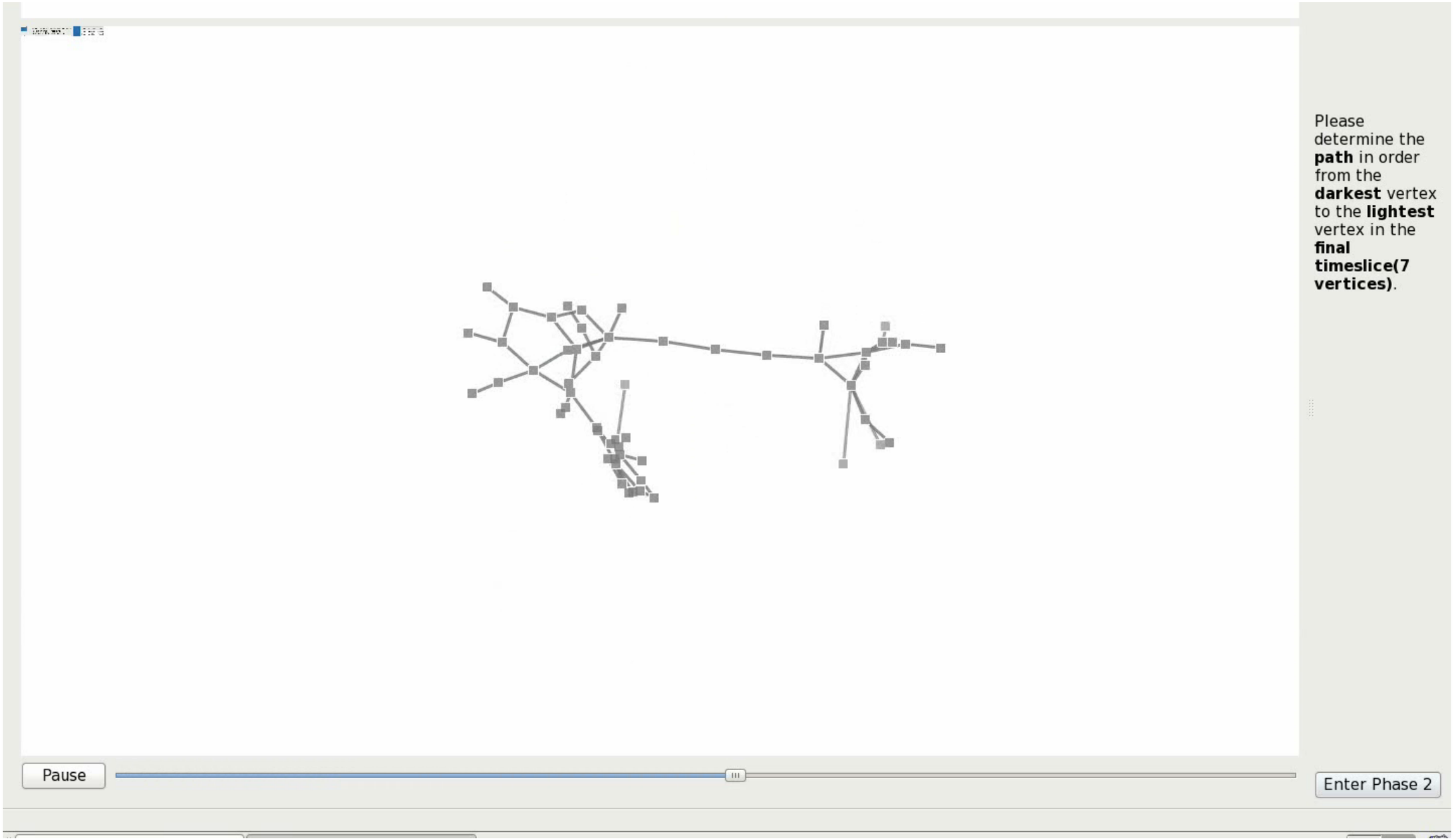

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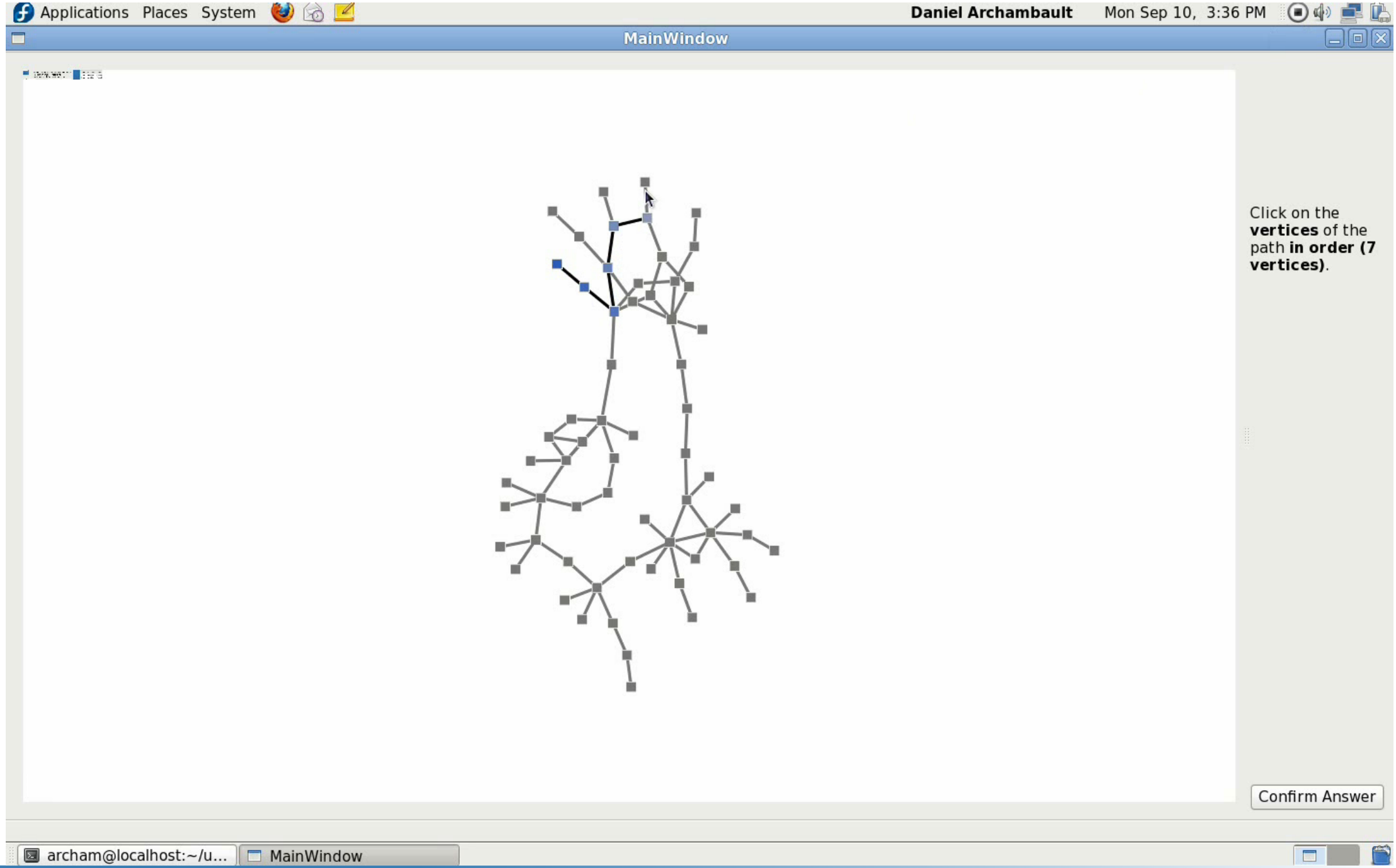

Results

- Drawing stability helps with both tasks
- Stable drawings were both significantly faster and more accurate when compared to unstable ones
- No significant difference between animation and small multiples
  - Stability was a very strong factor

Conclusions

- The drawing stability definition of the mental map helps (Yay!)
  - Nodes stay in similar areas of the plane
    Colman and Parker (1996)

Stable drawings help with identification of nodes and edges when they cannot be identified by other means

When is mental map effective?

- No highlighting of key nodes/edges
  - a red node is a red node that has moved
- Large number of targets (> 5) so human tracking is difficult
- In these cases, there is evidence that drawing stability improves human performance

Small multiples?

- Small multiples is usually faster than animation with little difference in error rate
- Exceptions:
  - Appearance of graph elements
- Drawings of low stability over small time intervals (1-2 slices) animation can help

Daniel Archambault and Helen C. Purchase. Can Animation Support the Visualisation of Dynamic Graphs? Information Sciences, 330:495-509, 2016.

What if only attributes change?

- Small multiples faster than animation with little difference in error rate

Daniel Archambault and Helen C. Purchase. On the Effective Visualisation of Dynamic Attribute Cascades. Information Visualization, 15(1):51--63, 2016

- Also, a hierarchical layout in the direction of cascade helps

Conclusions

- Exploration of Animation, Small Multiples, and Drawing Stability
- Guidelines on their use
- In future work, other definitions for the mental map?