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Observations of Daily Living: Visualizations

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The visualizations we worked on are linked to Annette Greiner and Nat Wharton's master's final project. Together with Abe Coffman, Matt Gedigian, and James Tucker, they are building an iPhone/web application, KidOoDL[1], for parents to enter health-related observation data about newborn infants. Data from the iPhone synchronizes to the web application, with which users can delve more deeply into the information they have collected. It is for this web application that we aim to build our visualization.

Parents can collect daily observations for activities including feeding (both bottle feeding and breast feeding), diapering, and sleeping. In addition, parents can note the completion of developmental milestones. For the daily observations, we designed two linked visualizations focusing on two factors that are important for parents, amounts and schedules. The two daily visualizations share a timeline for selecting date ranges. We designed two different visualizations of milestone data. The milestones are from the Center for Disease Control's list of developmental skills, and are grouped into categories (such as movement, cognitive, or social and emotional) and into age ranges.

Daily Observations Visualizations

We began with information gathered in the needs assessment phase of the master's project. This included interviews with parents and pediatricians as well as surveys of each major user group. In setting the scope for this project, we decided to focus mainly on the needs of parents. We considered what pediatricians would want as well, because we expect that parents will share the visualizations with their pediatrician. In our needs assessment, we found that parents had specific questions that they would want answered: Is my baby beginning to develop a specific sleeping pattern? How many hours does my baby sleep each day? How long are the naps that my baby takes? At what times does my baby tend to fall asleep? Is my baby eating more or less now than in a previous time period? At what time does my baby normally eat? How many diapers does my baby use every day? Is my baby acting differently on weekends in comparison to weekdays when he or she is in daycare? Is there anything extraordinary happening?

At first we wanted to focus on predicting the trends in sleeping, feeding, and diapering that the baby was developing. We wanted to visualize this by making a probability graph where we would plot the percentage chance that the baby was asleep, was hungry or needed another diaper at any given time of day. We were thinking about plotting this data on top of a representation of the current day. We would indicate at what time the baby slept, fed or needed a diaper that day. In Figure 1 you can find our first paper draft. The bars in the 'Daily View' indicate the activities of that day and the lines indicate the probabilities.

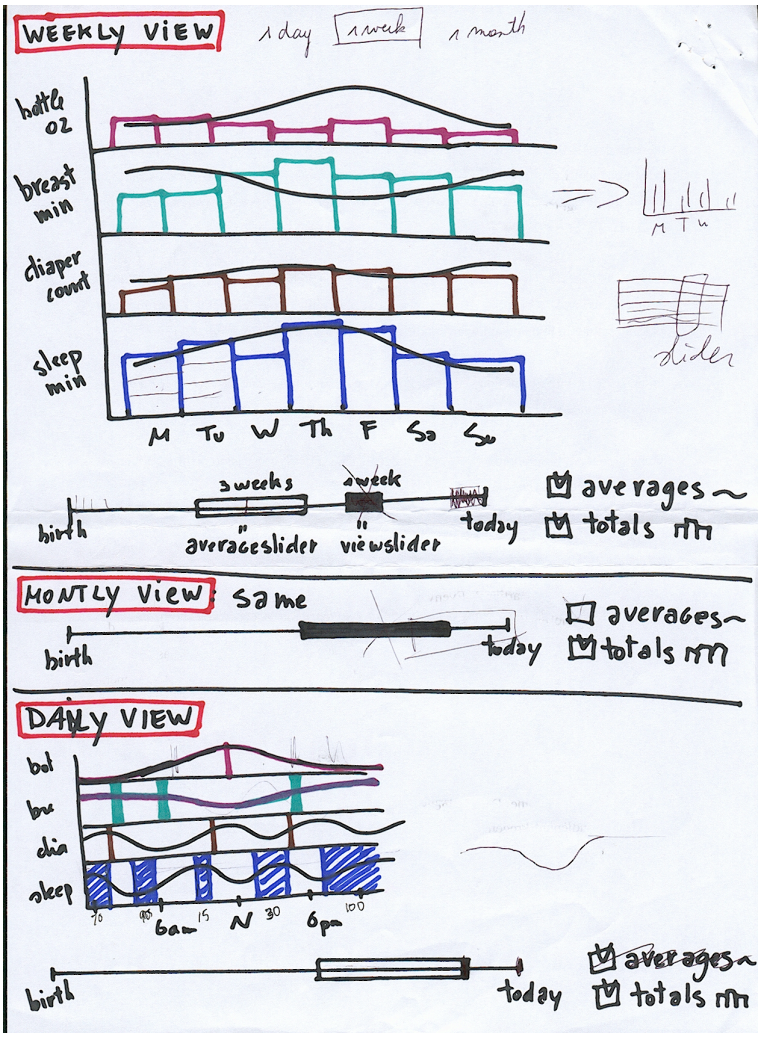

Figure 1: Early draft of daily observations with probabilities for events occurring at a given time.

Another thought was to include a bar graph where the amounts of sleep, breast feeding, bottle feedings and diapers were indicated. We planned to add a line in the graph so that parents could see if the baby's currently viewed activities were different than the average (see Figure 1, top). We wanted parents to be able to select the time period over which the probability and the average were calculated. We wanted to do this by adding a timeline where they could select the week for which they wanted to see the raw data with one slider and indicate which weeks should be included in the comparison calculations with another slider (see Figure 1, center). We concluded that this visualization was not very helpful for newborn babies who had not developed a stable pattern, because the older data would hide any patterns emerging in the newer data. We also thought it would be confusing to use lines for both probability and averages.

We liked the idea of plotting the amounts of sleep, breast feeding, bottles and diapers, and we have held on to this idea. A bar graph seemed the best way to indicate this, because it is

a view that most people can easily read and presents the data easily. It was clear early in the design process that we needed to keep the detailed view of each observation type on its own axis, since sleeping and breast feeding are measured in minutes, bottle feedings are in ounces, and diapers are in counts. We also liked the idea of allowing parents to select which time period they saw in detail. We translated this into a 'full view' at the top of the page where all the data would be presented in four different sparklines. We would use this graph for letting parents select the day, week or month they wanted to see in what we called the 'view area' (see Figure 2). The data from the selected time period would appear in the bar graph showing the amount of sleep, breast feeding, bottles and diapers.

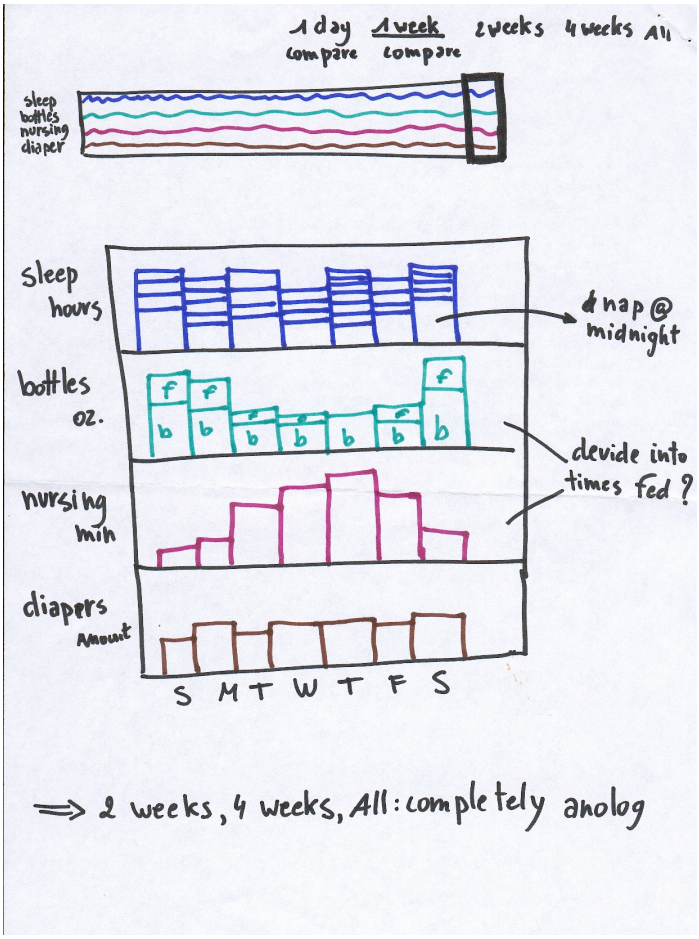

Figure 2. Early draft of daily observations with 'full view'.

Instead of letting parents select a time period from which the average would be calculated, we wanted them to select a 'compare area', so that they could spot increases or decreases. This would be an extra time period that would show up in the bar graph, in a different color, showing the activities of the baby during this second time range. The side-by-side bars would enable parents to compare the current selected week with the selected comparison week on a day-of-the-week basis. The parents could select those areas in the 'full view'.

We had a lot of trouble figuring out what would be the best way to enable parents to select the view and compare areas. We wanted to let them select each area independently and change the size of each area. At first we thought about letting them make the box bigger or smaller by dragging it. We realized, however, that this could be confusing because they might not make selections that could be compared on a day-by-day basis. For example, selecting to view a Monday, a Tuesday and a Wednesday in the view and choosing a comparison of Wednesday through Sunday would generate a confusing graph. After some more thought, we decided that the view area should be fixed to the most recent time period, because it seemed to make more sense for the parents to see how the child is doing currently compared to an earlier time. We also decided to use buttons for selecting the length of the view area instead of the slider, so that we could make sure the comparison days were a multiple of the view days. All these changes were made to restrict the actions on the full view (see Figure 3).

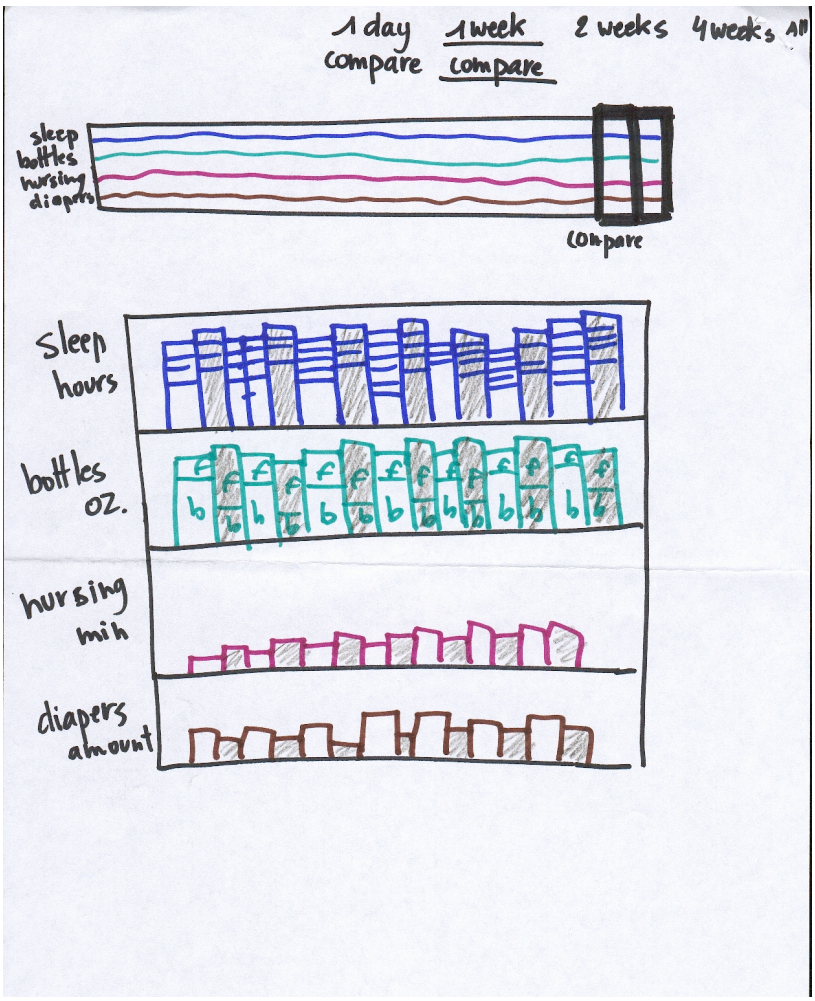

Figure 3. Early draft of dail observations with comparison option.

The parents could choose to show one day, one week, two weeks or four weeks. If they selected one week, two weeks or one month, four bar graphs would appear showing the

amount of sleep in hours, the amount of breastfeeding in minutes, the amount of bottle feedings in ounces and the number of diapers (see again Figure 3). If the parents selected only one day, another visualization would appear: instead of the bar graphs, a timeline of 24 hours would appear indicating at which times the baby was asleep, when it fed and when it needed a diaper (see Figure 4). We had some trouble with figuring out a comparison view when just one day was selected. Using gradations of color (lighter colors indicating older events) to indicate previous days did not work (see Figure 5).

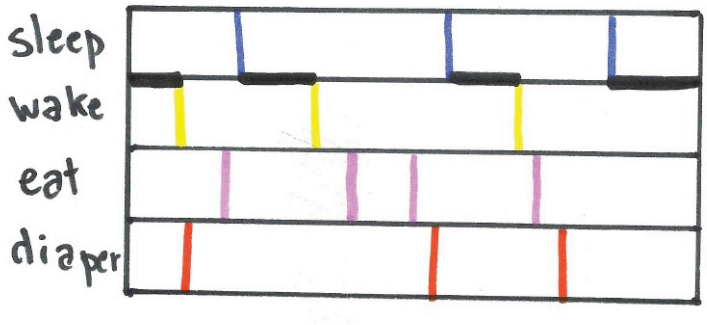

Figure 4. Early attempt at a design for a daily view for observations.

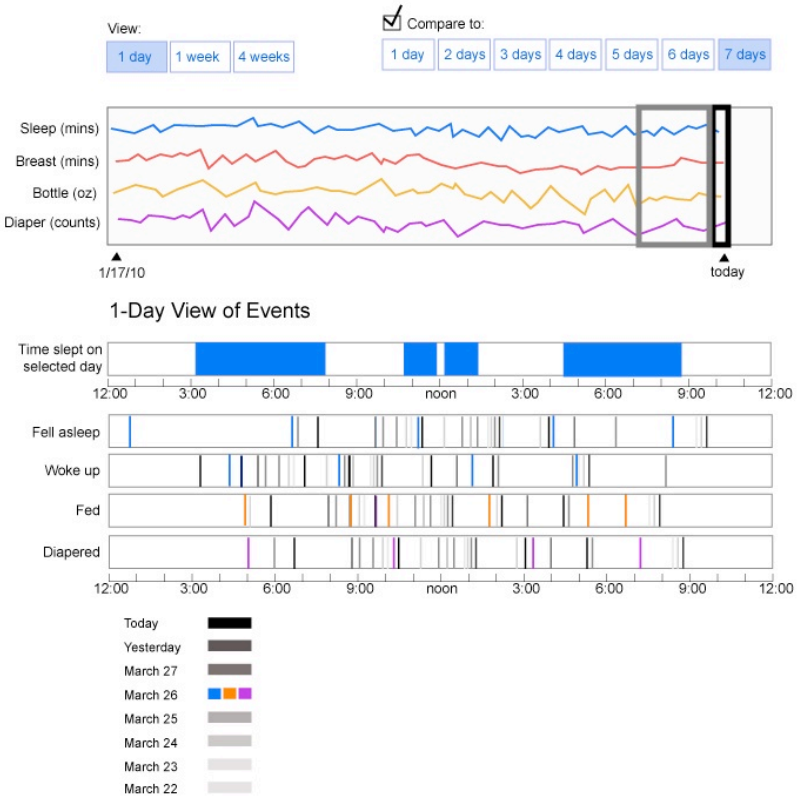

Figure 5. Second attempt at a design for a daily view for obsevations, using gradients to indicate past events.

After a meeting with prof. Aragon we decided to differentiate the views into an amount view and a time view. For the amount view, we kept the bar graphs we had been using for one-week, two-week and four-week views, because those graphs were showing the amounts of sleeping, feeding and diapering. We completely changed the daily view. Rather than just presenting a single day, it would present events for one day, one week, or one month over time. The y axis would then represent a 24-hour time period. Instead of placing the observation types one underneath the other, we placed them in side-by-side bar graphs for sleeping, feeding and diapering, grouped by day (see Figure 6). For comparisons, we allowed the user to select only one observation type, preventing the user from creating a confusing graph with both dates and observation types varying along the x axis. (see Figure 7).

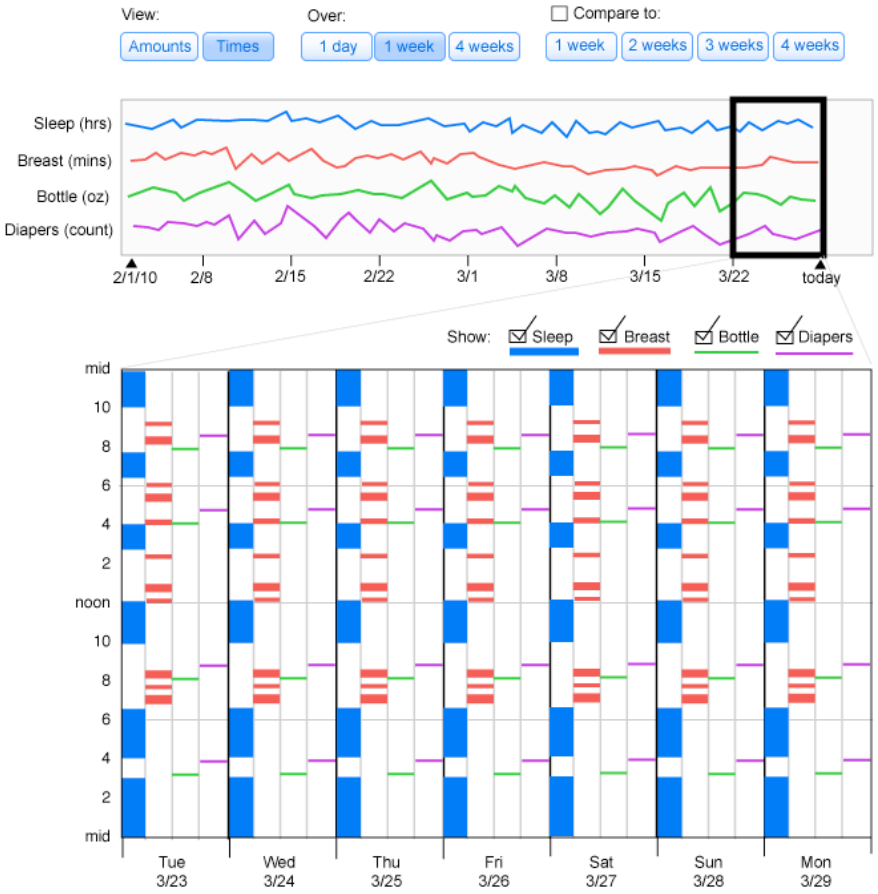

Figure 6. Time view showing all observation types for a single week, grouped by day.

Figure 7. Time view showing sleep events for one week compared to the previous week.

We mocked up the graphs in illustrator and presented them in the midterm presentation. After our presentation, we made some small adjustments to our illustrator views, moving and tweaking the buttons to avoid labeling them with colors used in the graphs (see Figure 8). We presented our then latest visualizations to three parents of small children to review. We asked each parent to work through a list of test tasks based on our initial list of parental questions.

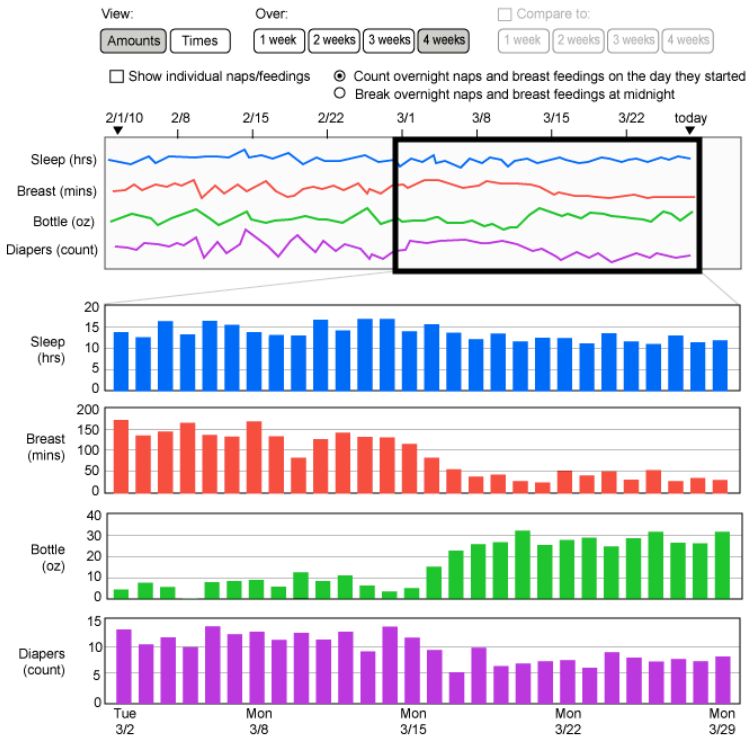

Figure 8. Daily observations with one month set in the view, paper prototype design for usability testing.

In the usability tests, parents told us that they really liked the information they received through the graphs. All testers had some problems with finding the buttons and navigating. A huge problem that came forward was the fact that they all used the compare view for tasks that would have been easier to answer when using the less complex presentation with "compare" turned off. We concluded that the compare view generally confused people, and for that reason we decided to drop it from the visualization. Deleting the compare view allowed us to reduce the restrictions on selection of dates and thus reduce the number of buttons on the screen, making it easier for people to navigate. Since we no longer needed to make sure that comparison selections were a multiple of the view, we decided to remove the time selection buttons entirely and allow the user to simply select a single date range with two separate sliders, one for the start and one for the end of the range. This allowed us to use more conventional looking sliders. We also added a textual prompt to indicate that the sliders could be used to select a date range (see Figure 9).

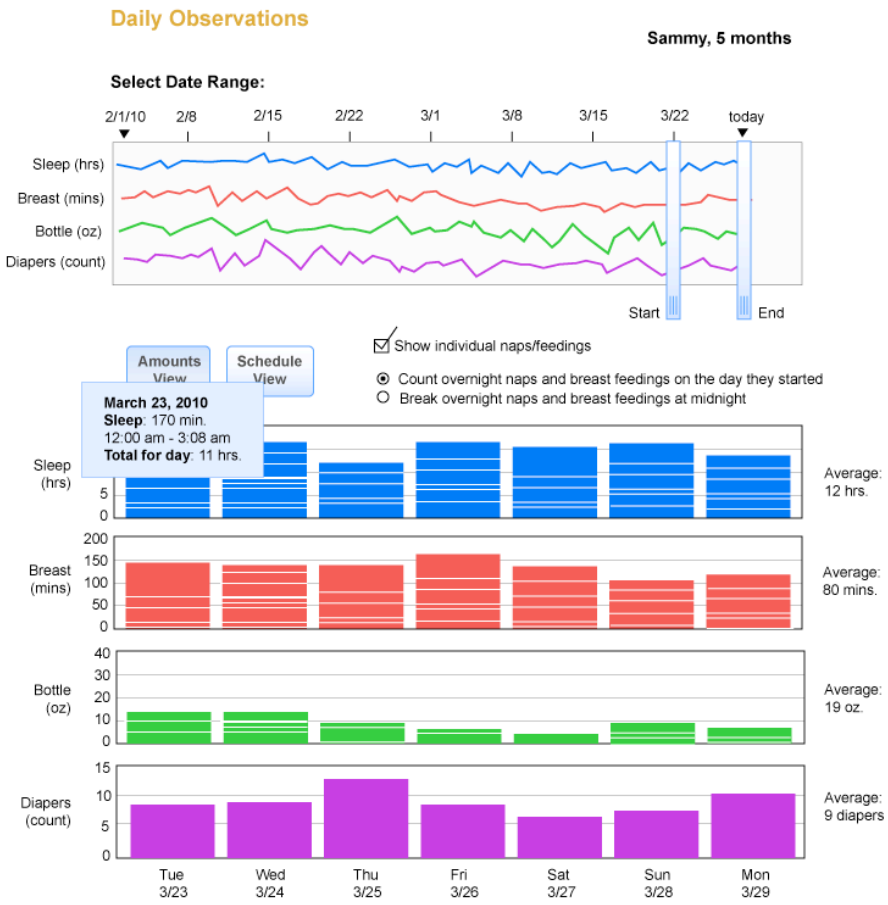

Figure 9. Final design for daily observations showing amounts view with sleeping and feeding totals broken into individual naps and feedings.

Users also were inclined to try interacting with the graphs. They wanted to see tooltips when hovering over the graphs with the mouse. We therefore added popup windows for hover states to the design.

We were not able to build a complete interactive prototype for this set of visualizations in the time allotted. We were able to make a partially functional version that used real data from one parent for the amounts view. (See Figure 10.) The prototype, such as it is, was built with the javascript graphing library Flot, and additional interactivity was built with JQuery. Other graphing libraries we tried did not allow us to use both stacked and side-by-side series on the same bar graph and did not appear to allow stacking of bars with space between, as called for in the schedule view. We did not consider libraries that we knew would not work with Internet Explorer, since we plan to use the visualizations in a real-world system. We chose not to use Flash because we would like users to be able to view the graphs with an iPad, which runs a version of Safari that is not Flash capable.

Figure 10. Screen shots of interactive prototype of amounts (top) and schedule (bottom) views.

Developmental Milestone Visualizations

Developmental milestones are skills a child typically can perform during a particular range of ages. Developing skills late or even early can indicate a problem that may require medical attention. Children vary in the order in which they develop skills, however, and one or two skills may develop late or early without signaling a serious developmental problem. All milestones in the current visualization are based on the set published on the Centers for Disease Control (CDC) website[2]. They include seven age ranges: 3 months, 7 months, and one each for 1 - 5 years, and eight different milestone categories. Our spider plot-like visualization, described below, required us to combine two of the categories, 'Social and Emotional' and 'Emotional', in order to make it possible to arrange and connect a contiguous pattern of dots without skipping wedges. The contiguous milestones categories were: 'Hand and finger skills', 'Language', 'Cognitive', 'Movement', 'Social and Emotional', 'Vision' and 'Hearing and Speech'.

With the visualization of the milestones we aimed to make it possible for parents and physicians to detect anomalous achievement dates of milestones and to indicate infant development progress in relation to the CDC-indicated "normal" age ranges. We also sought to enable parents (and physicians) to compare different developmental categories, and further wanted to present the information without overly alarming the parents.

Two visualizations were designed to present milestones. The first depicts the time-series data of the milestones categorically grouped into horizontal lines. Each skill the baby demonstrates is depicted on a timeline. The color of the "dot" of the milestone indicates the age range in which the milestone should typically appear (according to the CDC). The same distinct colors are then used to indicate the corresponding CDC age ranges above and below each milestone category, as a way to easily compare the achievement age of the milestone with the appropriate age range when it "should" occur.

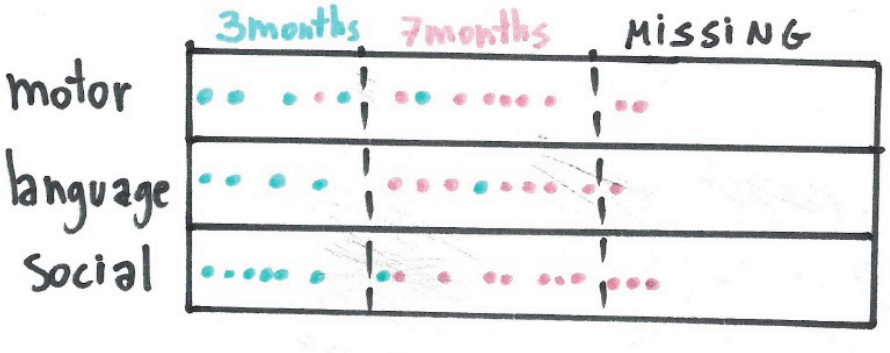

Figure 11: First draft: linear milestones: milestones all in-line.

Figure 11 shows our first draft of this idea. We next added a trailing column, indicating which milestones "should" have happened by the proper time, but still had not occurred.

We gave this column the caption, ‘delayed’, but after some debate we ultimately chose to use "not yet observed"(though this does not appear in our current designs for this paper). We further designed a view to reveal individual sections of all milestone details (the exact text) for a category of milestones, on-click. We actually implemented a simpler view that reveals all milestones at one click. We expect to implement the original category-based expansion idea soon. The expanded view is ideal for printing and for sharing milestone details with a physician. For the horizontal time-scale we decided that the first year milestones needed to take up more space than later-year milestones, but that the first year's months should be proportionally spaced. The visualization would be extremely wide, horizontally, and very sparse if we made all months equidistant to the early months, and too condensed in the first year to reveal detail if we spaced it equal to the later years. We decided to depict the difference in scale with diagonal lines connecting time ranges on a smaller, single-scale timeline with the corresponding columns. We did not get a chance to implement them on the live version, but plan to do so. (You can find multiple drafts in Figures 12 to 16).

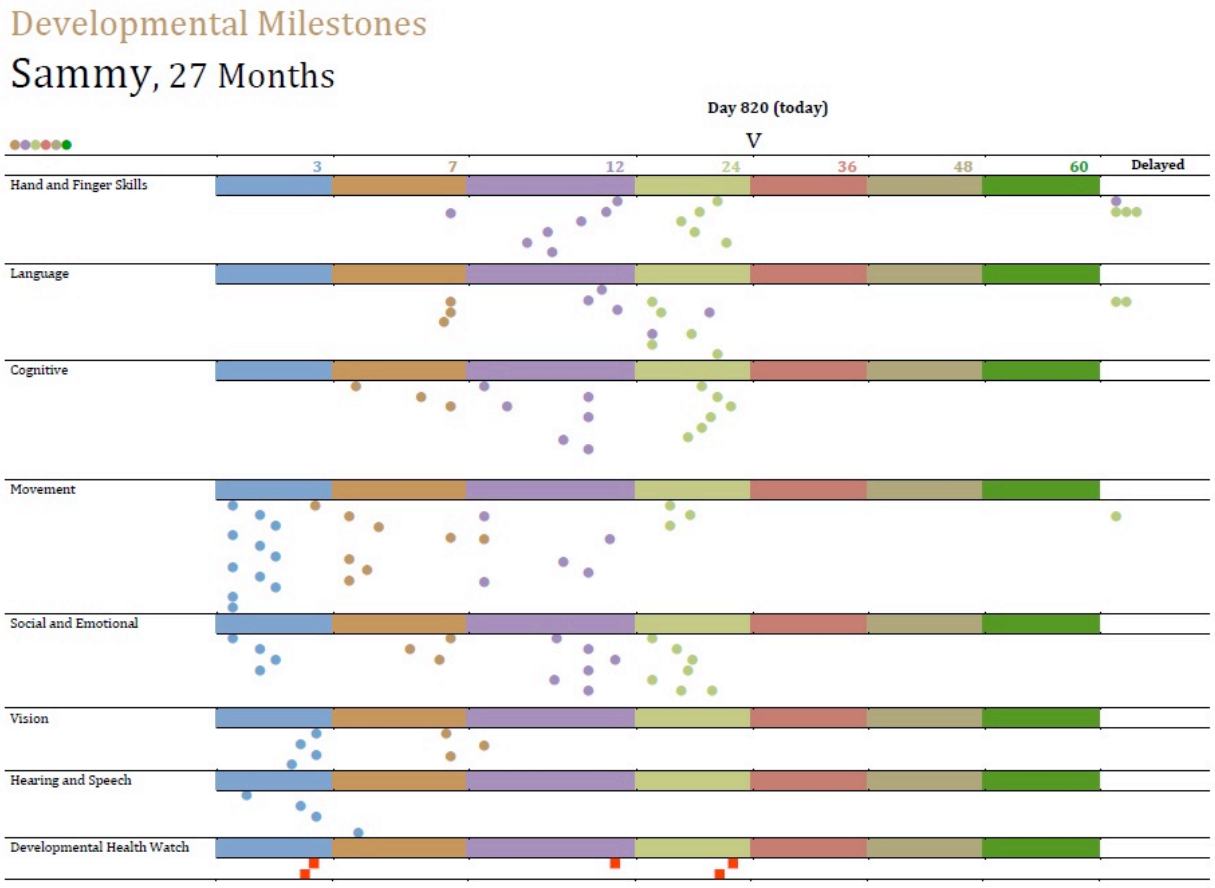

Figure 12: Second Draft: linear milestones: realistic milestone data is plotted – each milestone is plotted on a separate vertical line for each category. The infant's current age is depicted, and an indication of the current day is on top.

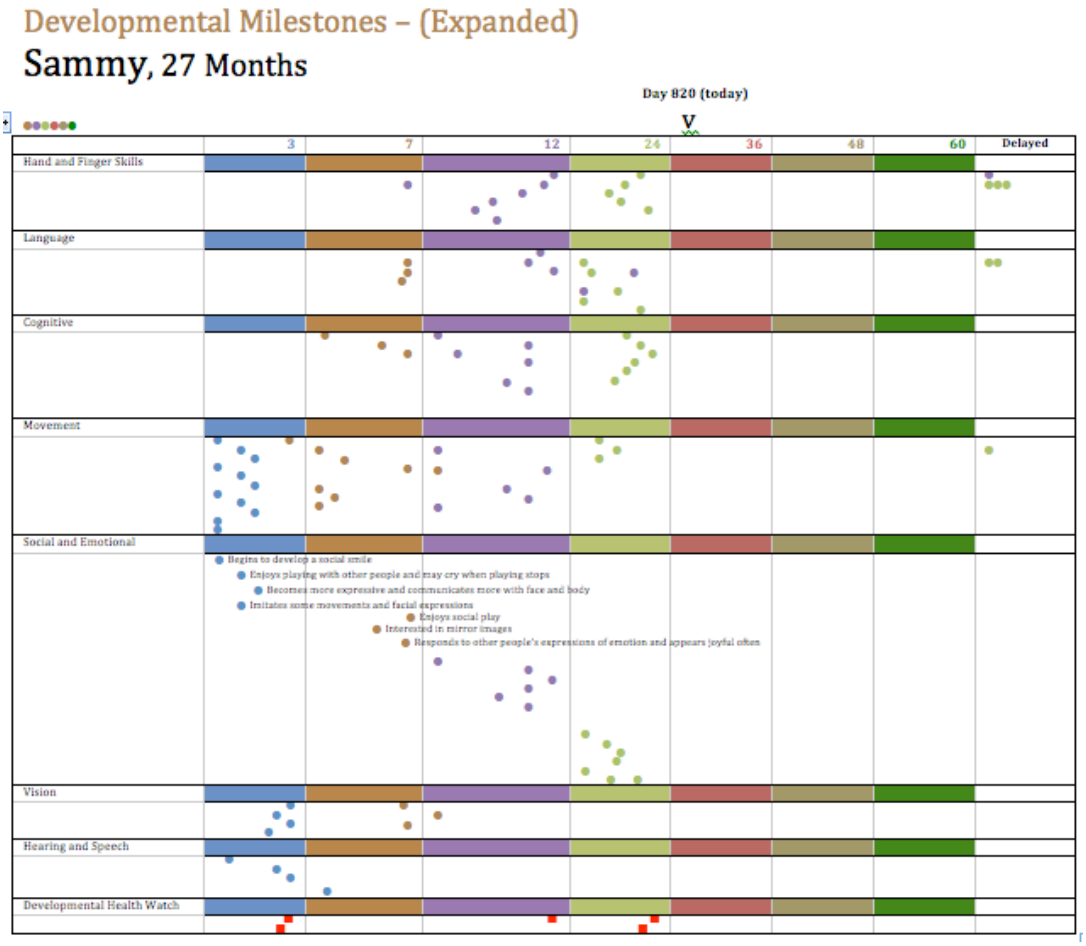

Figure 13: Second Draft: linear milestones: (expanded).
Milestone details appear when a category is expanded.

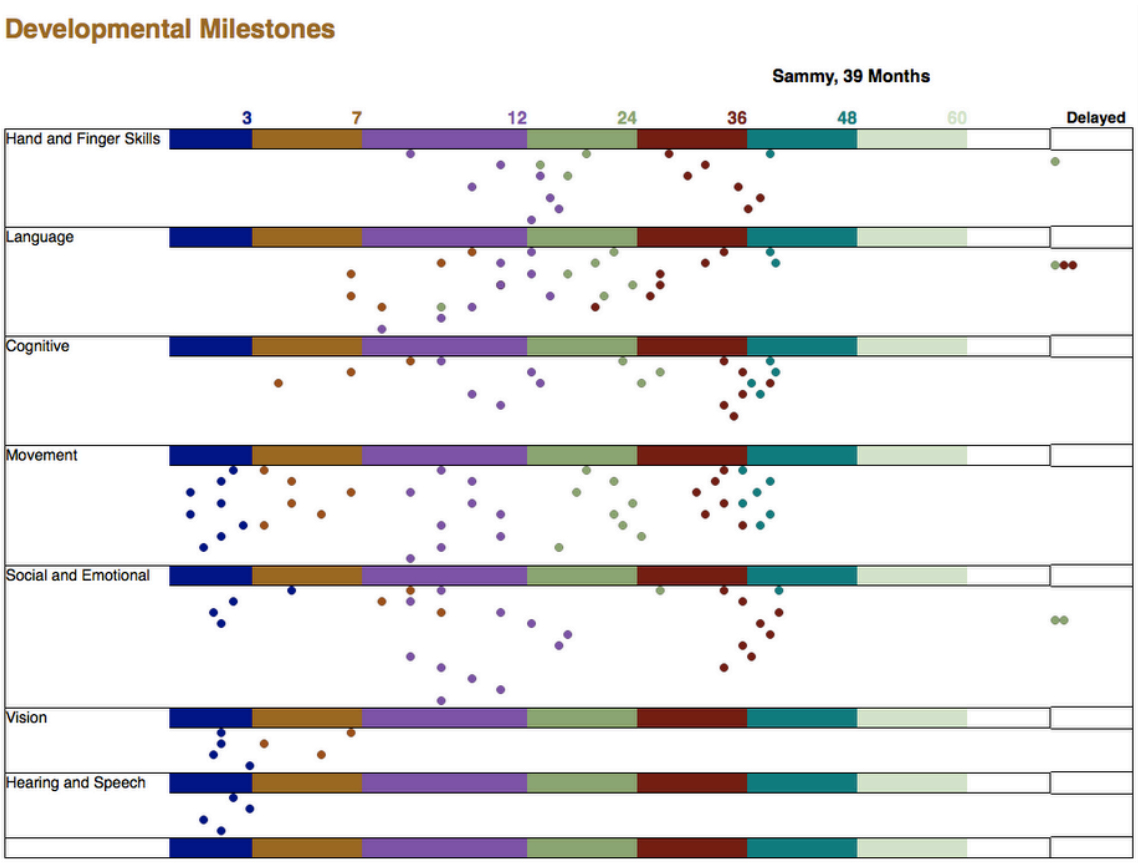

Figure 14: linear milestones: live version (pre-usability test).
Simulated data (in json) is plotted)

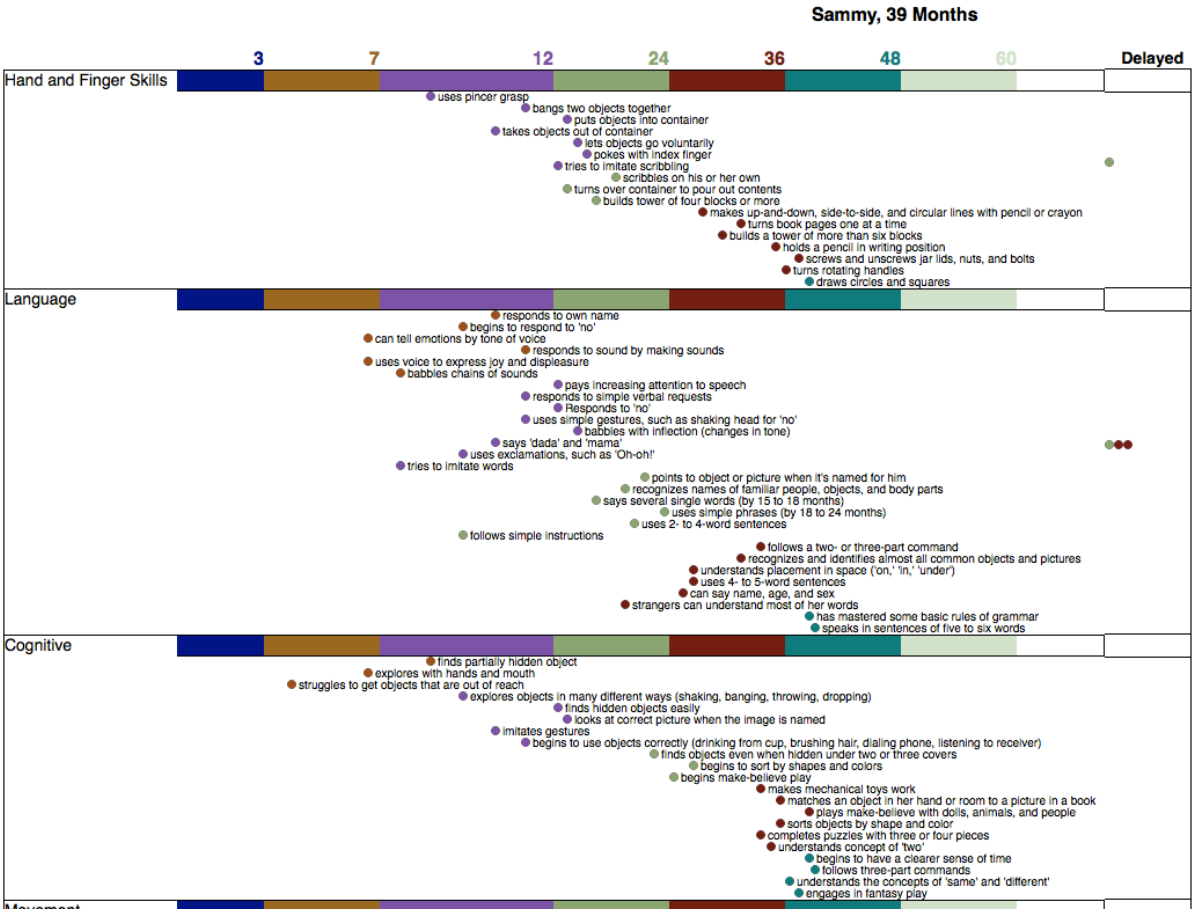

Figure 15: linear milestones: live version (expanded) – details are revealed.

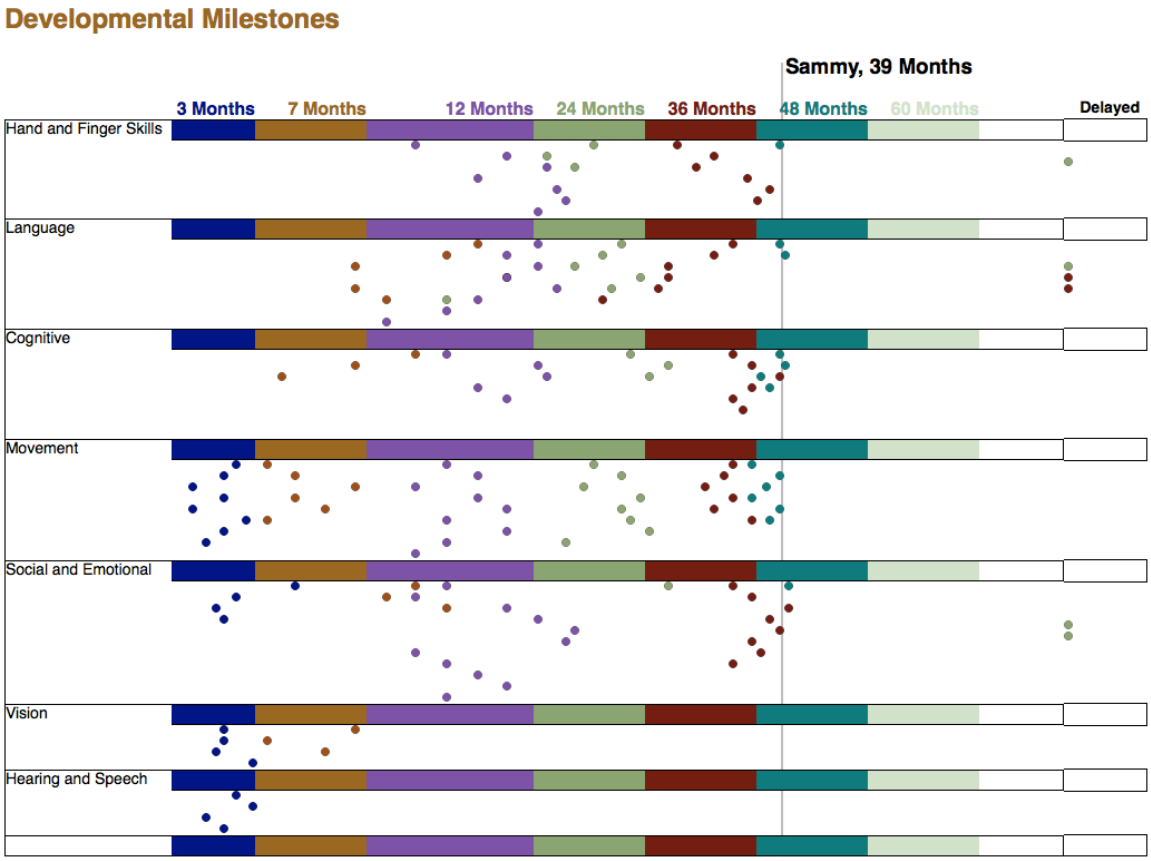

Figure 16: linear milestones: live version (current). Date line and month labels added.

Our usability tests revealed that people first needed to take some time to think about what the visualization depicted, but then we found that they could read the plot correctly without any explanation. They thought it was 'really cool' that the plot gave an overview of what their child had achieved, and one woman said she thought this would be great to show to friends and family. We also discovered that people expected to receive detailed information when hovering over the individual milestones. Subjects also indicated that they wanted explicit labeling with the word "Months" for each age range (our previous iterations only included numbers for the number of months), and also wanted a line indicating "today". After the usability test we also added specific milestone details on demand when hovering over individual milestone dots and we kept the idea of showing details on click.

After usability tests, we also succeeded in the significant challenge of implementing the visualization using our own custom javascript, jquery, css, and html. Our work involved developing a javascript function to appropriately scale the time and to figure out a means to draw on a background canvas to plot the current day (added after usability testing). Code to expand and collapse the visualization in pure javascript was completed, as well, but due to time constraints, a hack was made to trigger the different code on separate pages. In the future all the code will operate on a single page. Of special significance, we created a loosely-coupled data set to represent realistic milestones for a 39 month-old infant. All data was represented in json, and intentionally designed to be served from our custom web

service in the (very near) future. to integrate with our iphone/web service synchronization. We used identical json data in our other milestone visualization (in the next section of this paper) which makes comparison between the milestones possible.

After launch of our application, we plan to overlay actual date-ranges of other infants and when they achieved each milestone (after we capture more data). The range of dates corresponding to the group will be either indicated as a shaded region along the time axis in line with the milestone dot, or as a bullet graph or distribution graph, depending on which seems most appropriate.

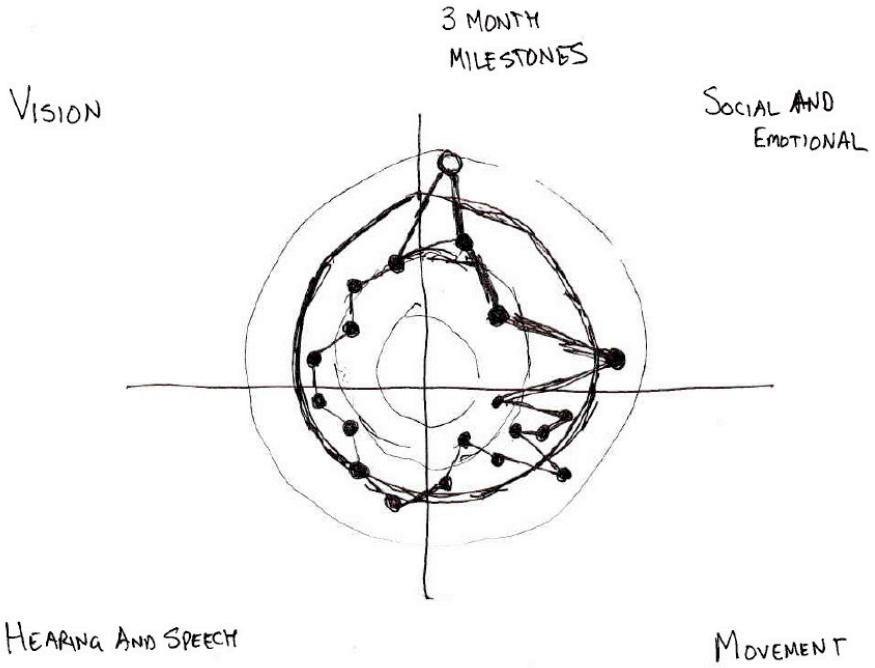

Figure 17: Spider milestone: early draft

The second milestone visualization is a bit more complex and experimental compared to the linear visualization, as it falls slightly more to the 'art' end of visualization 'science'. Our goal was to attempt to depict milestone data as a shape to act as a kind of a representational snapshot of the infant (see Figure 17). We hoped that drawing a line between points would allow category trends to better stand out. (instead of just deriving trends from individual dots alone). It should also be noted that parallel coordinates graphs include lines between 1-dimensional categorical data. Plotting the 1-dimensional categorical data could, of course, be performed on a straight vertical (or horizontal) axis, as already demonstrated in our linear timeline, and not suffer from typical comparative issues in discerning angular data, but we wondered if angles representing categories, and the addition of shape, and potentially reduced size might be worth the tradeoff. We also knew that while individual micro-angles within categorical data did not actually represent any particular dimension, the angle-ranges of each category did represent category membership.

We plotted all data points in a polar graph divided into the seven different milestone categories. We planned to reuse the same hues found in the linear milestone visualization to group the milestones with their appropriate age range, to facilitate concept mapping. We soon found out that this graph, with every color and age range, was really overwhelming and hard to read. At that point we decided to plot each age range on a different spider graph, in small-multiple regions, almost like archery targets. By using one age range background color as a "target", the idea was that we could indicate if a milestone happened sooner or later then expected (whether the milestone dot with the same hue "hit" the target region or not) (see Figures 18 - 19). We also added details on demand when a user hovers over the dots (see Figure 20).

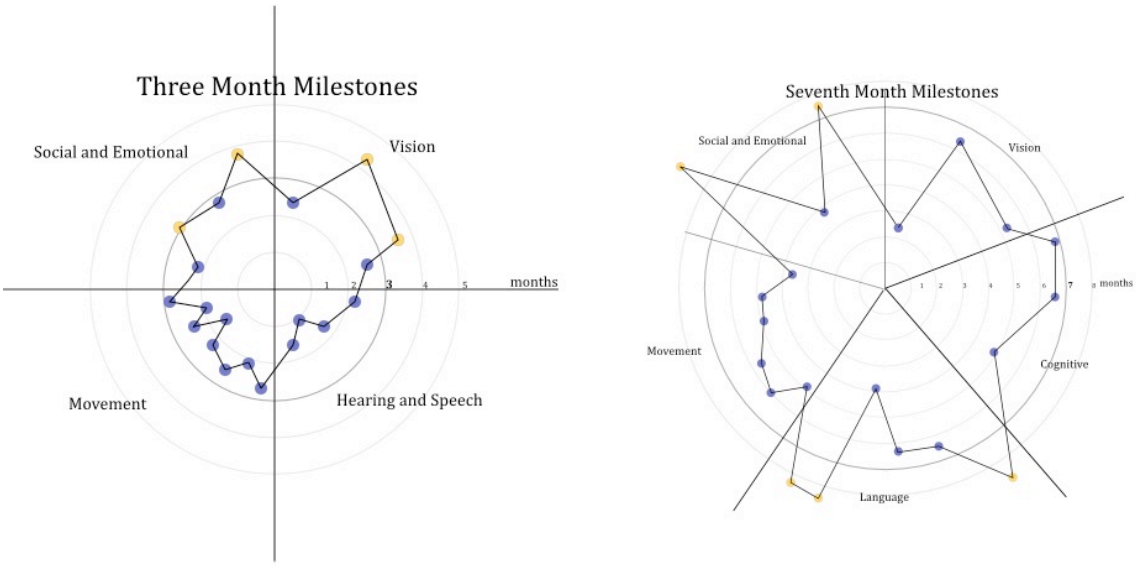

Figure 18: Spider milestone: second drafts drawn using inkscape

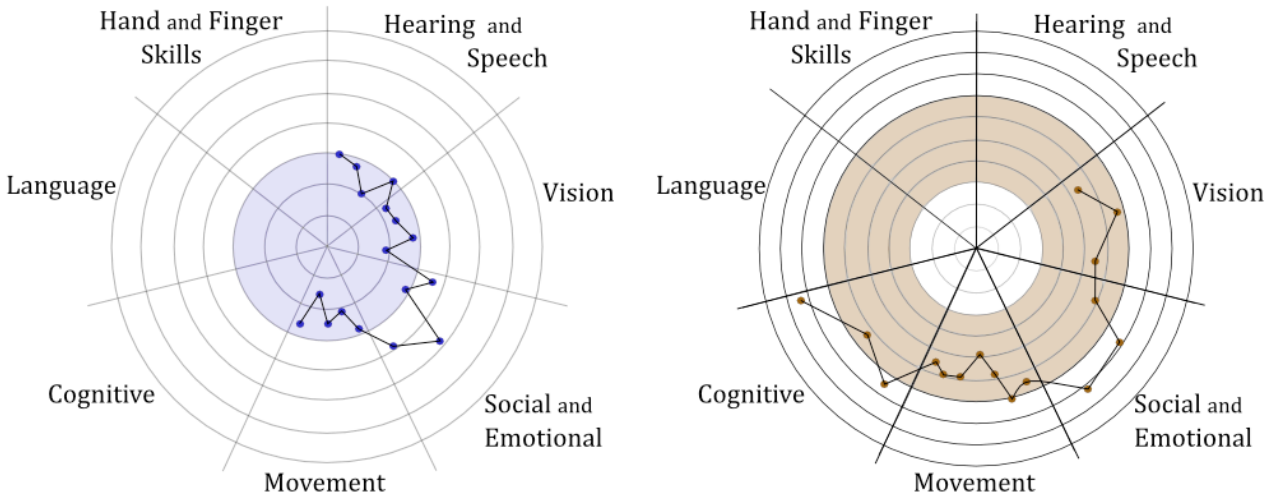

Figure 18: Spider milestone: third drafts drawn using inkscape

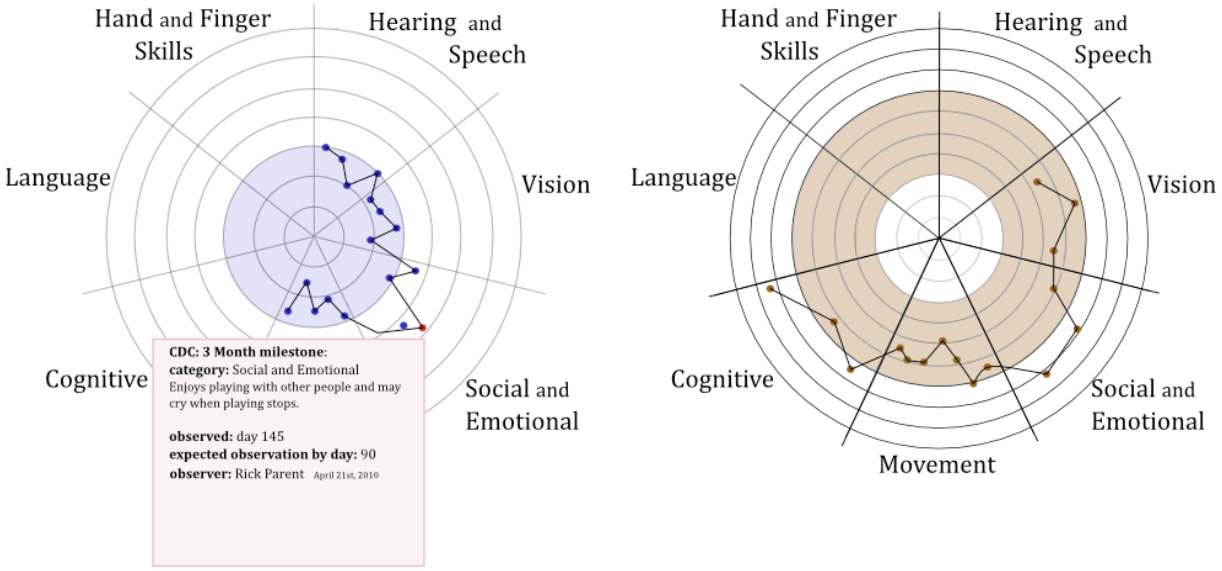

Figure 19: Spider milestone: third drafts drawn using inkscape – demonstration of hover-over

When carrying out usability tests we found out that the users initially had a hard time figuring out what the graph was showing them. All three persons thought that the different spider graphs showed different ages of the baby instead of different milestone ranges. After some time and some extra explanation they all could read the graph correctly and they thought it was a very helpful tool. One person pointed out that an outlier in the spider graph looked more dramatic, and he was not sure if that was a good or a bad thing, since this would clearly indicate if something happens outside the range but it also would make parents worry when it was possible this was not necessary. This may make the graph more suitable for a physician than a parent.

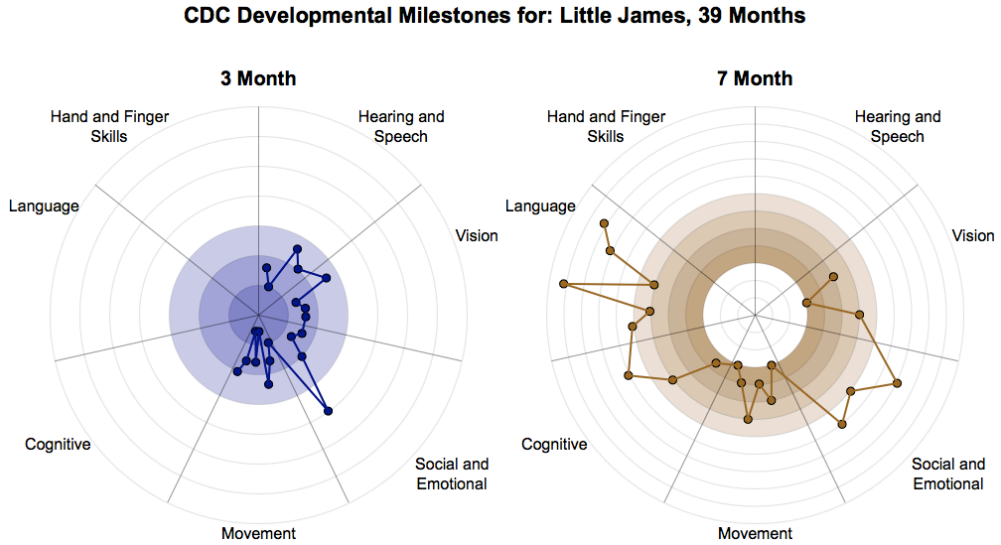

Figure 20: : Spider milestone: live draft

After the usability test we added more-detailed titles for the different spider graphs (‘3 month milestones’ instead of ‘3 months’) and significantly lightened background grid lines (see Figure 20). In response to our final presentation, we got some useful feedback saying that the empty spots in the graph, where there are no milestones for that period of time, could worry parents. For that reason we chose to gray out the titles of the categories that would not occur in that time range but have not yet had time to implement this in our live version of the application (see Figure 21). We also followed Cecilia's recommendation that we use the child's name in our mouseovers to personalize milestone exploration.

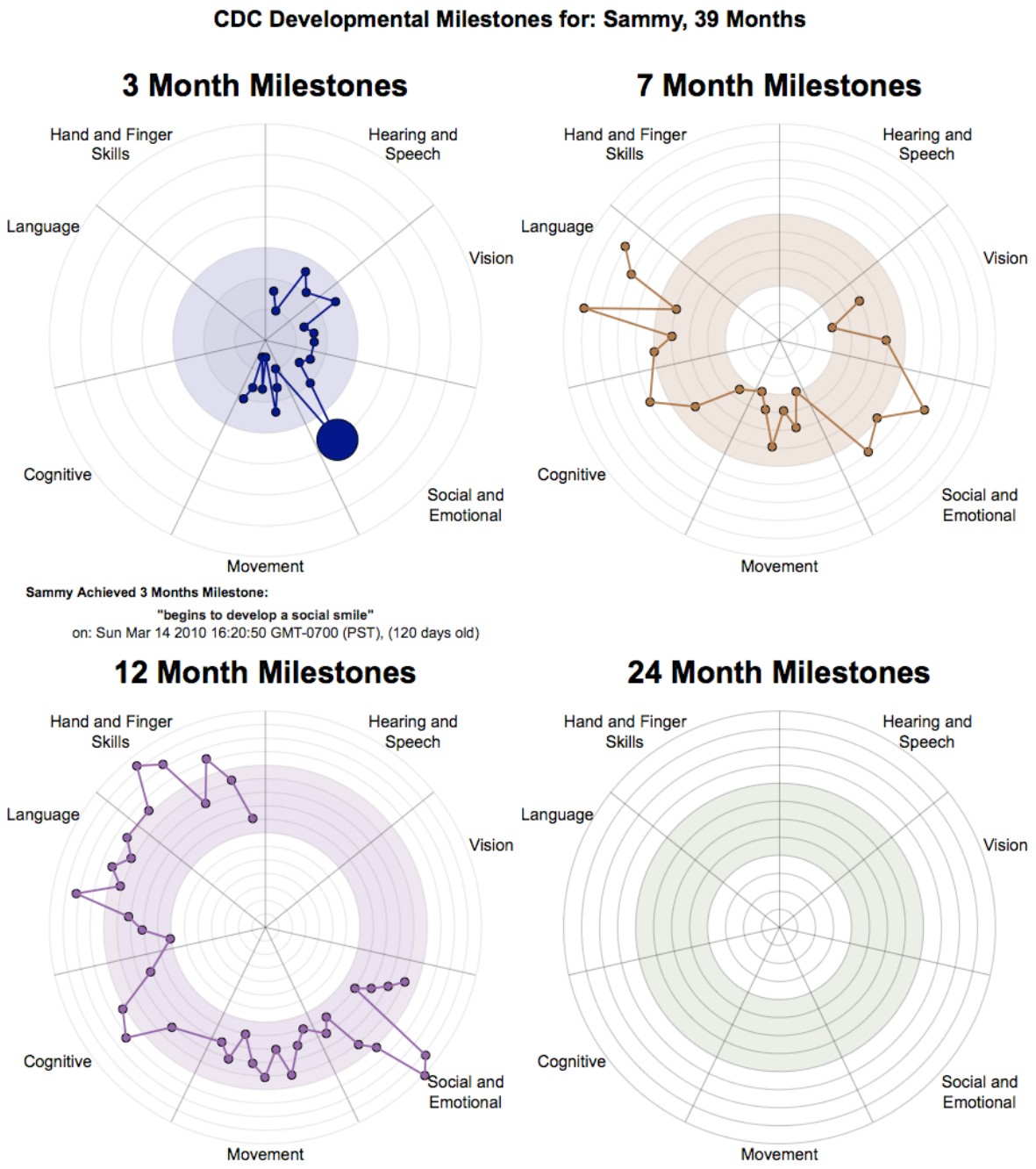

Figure 21: : Spider milestone: live

After mocking up the visualization in Inkscape, we succeeded in the significant achievement of programming this visualization using Raphael (an SVG shape-drawing library), jquery, and javascript. We decided not to use a "canned" charting library, which would have been simpler, because we could not find one that would implement what we were seeking. We performed coding experiments with the Google Chart API and Matplotlib (using python), looked through the documentation of other projects, and found that none of them gave us exactly what we were looking for.

The visualization was achieved by programmatically drawing a separate canvas for each milestone age range. Concentric circles were drawn to indicate age ranges. Axes were drawn using a custom trigonometry function where we drew 7 equidistant regions from an origin (that indicated the infant's birth day). Within each category, dots were dynamically and appropriately scaled and spaced depending on the number of milestones (with more milestones in a category, the angle within the category was decreased). A function was created to determine this appropriate angle for the various graphs, and also scale the length of the line from the origin (in conjunction with the varying scales of time for each graph). An SVG path function was then created to plot lines through the series of calculated dots. We additionally experimented with a series of other types of drawings and animations.

In the future, we expect to implement Ljuba Miljkovic's idea that we represent aggregate values for each of the seven categories with a more-traditional spider plot. By limiting the visualization to seven points , drawn along a labeled line with a 1:1 correspondence with category angles, it should present clearer shapes (as opposed to having many dots of differing, but similar angles form each category).

[1] see: http://www.ischool.berkeley.edu/programs/masters/projects/2010/medicalcommunication and http://kidoodl.com for more information

[2] see: http://www.cdc.gov/ncbddd/actearly/milestones/index.html