Summative overview of the ATUAV project: Advanced Tools for User-Adaptive Information Visualization

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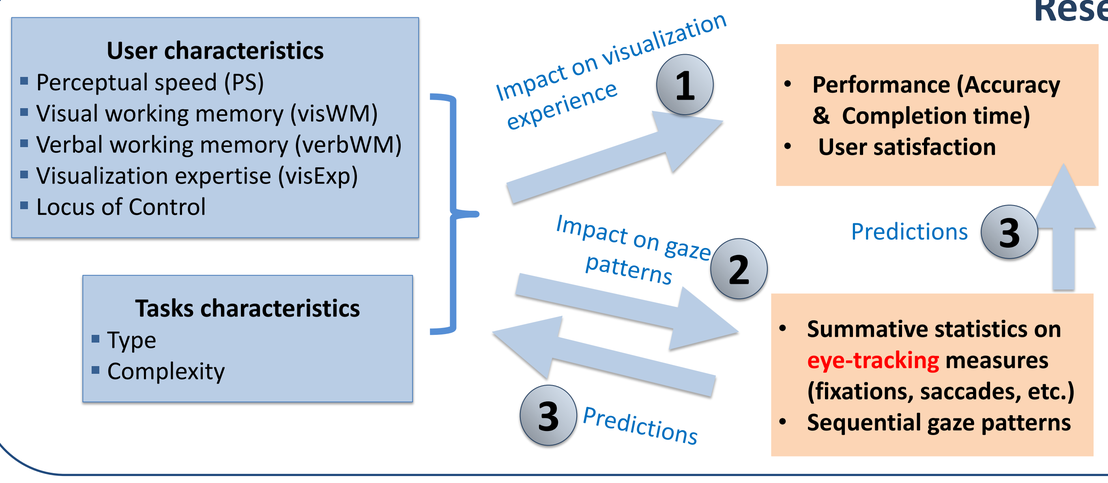
What are User–Adaptive Visualizations? Visualizations that can personalize information presentation to the needs of each individual user, in real-time.

Why are they important? There is mounting evidence that user differences can strongly impact visualization effectiveness.

Research Questions
- ❑ ***What*** user and task characteristics should be considered for adaptation?
- ❑ ***How*** to adapt to these characteristics?
- ❑ ***When*** to *adapt,* in order to maximize adaptation effectiveness and reduce intrusiveness?

Research Objectives

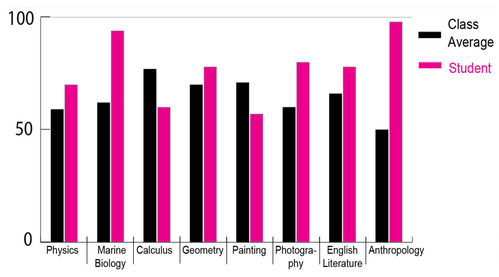


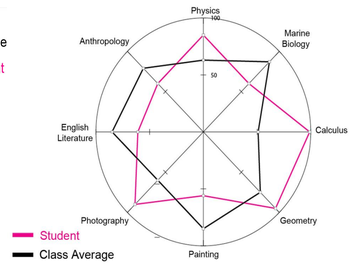
1. Identify which users/tasks characteristics impact user visualization experience enough to justify adapting to these characteristics (***What*** *to adapt to*)
2. Investigate impact of user & task characteristics on attention patterns for specific elements of a visualization, to identify possible targets for adaptation (***How*** *to adapt*)
3. Investigate if eye-tracking data can inform user models to predict, in real-time, characteristics relevant for adaptation (***How*** *and* ***when*** *to adapt*)

User studies

Bar/Radar study

Evaluate impact of individual differences on using bar and radar graphs.

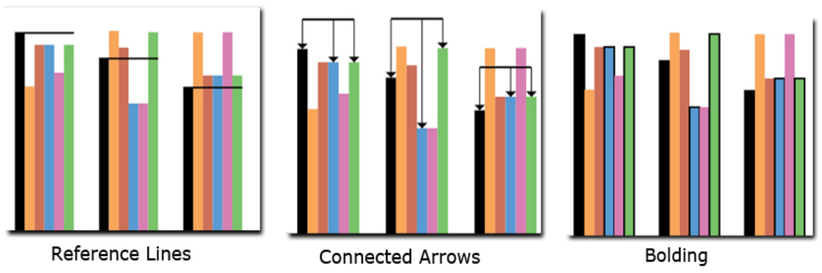




Study Factors: *Task Type, Task Complexity, Visualization Type*

Intervention study

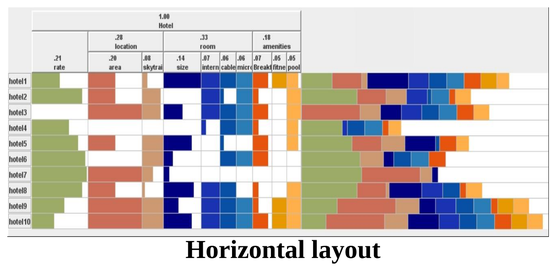
Compare intervention types designed to facilitate bar graph processing.



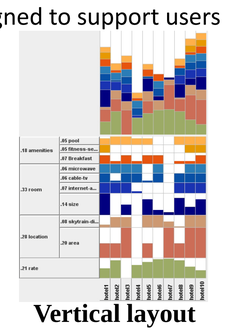
Study Factors: *Task Complexity, Intervention Type (e.g., Bolding)*

ValueChart study

Extend our research to an interactive visualization designed to support users in decision making tasks involving preferential choice.



Horizontal layout



Vertical layout

Study Factors: *Task Type, Task Complexity, Visualization Layout*

Summary of the analyses and results

	Bar/Radar study	Intervention study	ValueChart study
1 Impact of user & task characteristics on visualization experience	▪ Higher **PS** corresponds to faster completion time for simple tasks ▪ Confirmed that **PS** also impacts the compared effectiveness of two different visualizations (i.e., users with low PS are slower with radar graphs compared to users with high PS) ▪ Users with high **visWM** preferred radar graphs more than users with low visWM ▪ Users with low **verbWM** rated bar graphs easier to use compared to users with high verbWM [UMAP 2012]	▪ All three cognitive abilities (**PS**, **visWM**, **verbWM**) were found to significantly impact performance with complex tasks ▪ First study to connect **visWM** and **verbWM** to task performance with a visualization ▪ Found that three of the four evaluated interventions (**Bold, Connected Arrows, De-Emphasis**), all significantly improved task performance, regardless of task complexity and delivery time. [CHI 2014]	▪ All three cognitive abilities (**PS, visWM, verbWM**) were found to significantly impact performance with various low-level tasks ▪ Linked **visExp** to performance with complex low-level tasks (i.e., low visExp users have lower performance) ▪ For low-level tasks, users with low **visWM** were faster with the horizontal layout, contrary to previous findings showing that lower visWM users are at a disadvantage [Euroviz 2014]
2 Impact of user & task characteristics on gaze patterns	▪ Users with low **PS** spent more time and transitioned more often to the 'legend' and the 'labels' of the visualization ▪ Users with low **verbWM** transitioned more often to the main textual components of the visualization and had higher std.dev. of gaze angles [CHI 2013] ▪ Patterns in gaze sequences indicate that users with low **PS**, **visWM**, and **verbWM** spent more time reading the task question ▪ Users with low **PS** and low **verbWM** transitioned more often to non-relevant parts of the visualization [UMAP 2014] (a)	▪ Users with low **PS** spend more time processing the 'Label' region of the visualization with complex tasks ▪ Users with low **visWM** spend more time and transitioned more often to the 'Answer input' region of the visualization on complex tasks ▪ Low **verbWM** users spend more of their time reading the textual elements of the visualization ▪ Identified several gaze measures (e.g., fixations, transitions) that were higher for **Reference line** intervention suggesting that it is a visual distractor [UMAP 2014](b)	*To be done*
3 Predicting user & task characteristics from gaze data only	▪ Predict cognitive characteristics - **PS, visWM,** and **verbWM**: • Max accuracies in the range of 59%-64% • Achieved near the **beginning** of each task ▪ Predict **user performance** and **task difficulty** up to 84% accuracy ▪ Can predict **visualization type** up to 70% accuracy using only *visualization-independent* gaze features (e.g., fixation rate, saccade angles) ▪ Reported predictions are significantly better than the majority baseline [IUI 2013, TIIS 2014]	▪ Predict cognitive characteristics - **PS, visWM,** and **verbWM**: • Maximum accuracies in the range of 63%-65% • Achieved in the **first half** of each task ▪ Predict **user performance** and **task complexity** in the 80%'s after 5 sec. and in the 90%'s given more time ▪ Predict a user's **skill acquisition** with up to 64% accuracy ▪ Reported predictions are all sig. better than the majority baseline ▪ Above results do not generally require interface-dependent **Areas of Interest (AOIs)** as features for prediction [IUI 2014]	*To be done*

Suggestion for adaptations

	Bar/Radar study	Intervention study	ValueChart study
Intervention on a given visualization	▪ For users with low **PS**, provide support with the **legend** and **labels** regions of the visualization, especially for complex tasks ▪ For users with low **verbWM**, provide adaptive support to the **textual elements** of a visualization (e.g., give more emphasis to text)	▪ For users with low **PS**, provide support with the **labels** region of the visualization for complex tasks ▪ For users with low **visWM**, provide support with the **answer input** region for complex tasks (e.g., radio buttons vs. drop-down menus) ▪ Avoid using **Reference Line** intervention since it did not improve performance	▪ Supporting users with low **visExp** on **complex low-level tasks** (i.e., tasks which required more steps)
Selecting a visualization or layout	▪ For users with low **PS**, select **bar graphs** when working with simple information seeking tasks ▪ For users with high **visWM** and high **radar graph visExp ,** select **radar graphs** which they are more likely to prefer ▪ For users with low **verbWM,** select **bar graphs** which they find easier to use		▪ For low-level tasks, provide a **horizontal** layout to users with low **visWM,** which allows these users to compensate for limitations in their abilities ▪ For high-level tasks, provide a **vertical layout** to users with **low frequency in using visualizations for preferential choice-making**, as they spent less time making their decision with this layout at no cost of decision quality

Conclusions

- ❑ User characteristics have a significant impact on performance and satisfaction
- ❑ Eye tracking data is informative for predicting user & task characteristics in real-time
- ❑ Eye tracking data can explain poor performance and allow us to identify possible targets for adaptation
- ❑ Most of the studied interventions are more effective than no interventions
- ❑ Visualization type & layout play an important role according to the needs of each user

Future work

- ❑ Complete missing analyses
- ❑ Extend analysis of eye-tracking data to include more gaze-features: pupil dilation and pattern analysis on AOI sequences
- ❑ Use interactive real-world visualizations designed by our industrial partner: www.metroquest.com

a place of mind
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