Innovation through Knowledge and Experience (ike): Enabling Value Creation by Developing a Group Decision Support System for User Experience Research & Development

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Abstract

Because innovation with user experience (UX) is becoming increasingly important in creating successful social and business value, this project discusses the design and development of an innovative software platform for developing, analyzing, and managing UX research efforts in organizations. The ever-increasing need for designing a comprehensive UX platform for developing and managing comprehensive strategies for UX research both at organizational and individual levels is supported by a recent article by Soussan Djamasbi and Diane Strong in 2019. It is imperative for companies to meet users' expectations, but also to empower them and improve their overall quality of life. To address this need, the User Experience and Decision Making (UXDM) lab at WPI developed ike, a software platform that can meet the needs of UX practitioners to support their efforts in designing and creating effective user experiences for their customers. The goal of this project is to extend ike's development to include new capabilities for storing and managing large datasets. The scope of this project also includes the development of ike's eye tracking module, which enables researchers to collect, visualize, and analyze large datasets generated from eye tracking sensors.

Keywords: User Experience, Design, Development, Social & Business Value, Eye Tracking, Persona Development, Design Thinking, Card Sorting, Decision Making, Group Decision Support System (GDSS)

Innovation through Knowledge and Experience (ike): Enabling Value Creation by Developing a Group Decision Support System for User Experience Research & Development

Designing UX driven innovations calls for collaboration and group decision making and requires effective management of UX R&D efforts (Djamasbi and Strong 2019). However, as of today, there is no group decision support system (GDSS) in the market to help organizations create and manage UX driven innovations. Ike, a novel GDSS that addresses this need, is a great example of the impact that technology can have on society. Ike impacts society in two major ways. As a software platform for developing UX driven innovations, which have become a stable force in market competition in our fast-paced digital economy, ike has a major positive economic impact on society. By providing a platform for managing UX research ike fosters effective and efficient group decision making that is needed to come up with novel solutions for societal problems. Driven by the never-ending need for UX driven solutions (Wilson and Djamasbi, 2015), ike development was initiated in the User Experience and Decision making (UXDM) lab at WPI. As such ike's design had to meet the requirements for a comprehensive UX research platform for developing, updating, and managing UX research that is necessary for creating novel products and services that can compete successfully in the marketplace. It is important to note that this project is a work in progress. The current IQP reports the initial work and the work that has been completed during this IQP.

The paper is organized in the following fashion. First, it discusses the initial design process, including the work that was done to identify the specific target markets that ike is being developed for. This discussion also includes the incipient infrastructure design, highlighting technology and framework choices that were made to allow flexibility and scalability, ensuring ike’s growth and adjustment to new business requirements. Next, this IQP report will discuss each of ike’s modules that are being refined or newly developed. These modules include personas, card sorting, and eye tracking. The latter is the primary focus of this IQP.

Design Process

Using the experience-first approach to design, market analysis and user research were among the very first steps that were taken to develop ike. The results of research in this first step informed the process for choosing development frameworks and technologies that would make ike a powerful tool now and in the future. This section provides an overview of ike’s initial design process, scrutinizing why certain product design decisions were made as well as how they will prospectively effect ike. Appendix B provides a snapshot of ike’s login screen and URL.

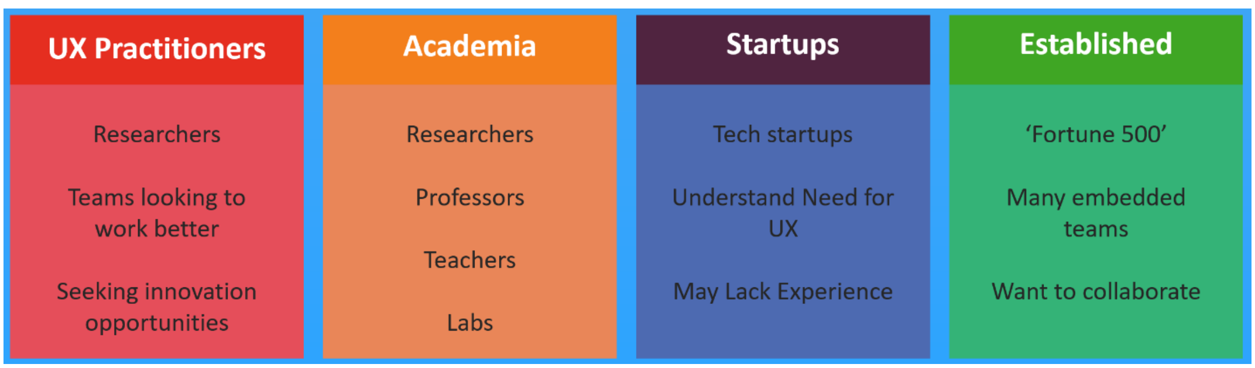
Target Market

In the incipient stages of the design it is not unusual to aspire to set initial design goals for a product to be one that is pleasing to everyone. While appealing to a broader market can result in much larger return on investment (ROI), designing for everyone at the initial stages of development is likely to result in designing for no one (Johansen, 2014). Recognizing this fact, it became an important step in the process of designing and developing ike to ensure that the design is focused on a few specific target markets. Beginning with assumptions about who the user base might be for ike, four possible segments were identified with the intention of choosing only one or two of these segments to majorly inform ike’s initial design (Figure 1). Each of these segments stems from a set of assumptions that are relevant to research and development (R&D) efforts both in academia and industry:

1. UX Practitioners care about academic rigor in User Experience Research
2. Budget and access are typical barriers to entry
3. Persistence and collaboration are pain points
4. Target users of products/services have budget influence; this is particularly true in established organizations

Figure 1

Four possible market segments (or groups of users who might use ike)



Working in the field of UX research in higher education alongside small and large companies, the UXDM lab at WPI has had a great deal of exposure to people across all four of these types of users. The design of ike was started by focusing on target users in academic settings. The ike development team started with the WPI community as target users by providing demos to students and faculty and asking them for qualitative feedback. As part of the WPI I-CORPS program (I-CORPS), the development team also collected feedback from some faculty members at other universities in the Worcester, MA area (such as Framingham State University and Brandeis). Aggregating the collected feedback, an early trend emerged from this academia segment showing that academic rigor was important to this group of users only if it could be translated to return on investment (ROI). While UX is a blend of research, design, human-computer interaction, engineering, and many more fields, it is also very heavily valued as a field of business. To be incorporated in the product design process, the outcomes and artifacts that are produced from UX research need to be translatable to business value. Another early trend emerging from the analysis of the collected feedback was that cost mattered a great deal for the adoption of ike, e.g., the less expensive the cost of accessing ike the better the likelihood of adopting it. Similar trends emerged from the analysis of feedback that was gathered from industry target users such as people who worked at startups and current members of the WPI UXDM consortium. The collected feedback clearly indicated that there needs to be a balance between the cost of using the platform and the benefits it can deliver to its target users. In other words, target users will look for resources and find the needed budget if they think the tool is the right fit for them.

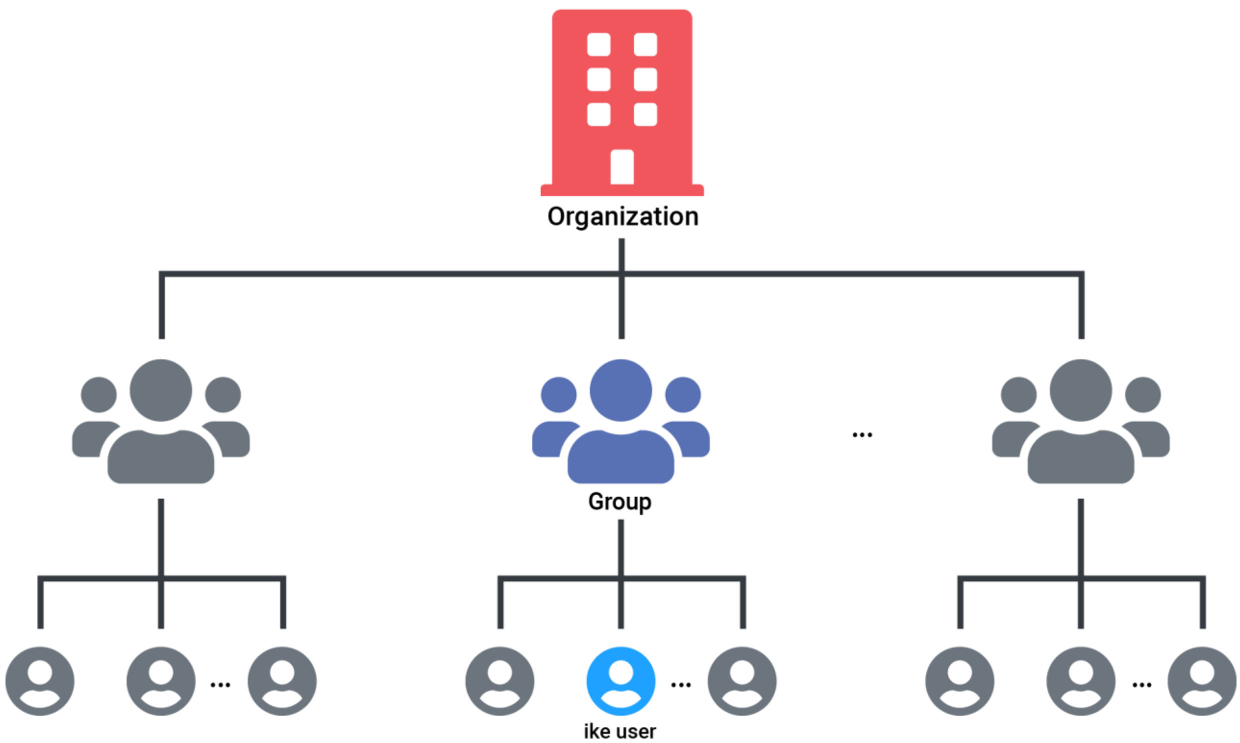
Additionally, while interviewing those who work at startups and those who are current UX Practitioners, the ike design team was able to confidently confirm the assumption that persistence and collaboration are pain points. Persistence, in this case, refers to the idea that things do not get lost and are easily findable in the future, thereby contributing to the management of UX artifacts. The typical artifacts of UX research are often distributed via emails as PDF files, which are then often printed and distributed to interested parties. Over time, these documents tend to get lost in the history of someone’s email inbox or buried in a pile of papers that will eventually get recycled. To be able to meet the continual demand for UX driven innovations, there is a need to manage UX research artifacts in way that it can foster effective communication and hence effective collaboration. Identifying this as a major need in the industry, ike focuses on providing a platform for creating and managing UX research in a way that fosters communication and collaboration among teams within an organization. This enables iterative design of UX artifacts over time while allowing for teams to collaborate remotely or in-person.

Designing the Infrastructure

In designing the infrastructure for ike for the above target market, it was critical for the chosen technology stack to be fast, scalable, and flexible. Speed and scalability matter for real-time communication on ike, and the flexibility is important because ike's target users have diverse needs that will need to be met by the platform. For this reason, MongoDB was chosen as the database service and Node.js was chosen for the application framework. This technology choice is modern, fast, and reliable. Based on user feedback collected during interviews, the database was structured to support organizations, groups (or teams) within organizations, and granular permissions for users (Figure 2). This allows the application to be multi-tenant in a single instance. Additionally, it accommodates a wide-ranging type of UX research artifacts, such as design thinking documents (e.g., personas), documents for conducting studies and reporting results (e.g., experimenter scripts, study protocols, interview questions, reports), and qualitative and quantitative data (e.g., data from eye tracking experiments, qualitative responses to surveys, or responses generated from unstructured interviews). Each UX research artifact in ike belongs to a group and is private (is visible only when explicitly shared) to the group. If the users in a group decide they want to share any part of their research artifacts (e.g., data or the results of a study) with the other groups in their organization – it is entirely possible to do so. Authentication and access control were designed around these same principles. Any user can create a free account with their email address and a password; they can then request a license for an organization through the UXDM Lab. This will allow them to create their own groups, add any other users they would like, and start designing, conducting, and managing research with ike.

Figure 2

Organizational structure of ike



The infrastructure was developed so that it could be extensible; so that the platform is not limited in any way as it grows, and that functionality can be added to the platform as needed. In addition to the ability to use ike's web platform, users will also have access to the representational state transfer application program interface (REST API), in which the transactions between users and the ike system are completely modular. Such modular transactions allow for a more extensible configuration for a platform like ike because endpoints and functionality can continuously be added without affecting other operations in the platform. To take advantage of this capability, users can request a token with their email and password, and this token can be used in subsequent requests to interact with their account and data on ike. The token expires after four hours, after which it can be renewed by the user at their request if they wish to continue using the REST API. While this approach enables intermediate and advanced users of ike to interact with the platform in a more powerful way, it also enables the decoupling of ike's application and data processing layer from its data collection layer. This is the foundation for how ike is able to consume and use data from eye tracking platforms, specifically the UXDM Lab's eye tracking software which is heavily integrated with the ike web platform.

Modules

The ike platform was built in a series of modules with each module designed to serve a set of UX research needs. One of the overarching goals of UX is to better understand who the users of a product might be. This includes things such as their goals, frustrations, background information, and anything else that might be relevant to product design for the intended user. One of the primary methods to gain a deep understanding of user needs in UX research is through the persona development framework. "Personas are a representation of the goals and behaviors of prospective users and they help guide our decisions and push the organization of the system we're building to be as approachable as possible. A deep understanding of users is fundamental to creating a stellar product" (Jacobs, 2017). For this reason, the persona module was the first module that was implemented on ike, serving as the foundation for future modules, including modules for card sorting and eye tracking research and analysis.

Personas

Personas give organizations the ability to have a common understanding of who they are designing products for. Persona development activities can be divided into two major groups: proto-persona and research-persona development activities. Proto personas, which form a set of assumption-based user groups, are typically developed through indirect interaction with users. “These personas are created by members of an organization, usually through a workshop where a group of selected employees are invited to estimate the goals, needs, behavior, and other life and work aspects of their customers” (Jain et al., 2019, p.2). Research personas, on the other hand, are developed through direct interaction with users through conducting some form of user studies. Both proto and research personas provide important business value for an organization.

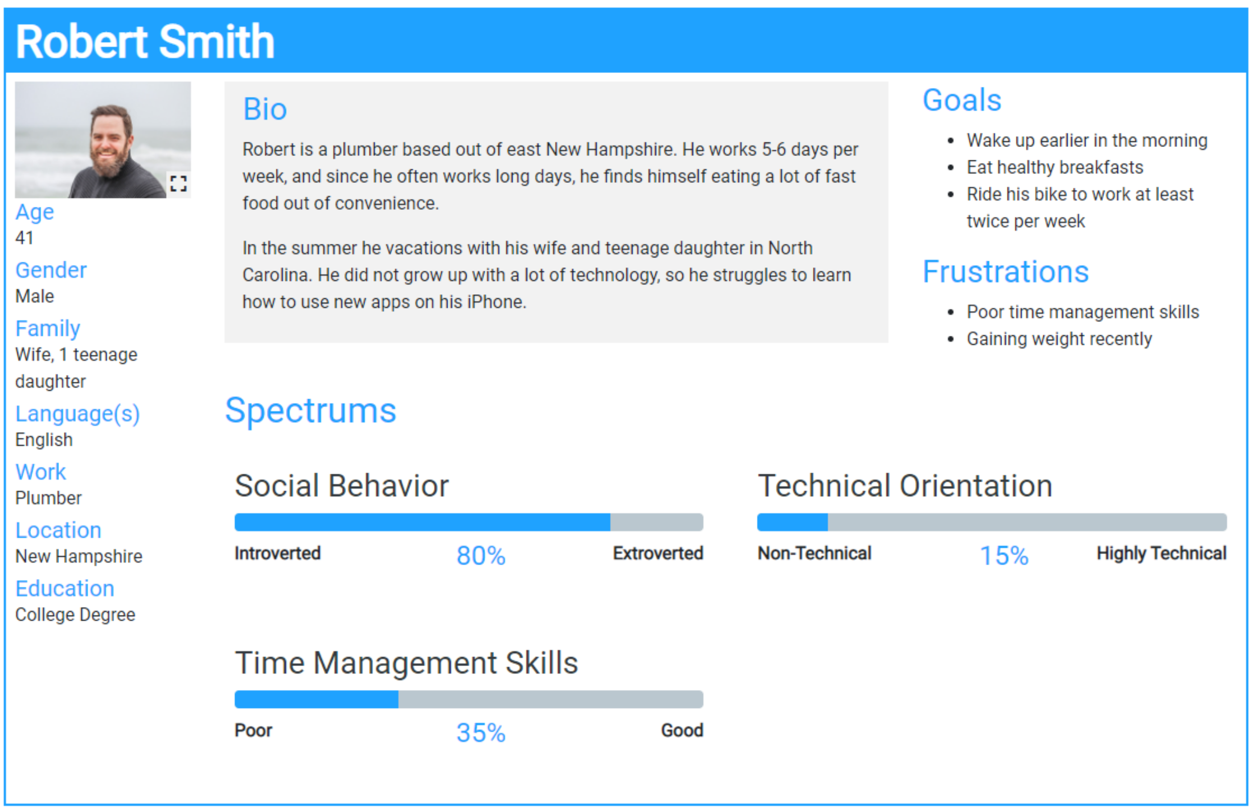
Currently, ike has a module for proto personas. Research personas that are created via user research can be added to the persona library via proto-persona module as of today. However, a new research persona module is scheduled to be added to ike. The following section provides a brief discussion for ike’s proto-persona module.

Proto Personas

The proto personas module in ike was built with collaboration in mind so that organizations can easily share their personas with their team members from anywhere in the world or share the work across various teams. Ike members belonging to an organization have the ability to work together and communicate with each other online in real time. Personas help to foster the concept of a “human-centered” approach to the design process. This means empathizing with and developing a deep understanding of the end-user and using that knowledge to design tailor-made solutions that best suit their needs (What is Human Centered Design). When researchers on ike are finished with their personas, they are able to easily share their personas with other teams in their organization so that everyone is able to see the work that they completed (Figure 3).

Figure 3

Sample proto persona created with ike



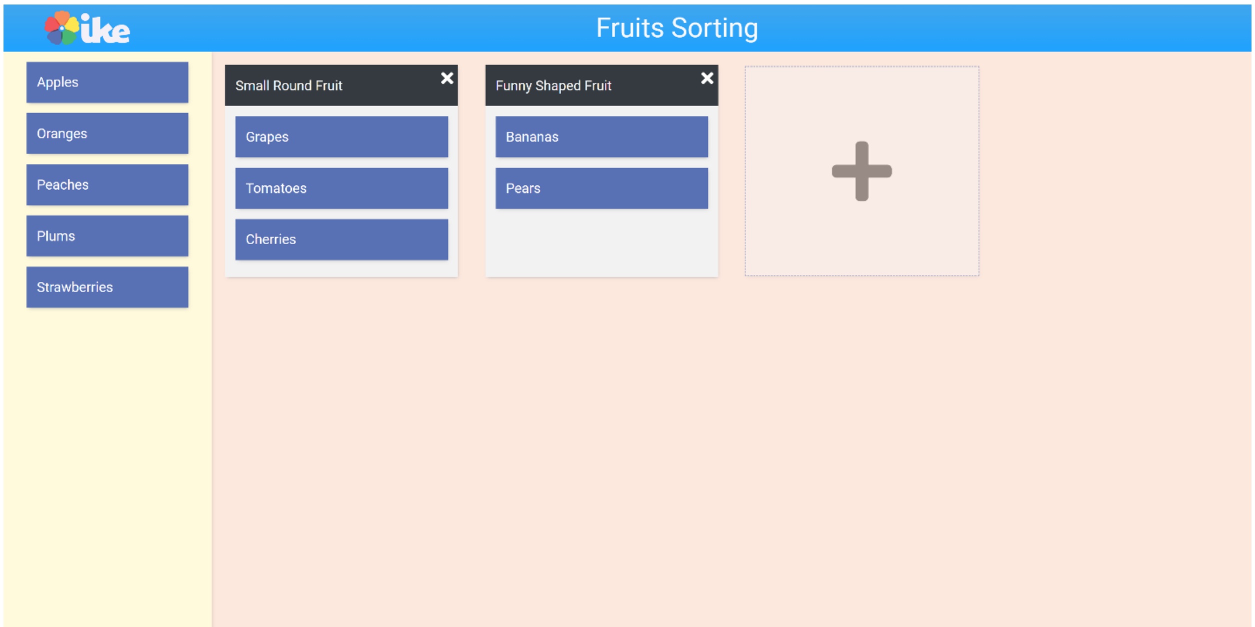
Card Sorting

When designing or evaluating the information architecture of a website or application, researchers often use a card sorting study. In a card sort, participants organize topics into categories that make the most sense to them. This knowledge of how the end-users would group information is helpful for building the structure of a website as well as labeling categories and navigation (Affairs, 2013). The details of how a card sorting study is setup varies, but two common types are the “open” card sort and the “closed” card sort. In open card sorting, participants are asked to make their own groups and assign labels to these groups as they go. In a closed card sort, the categories are pre-defined, and participants are asked to place the topics in the pre-defined categories. A typical pattern for conducting information architecture research is to conduct an open card sort first, then use the groups that the participants identified in a closed card sort. This can help to identify which categories resonate most with the participants in the open card sort, then discover how the participants would group the topics when given a fixed set of pre-defined groups.

While card sorting sessions are traditionally conducted in person using physical cards and placing them in bins, remote (online) card sorting is also becoming more prominent and useful. For this reason, it is imperative that ike has card sorting functionality. ike users can design and deploy both open and closed card sorting studies. Additionally, ike users are able to collaborate in real time with other team members to design and or edit card sorting experiments. In addition to fostering flexibility, ike’s ability to provide remote collaboration on designing and deploying card sorting studies allows researchers on ike to take advantage of expertise that maybe not available to them locally. Figure 4 displays the snapshot of an open card sorting example with ike.

Figure 4

A sample card sorting study built with ike



Card Sorting Analysis

Once the data for a card sort on ike has been collected, analysis is automatically performed in the background so that the results can be quickly reviewed by researchers on ike. One of the artifacts that is produced by this analysis is a distance matrix (Figure 5). The distance matrix shows the distances between pairs of cards based on how participants grouped them. Higher values here correspond to a greater distance between the cards (or a higher dissimilarity). Another artifact produced by card sorting analysis is the dendrogram, which is a tree diagram that represents the clustering (or grouping) of cards from the study using a Hierarchical Clustering Analysis (HCA). The cards are clustered according to the Unweighted Pair Group

Method with Arithmetic Mean algorithm (UPGMA) (Sokal, 1958). This is an agglomerative approach to clustering, meaning that the cards begin separately and are iteratively grouped together, producing a tree-like structure. In each step, the two nearest cards or clusters are grouped, producing a higher-level cluster. This new cluster is then assigned distances to the remaining cards and clusters using a proportional average (see formula in Appendix A). This clustered data is used to generate a dendrogram (Figure 7), which provides a clear and understandable visualization of the data. The dendrogram provides a powerful tool for researchers to examine the strength of the relationship quickly and easily between groups of cards. The same data is also used to generate a tree structure, which provides a way for users to see only the hierarchy of the cards from the card sort, ignoring relationship strength (Figure 6). Such a tree diagram is helpful to see how the cards might look in a hierarchical manner.

Figure 5

Sample distance matrix from an ike card sorting study

Distance Matrix

The distance matrix (or dissimilarity matrix) is a table that shows the distances between pairs of cards. Higher values correspond to greater "distance" between the cards.

	Apples	Bananas	Cherries	Grapes	Oranges	Peaches	Pe
Apples	0	1	2	2	1	1	2
Bananas	1	0	2	1	2	2	3
Cherries	2	2	0	1	1	3	2
Grapes	2	1	1	0	1	3	2
Oranges	1	2	1	1	0	2	1
Peaches	1	2	3	3	2	0	1
Pears	2	3	2	2	1	1	0
Plums	1	2	3	3	2	0	1
Strawberries	3	2	3	2	3	2	2
Tomatoes	3	2	3	2	3	2	2

Figure 6

Sample tree structure from an ike card sorting study after performing HCA

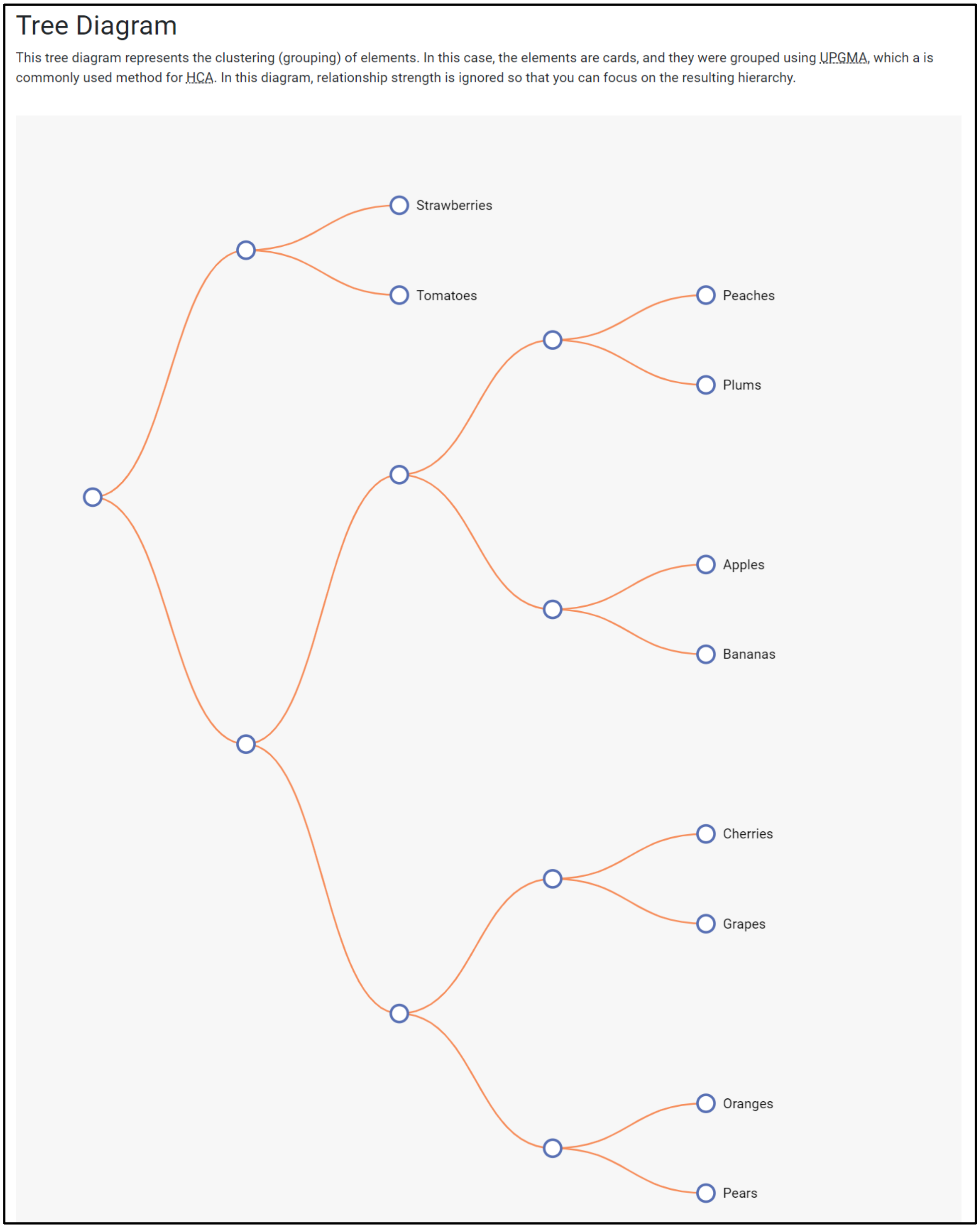
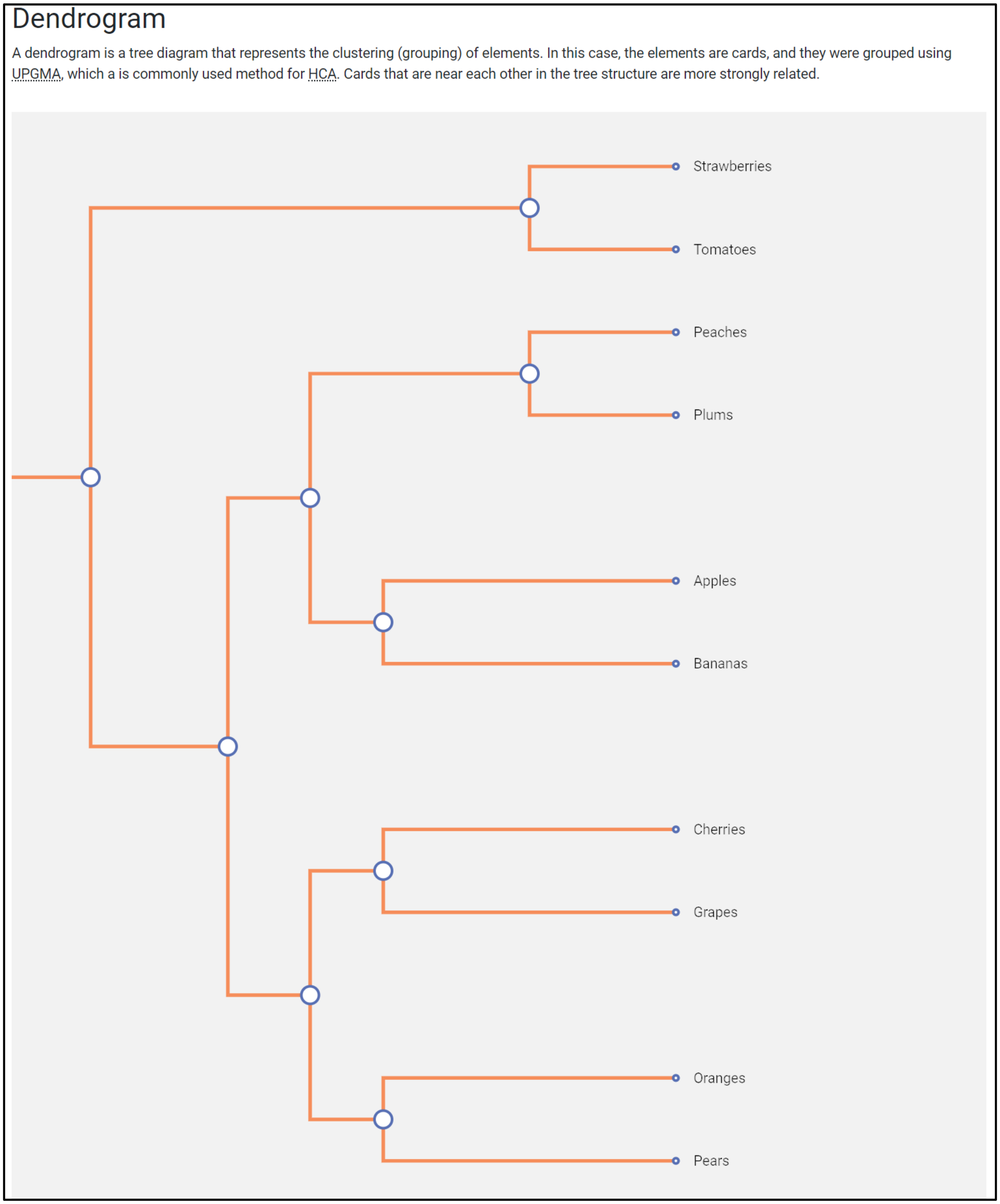


Figure 7

Sample dendrogram from an ike card sorting study after performing UPGMA



Eye Tracking

The most recent addition to the ike ecosystem is the eye tracking module, which allows ike users to manage eye tracking experiments and create heat maps for qualitative analysis of collected data. One of the most widely used remote eye tracking technics to capture the focus of a person's gaze on a visual display is video-based eye tracking (Djamasbi, 2014). This technique captures gaze unobtrusively at any given time by recording and measuring the changes in pupil position. The eye tracking device shines an invisible infrared light onto the person's eyes. The reflection of this light, which produces a small bright light on the eye surface (glint) and makes the detection of pupil easier, is captured by an infrared sensing video camera embedded in the eye tracking device, which is typically mounted beneath the stimuli, e.g., computer monitor. Using the relative position of the glint and pupil center, the eye tracking software can calculate a person's gaze point on the stimulus (Holmquvist et al., 2011).The primary motivation for recording human eye movements is to gain insight as to where the user's attention is and what their focus may be. "This may give us some insight into what the observer found interesting, that is, what drew their attention, and perhaps even provide a clue as to how that person perceived whatever scene she or he was viewing" (Duchowski, 2017, p. 3). This data can have a variety of applications in UX – anywhere from measuring and analyzing system usability to real time gaze-interaction, in which users control a computer with their eye movements (Djamasbi and Mortazavi, 2015). However, as the technology for eye tracking hardware progresses, it presents challenges for data consumption, storage, and analysis. A 60Hz eye tracker, for example, will take 60 readings of the eye per second. Even considering just the raw gaze data (eye position), a 15-minute experiment produces 54,000 data points. Modern, research grade video-based eye trackers may collect at even higher rates, with some reaching 1200Hz. This same 15-minute experiment with a 1200Hz eye tracker would produce just over 1 million gaze points. Keeping in mind that this is only the data for a single participant, and modern eye trackers produce much more than just the position of the raw gaze points (some also give pupil size, angular velocity of the eyes, some normalized data points, etc.) – eye tracking data sets can grow to be massive in size very quickly.

Eye Tracking Data Collection

One of ike's major design objectives was the ability to support the storage and analysis of large data sets (e.g., such as those obtained from sensors). This is another reason that MongoDB was chosen in the initial database and infrastructure design. MongoDB is scalable to support big data using their native MongoDB GridFS framework. "Instead of storing a file in a single document, GridFS divides the file into parts, or chunks, and stores each chunk as a separate document" (GridFS). GridFS is fast and is able to be distributed and synchronized across any number of systems and facilities – making it the most future-proof and scalable option for ike to support big data as well as real time data streaming.

The current eye tracking data collection technique in the UXDM lab includes custom software that was developed using the SDK for Tobii eye trackers. This custom software, which has been heavily integrated with the ike ecosystem, enables researchers who are conducting eye tracking experiments to synchronize their data on ike. This means that they can share their work across various research teams if they choose to do so; enabling their research collaborator, regardless of their geographical location, to access the data and participate in the analysis of the experiment.

Eye Tracking Data Analysis

As soon as the data from an eye tracking study is imported to ike, analysis is automatically performed in the background using the eye tracking data to generate heatmaps and other visualizations. This process involves aggregating multiple eye tracking data components, resulting in a set of processed data and analysis (Figure 8). The data components consist of the raw data and any other auxiliary documents, as well as a study medium that is typically in the form of an image, web page, or video. In ike, researchers can see the raw gaze data overlaid on top of the study medium (Figure 9). The color of the gaze points is configurable; blue was chosen as the gaze point color in the example in Figure 9 because that color does not appear in the image, making the gaze points much easier to see.

Figure 8

ike eye tracking automated analysis process

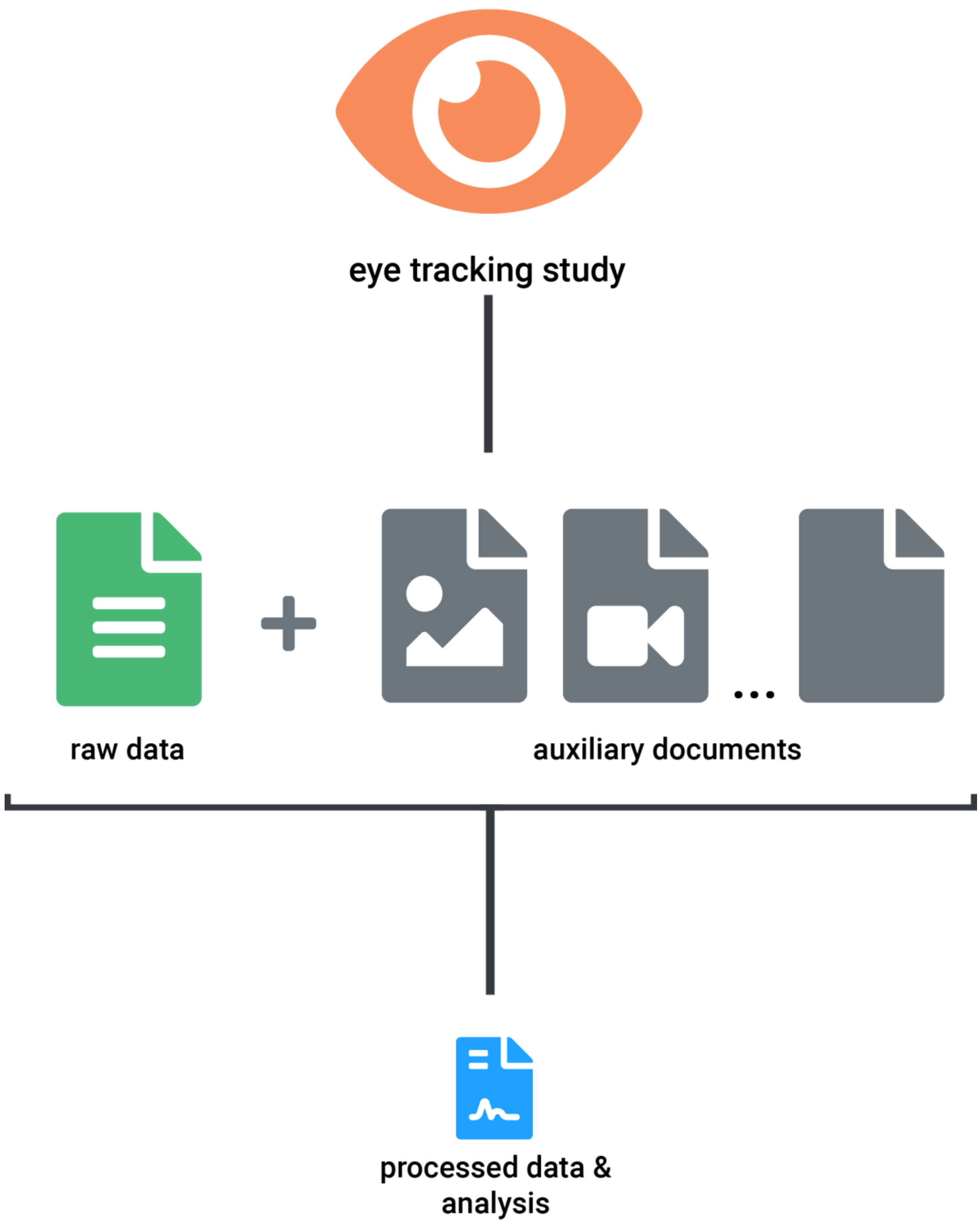


Figure 9

Eye tracking gaze points from a sample eye tracking study on ike

While it can be helpful to look at the raw gaze points on top of the study medium, it is customary to translate this raw data into heatmaps. For this reason, the analysis on ike also includes transforming the raw gaze data into heatmap-ready and opaque-map-ready data sets. The heatmap is one of the most common eye tracking techniques for qualitative analysis because it provides an excellent overview of what captures the attention of the participants in a study (Figure 10). The heatmap is a gradient starting with blue to visualize weaker level of attention and ending with red to indicate the most intense level of attention. Another method for visualizing eye tracking results is the opaque map, which can be considered as a sort of inverse of the heatmap. In this visualization, the entire image begins covered with a black shadow, then the pieces of this black shadow that were viewed by participants become transparent. The more intense the gaze the more transparent the shadow (Figure 11).

Figure 10

Heatmap from a sample eye tracking study on ike

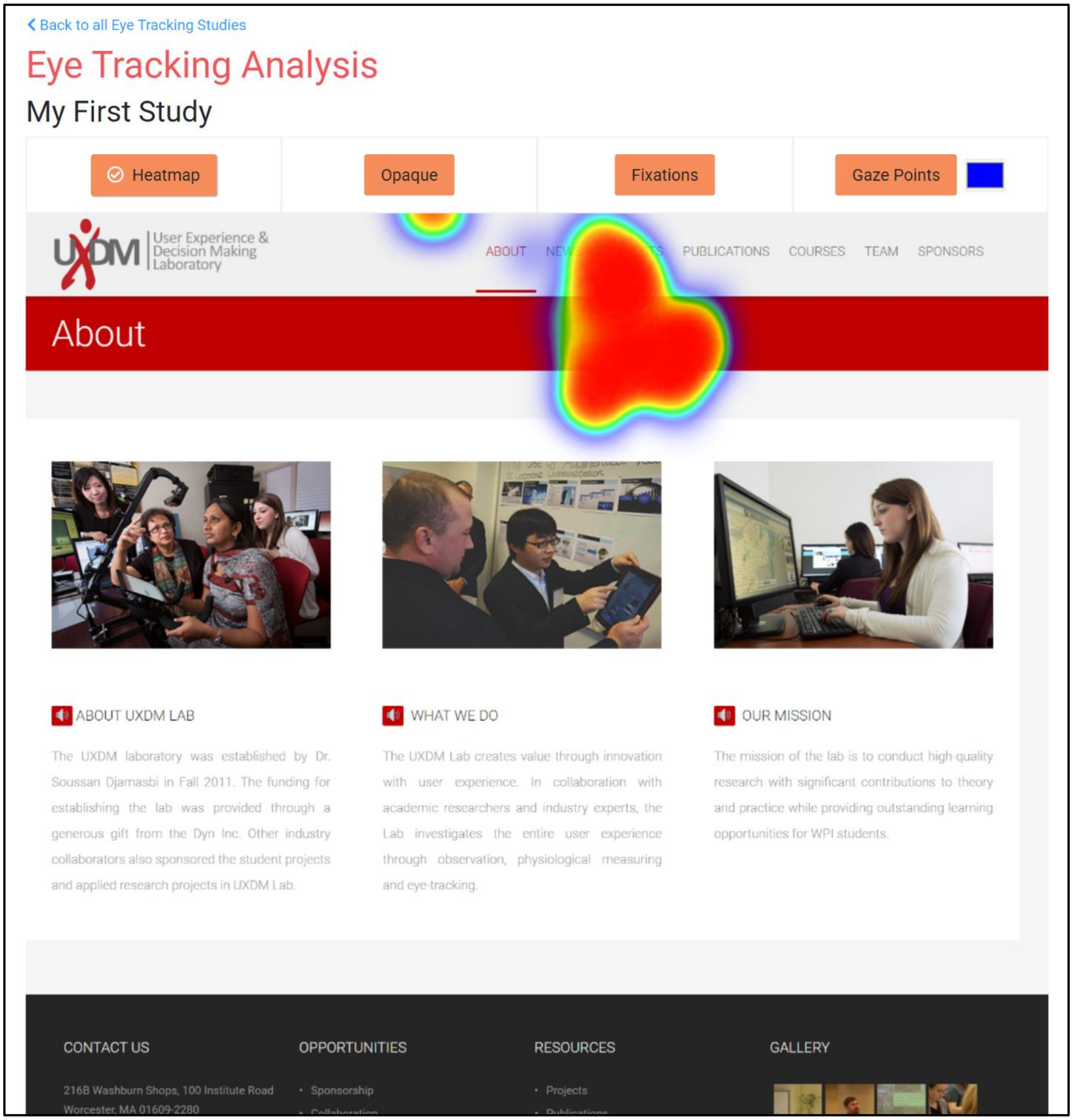
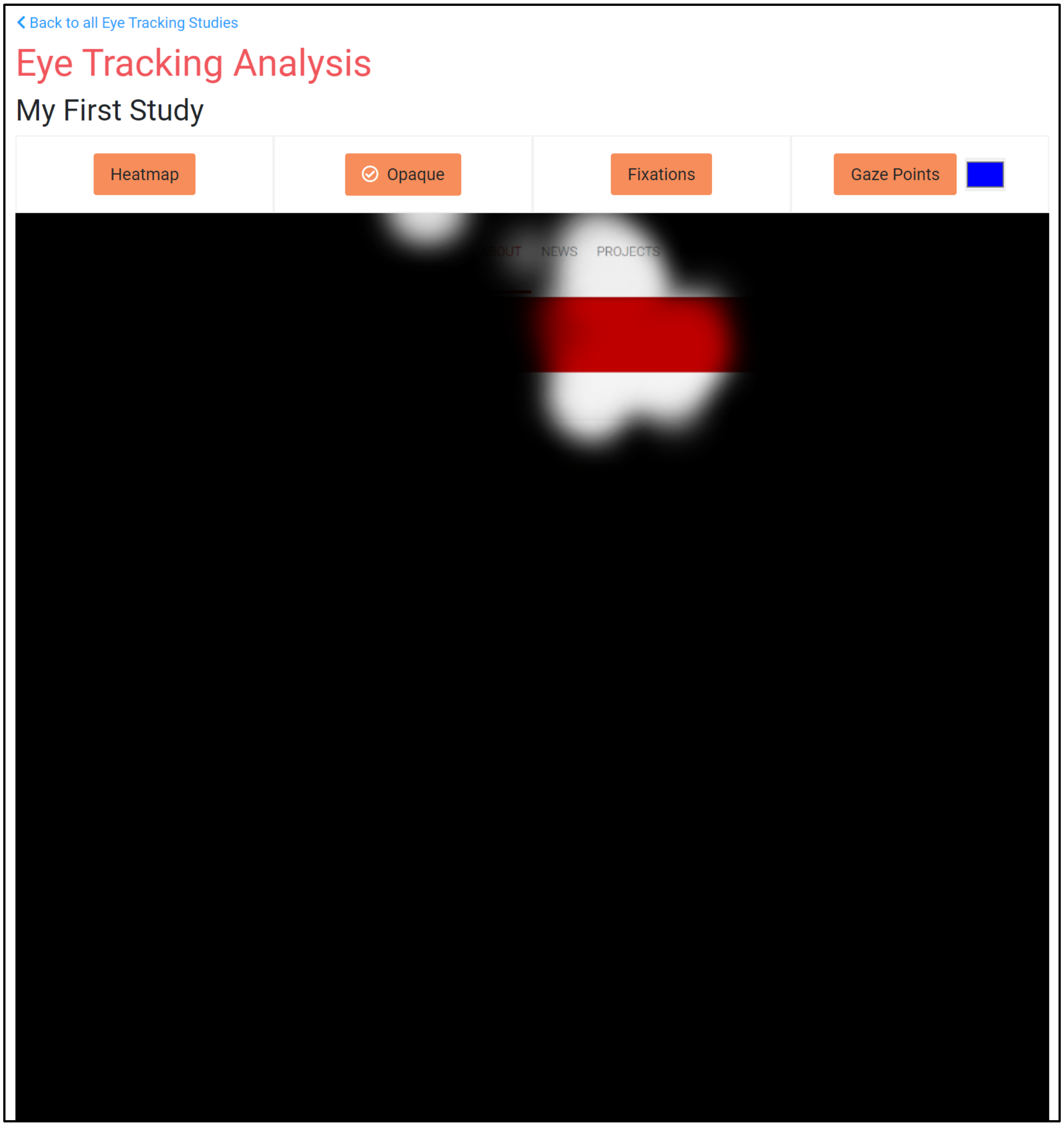


Figure 11

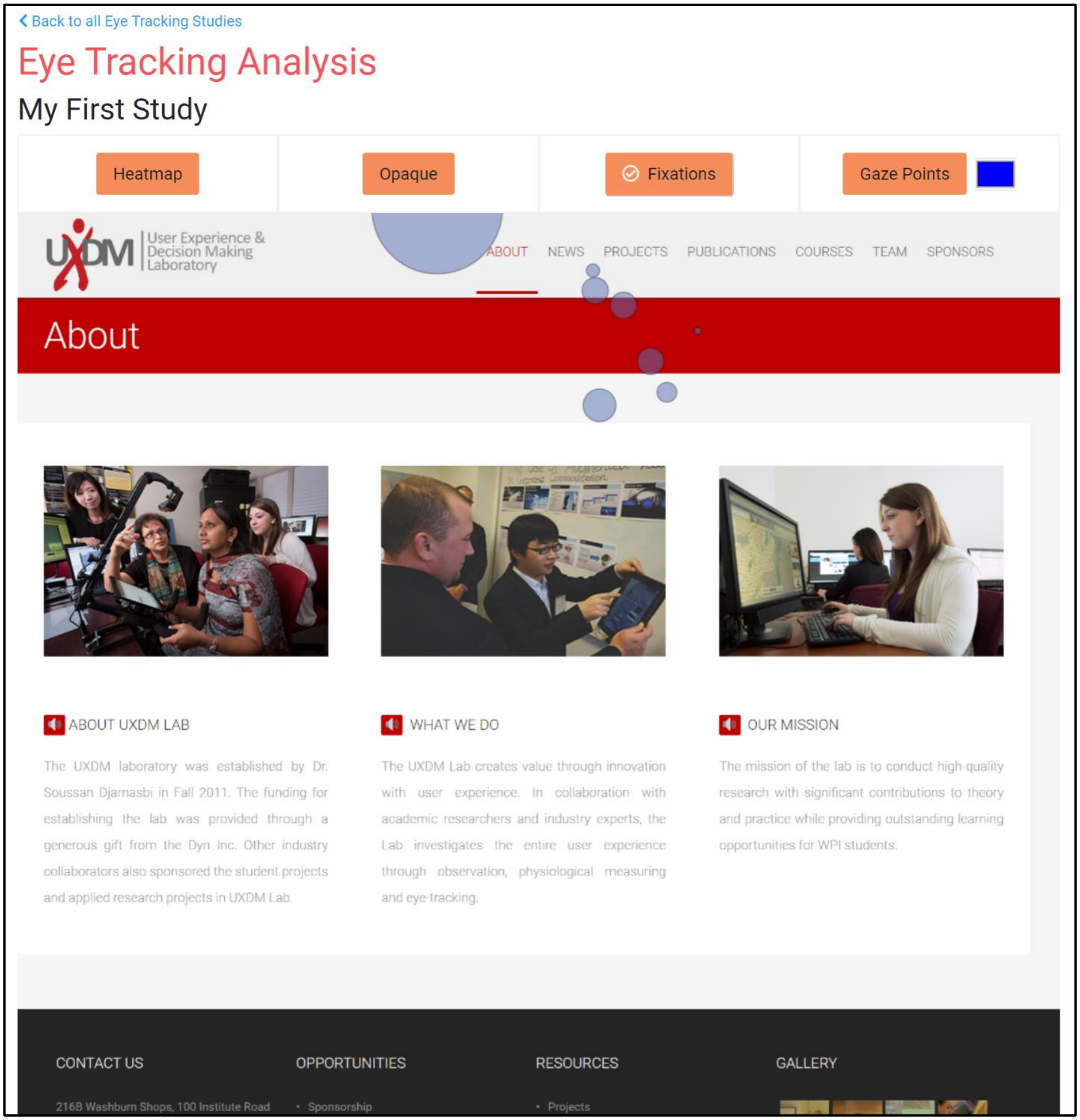
Opaque map from a sample eye tracking study



In addition to heatmaps, ike also generates visualizations for individual fixations. Fixations, which refer to a group of gaze points that are close in both spatial and temporal proximity, on ike are currently calculated using the Identification by Velocity Threshold (IVT) algorithm. This algorithm “uses a fixed velocity threshold to identify fixation and saccades, where fixations are segments of samples with point-to-point velocities below the set velocity threshold, and saccades are segments of sample with velocities above this threshold” (Andersson, 2017). The data is then overlaid on top of the study medium in the form of circles, with the radius of the circle correlating to the duration of the fixation (Figure 12). This fixation data describes when a participant’s eyes are not scanning for information, but rather holding their central foveal vision. In other words, the participant is focused on these areas, allowing them to take in detailed information about what they are looking at.

Figure 12

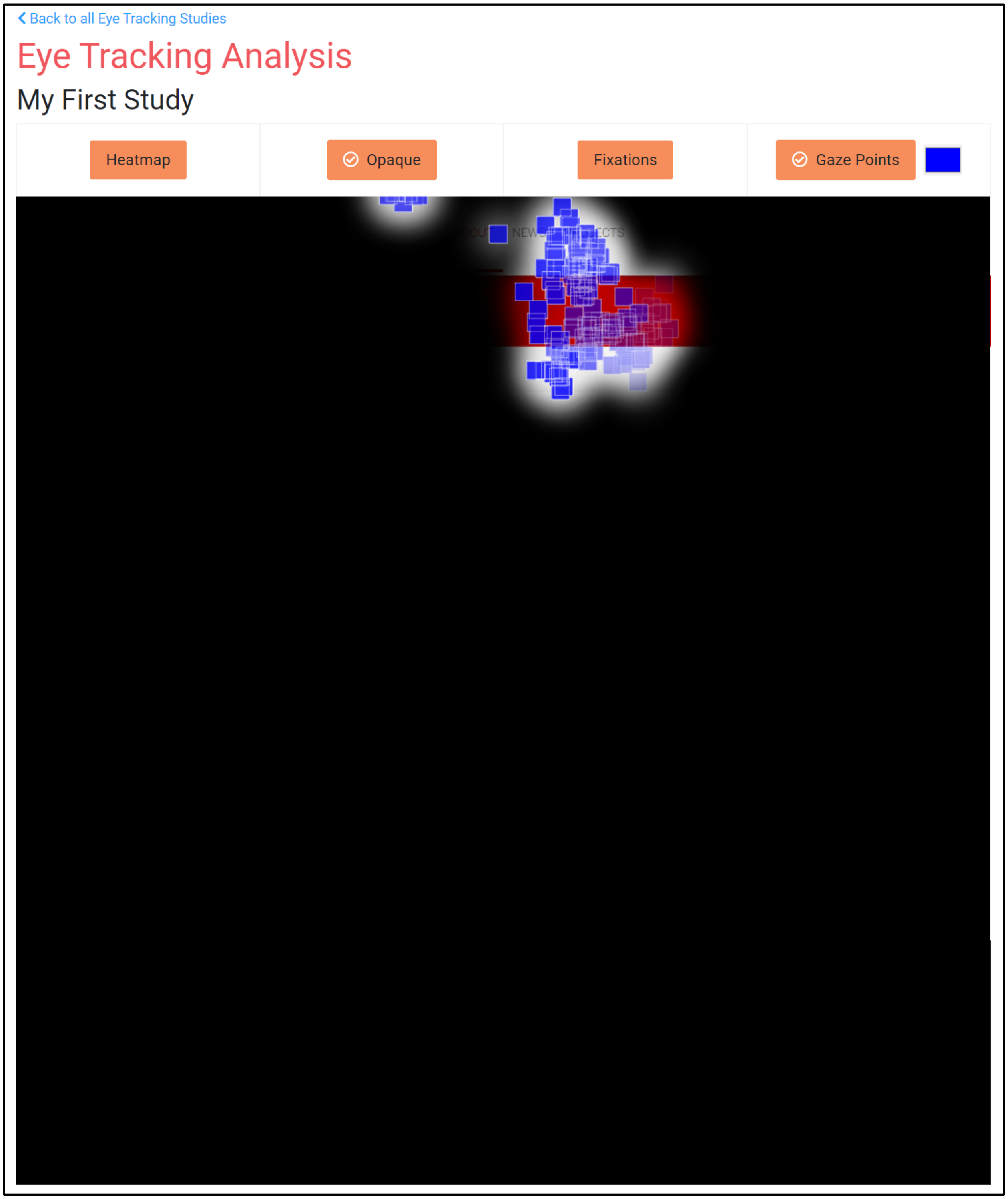
IVT fixations for a sample eye tracking study on ike



It is also possible to combine any of the eye tracking data visualizations on ike. Having the ability to look at any combination of visualizations provides many unique ways to look at the same data, empowering the researcher to draw more meaningful conclusions (Figure 13).

Figure 13

Visualizing gaze points and the opaque map simultaneously on ike



Discussion and Contributions

There is a clear need for a user experience research platform that is able to aid organizations in the creation and management of UX-driven innovations. Organizations need the ability to perform meta-analysis and share their user experience research artifacts across teams and departments. Ike fosters these opportunities for communication and heavily promotes collaboration Ike has been designed to fit this need in a way that is scalable, modular, and ready to grow as an ongoing project. This product has been developed in such a way that it is flexible to adjust as the demands for innovation are constantly changing at a rapid pace.

While UX driven innovations require organizations to manage their UX R&D efforts and share them with various teams across the organization, currently there is no comprehensive solution in the market that can effectively and efficiently address this need. Ike, as a group decision support system (GDSS) for developing, analyzing, and managing UX research, contributes to both knowledge and practice. From a theoretical point of view, ike can foster meta-analysis that can lead to new discoveries. From a practical point of view, ike can facilitate products and services that are successfully adopted by their intended users. As a novel GDSS that enables UX driven innovations, ike has a major positive impact on society.

Future Work

Because ike was built in such a way that it is extensible and modular, there are endless opportunities for it to grow as a research platform. Ike is flexible to adapt to market needs – and it is necessary to treat it as a product rather than a project. This means that ike is never finished, but is meant to continue to be refined, improved, and extended.

The card sorting module can be extended by adding more visualization options, one of them being a Multidimensional Scaling (MDS) visualization. The way MDS works is best described in Tullis and Albert's *Measuring the User Experience: Collecting, Analyzing, and Presenting Usability Metrics*,

> Imagine that you had a table of the mileages between all pairs of major U.S. cities but not a map of where those cities are located. An MDS analysis could take that table of mileages and derive an approximation of the map showing where those cities are relative to each other. In essence, MDS tries to create a map in which the distances between all pairs of items match the distances in the original distance matrix as closely as possible (Tullis and Albert, 2013, p. 222).

MDS produces a two-dimensional map of where cards in a card sort would be in relation to one another. By mapping the cards out on this scale, the cards can be clustered to form meaningful groups using participant data.

A study that is often paired with card sorting is tree testing, which is a type of study for evaluating the findability of topics in an organized hierarchy. In a tree testing study, participants are provided with a proposed information architecture (e.g., such as a menu). They are then given a set of tasks and asked where they would go if they wanted to complete that task. This type of study is possible to be performed remotely, enabling the collection of much more data than would be possible if each participant were required to visit for an in-person experiment. "Remote tree testing provides a quick, flexible, and high-volume method of acquiring feedback in a structured format that allows for quantitative comparisons" (Le, 2014). Since tree testing can be performed remotely, and task success can be easily quantified and measured, it makes sense for ike to have this capability.

With ike having the ability to consume and analyze large eye tracking datasets, a natural extension to the platform would be for ike to be involved in the data collection process as well. Due to the high cost of eye tracking hardware, low availability, and barriers to entry (e.g., participants need to be physically in the lab), there is a growing trend of webcam-based eye tracking, and its accuracy can be considered good enough for some basic eye tracking applications. “Only those studies that require a very detailed spatial resolution of fixations (e.g., studies in reading, or the dissection of singular items in a crowded display), very time-sensitive information (e.g., high spatio-temporal resolution), or a very short number of trials (e.g., one-trial paradigms) cannot be conducted online” (Semmelmann, 2017). This is an opportunity for ike to significantly lower the barriers to entry for researchers who want to perform eye tracking research but do not have access to an eye tracking lab or eye tracking hardware, as well as being able to perform the analyses and provide visualizations on the eye tracking data collected in the experiment.

References

Affairs, A. (2013, October 09). Card Sorting. Retrieved May 06, 2020, from https://www.usability.gov/how-to-and-tools/methods/card-sorting.html

Andersson, R., Larsson, L., Holmqvist, K., Stridh, M., & Nyström, M. (2016). One algorithm to rule them all? An evaluation and discussion of ten eye movement event-detection algorithms. *Behavior Research Methods*, *49*(2), 616–637. doi:10.3758/s13428-016-0738-9

Djamasbi, S. (2014). Eye Tracking and Web Experience. AIS Transactions on Human-Computer Interaction, 6(2), 37-54. Retrieved from https://aisel.aisnet.org/thci/vol6/iss2/2

Djamasbi, S., & Mortazavi, S. (2015). Generation Y, baby boomers, and gaze interaction experience in gaming. *Proceedings of the Annual Hawaii International Conference on System Sciences*, 2015-, 482–490. https://doi.org/10.1109/HICSS.2015.64

Djamasbi, S., & Strong, D. (2019). User Experience-driven Innovation – Theory and Practice: Introduction to Special Issue. *AIS Transactions on Human-Computer Interaction*, 208–214. https://doi.org/10.17705/1thci.00120

Duchowski, A. T. (2017). *Eye tracking methodology: Theory and practice* (3rd ed.). London: Springer. doi:10.1007/978-3-319-57883-5

GridFS. (n.d.). Retrieved May 08, 2020, from https://docs.mongodb.com/manual/core/gridfs/

Holmqvist, K., Nyström, M., Andersson, R., Dewhurst, R., Jarodzka, H., & Van de Weijer, J. (2011). *Eye tracking: a comprehensive guide to methods and measures*. Oxford: Oxford University Press.

I-CORPS. (n.d.). Retrieved May 12, 2020, from https://www.wpi.edu/offices/technology-commercialization/i-corps

Jacobs, A. (2017, March 09). UX: Creating Proto-Personas. Retrieved April 05, 2020, from https://uxdesign.cc/ux-creating-proto-personas-76a1738401a2

Jain, P., Djamasbi, S., & Wyatt, J. (2019). Creating Value with Proto-Research Persona Development. *Lecture Notes in Computer Science (including Subseries Lecture Notes in Artificial Intelligence and Lecture Notes in Bioinformatics)*, *11589*, 72–82. https://doi.org/10.1007/978-3-030-22338-0_6

Johansen, E. (2014, October 29). Essay #3: Design for Everyone is Design for No One: How Focus Leads to Bigger Impact. Retrieved May 01, 2020, from https://www.designthatmatters.org/blog/2014/10/28/firefly-essay-3

Le, T., Chaudhuri, S., Chung, J., Thompson, H. J., & Demiris, G. (2014). Tree testing of hierarchical menu structures for health applications. *Journal of Biomedical Informatics*, *49*, 198–205. doi:10.1016/j.jbi.2014.02.011

Semmelmann, K., & Weigelt, S. (2017). Online webcam-based eye tracking in cognitive science: A first look. *Behavior Research Methods, 50*(2), 451–465. doi:10.3758/s13428-017-0913-7

Sokal, R. R., & Michener, C. D. (1958). A Statistical Method for Evaluating Systematic Relationships. *The University of Kansas Science Bulletin, 38*(2).

Tullis, T., & Albert, B. (2013). *Measuring the User Experience: Collecting, Analyzing, and Presenting Usability Metrics*. Waltham, MA: Elsevier/Morgan Kaufmann.

What is Human-Centered Design? (n.d.). Retrieved May 06, 2020, from https://www.designkit.org/human-centered-design

Wilson, V., & Djamasbi, S. (2015). Human-Computer Interaction in Health and Wellness: Research and Publication Opportunities. AIS Transactions on Human-Computer Interaction, 7(3), 97-108.

Appendix A

The distance between cluster A union B and another cluster x is given by multiplying the magnitude of each branch in the cluster (A and B) by its individual distance to the cluster x, divide by the total magnitude of the new cluster A union B.

$$d_{(A \cup B),x} = \frac{|A| * d_{A,x} + |B| * d_{B,x}}{|A| + |B|}$$

Appendix B

Ike can be visited at https://ike.wpi.edu