Abstract
We are in a new age of personal measurement due to the proliferation of a vast array of new instruments and technologies. Never before have we been able to continually or affordably monitor and log so many aspects of our lives. One downside of this fast developing space is that there are as many data types and repositories as there are devices and brands, so now we are faced with a new forest of disparate datasets all collecting and reporting partial information about individuals. Consequently, making sense of and leveraging this data for any given individual presents a new data challenge. The theme of this symposium raises the question: Now that we have all this data, how do we get our hands on it, make sense of it and use it to derive personal value? In this paper we will introduce a personal health and wellness data value chain, demonstrate some examples of this chain in action and propose some extensions to this chain that we believe will be of interest to researchers and practitioners.

Introduction
The concept of recording details of our daily lives including our physical wellbeing and activity is by no means new. The personal journals maintained in pen and ink by our forebears in many cultures for hundreds of years provide many examples. Therefore it could be argued that it is only the means of collecting, storing and sharing personal health and wellbeing information that has changed and, like pen and paper did before them, these new modalities are now becoming affordable and accessible to the general population for every day personal use. Subsequently, the collection of personal health and wellness information through various means is a rapidly growing behavior surrounded by an equally rapidly evolving ecosystem of devices and applications.

Some have argued that this is an unwelcome advancement with reasons ranging from the perceived unreliability of people entering and managing their own data, privacy, and safety through simple distrust and/or discomfort with technology all the way through to the “unnaturalness” of close electronic monitoring and its potential overuse, misunderstanding, and the possible emergence of new related disorders, incorrect and ill-informed self-diagnoses, and possible over-reaction. There is the additional concern that medical workers are inundated with data and have no realistic means to synthesize and consume data collected by the individuals they are treating. On the other hand, there is a growing number of individuals including those that identify as “quantified selfers” that are quietly documenting many aspects of their lives and some healthcare and life science practitioners & researchers are very excited about the possibilities that the availability of this new wave of data will open up.

Although the focus of this paper is on consumer-accessible sensors and information, beyond this there is a growing field of research and practice with wearable, implanted and ingested medical-grade sensors for use within and beyond the treatment setting whose data streams may eventually be made available to be added to the personal data sets addressed here.
The Personal Health and Wellness Data Value Chain

We believe there is a value spectrum ranging from the collection of single ‘channels’ of personal health and wellbeing data through the collection and concurrent analysis of multiple channels, and then advanced analytics that bring in other relevant datasets that may build a more complete picture of the whole person. In this paper we have identified three stops on this spectrum: single channel, multi-channel and advanced personal analytics. Figure 1 describes the relative value and complexity of each of these stops on the value spectrum.

An example of single channel collection and analytics is the logging of single personal health and well-being attribute. A common single attribute in this class is body weight. Collecting and logging body weight is quite simple, but allows the individual to analyze just this one attribute, which definitely has some value, yet this value is limited by the fact that it is only one aspect of the wellbeing of the whole person. Multi-channel collection and analysis would allow the individual to collect and analyze more than one attribute, for example, body weight alongside physical activity and dietary intake. Advanced personal analytics would combine all the available channels and also incorporate other lifestyle and environmental information to give an expanded view of the person.

The Value Chain in Action

Collection, Storage and ‘Single-Channel’ Analytics

There are many personal/wearable devices which collect movement and activity information, upload wirelessly to their own web applications which provide the means to manually enter additional information (such as dietary intake) and provides simple visualizations & analytics functionality. Although this functionality is limited to the data received from the one device or a single brand-family of devices and manual input, there is a degree of insight & knowledge delivered to the user.

The proliferation of devices from many different manufacturers and the fact that there is no agreed interoperability standard presents a challenge for individuals who have multiple devices for different purposes, especially when it comes to bringing all the collected data into a cohesive single data set. While it is technically possible to manually harvest the data from all the various web applications and merge it into one set, this is beyond the capability of all but a few consumers of these services. Figure 2 shows some examples of single channel analytics available in the Fitbit.com application.

Aggregation and ‘Multi-Channel’ Analytics

In order to make the most of the available personal health and wellness data it is really essential to bring all the data from the various collection modalities together in one data set. To improve the access and usability of the data from these multiple sources, data from individual devices and applications may be shared with a more universal, personally controlled, health record system like Microsoft HealthVault along with medical information, allowing a much broader picture of an individual’s health and wellbeing to be built up. Not only can we then see activity and diet information (and other device-collected data), but now we can also see medications, allergies, lab results,
& many more pieces of medical information all in one application.

Along with the storage of these disparate data sets, HealthVault offers its own simple visualization and analytics tools, and they provide another degree of insight and knowledge to the user, however the greater value of HealthVault might be the greatly expanded longitudinal and multidimensional personal health and wellness data all in one database. Exporting the entire record for more advanced analysis offers the user the opportunity to gain greater insights. Figure 3 shows some samples of combined data sets and analytics available in the HealthVault application.

**Advanced Personal Analytics**

There is a lot more data available about an individual than all the information we have mentioned so far. Figure 4 shows some of the many aspects of a person’s life and environment that may have some impact on their overall health and wellness, for example where they are in the world, what they are doing, how they are feeling (apart from how they are reported in a medical sense), their physical environment such as weather conditions, pollution levels, allergens, forest fires, traffic patterns & water quality.

Many of these additional attributes are measured and recorded, but are not captured within a single personal aggregation platform or record. They are, however, accessible to interested individuals. This is where advanced personal analytics, and a higher degree of complexity and skill, come into play, allowing the skilled user to bring together a larger set of attribute data, and more fully analyze their health.

Due to the fragmented data world that contains our personal and environmental data sets, there is a need for data search, ingestion, normalization, and visualization tools that can span these disparate data locations, types & formats and bring together the parts that are relevant to the individual. One such tool, which is familiar and accessible to many individuals, is Microsoft Excel, and Power Query a recently released add-on.

Using Microsoft Excel’s Power Query, an individual can open a single workbook, search for & ingest relevant data sets (for example weather data for their location for a period of time), select and ingest health & fitness device data along with dietary information, medical treatment information from HealthVault (using the available API tools), shape the data as required to allow the various sets to work together, and add this and any other relevant data to a comprehensive data model that can be saved, refreshed & reused in the future.

![HealthVault Dashboards & Health/Wellness Data Access](image-url)
The user can then create data visualizations on their personal data model to analyze many aspects of their own health and well-being. Figure 5 shows some samples of how data from many dimensions can be collected, combined and visualized using Microsoft Excel and Power Query. Table 1 compares the different stages of the value chain and assesses the relative complexity and value of each stage.

**Conclusion**

The collection of huge quantities of individual health and wellbeing data is becoming more affordable, practical and common. This presents challenges and opportunities. The challenge is to access, gather and make sense of this new treasure trove of personal information. Access itself is a very significant challenge. This data is private to the individual whose information is being recorded and is very likely distributed across quite a few different platforms, tools and ‘apps’. The opportunity is to find ways to use this data to inform personal health and wellbeing decisions and provide new tools and apps that allow individuals to achieve this without needing to become amateur data scientists.

To extend the individual value in this area traditional business intelligence and analytics tools may need to be modified or repackaged. There may be new market opportunities in the area of ‘personal analytics’ as more people participate in their own healthcare. The collection and availability of this longitudinal and multidimensional personal data creates a significant opportunity for machine learning, predictive and prescriptive analytics.

Providing affordable access to tools that help individuals monitor their own health and wellbeing and that provide proactive suggestions and recommendations on an extensible platform for new waves of personally accessible medical and health information will provide a fertile field for sensor device companies, analytics providers, medical researchers and, most importantly, the interested and engaged individual.
### Table 1 - Value Chain Stage Comparison

<table>
<thead>
<tr>
<th>Stage</th>
<th>Simplicity/ Accessibility</th>
<th>Advantages</th>
<th>Disadvantages</th>
<th>Attribute Examples</th>
</tr>
</thead>
<tbody>
<tr>
<td>Single Channel</td>
<td>Simple/ Easily Accessible</td>
<td>Familiar ‘app’ model</td>
<td>Single channel view</td>
<td>Weight or Blood pressure or Blood glucose or …</td>
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<td></td>
<td></td>
<td></td>
<td>Data may be trapped ‘in app’</td>
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<td></td>
<td></td>
<td></td>
<td>Limited analytics</td>
<td></td>
</tr>
<tr>
<td>Multi-Channel</td>
<td>Simple/ Easily Accessible</td>
<td>Multi-factor Aggregation</td>
<td>Limited channel view</td>
<td>Weight and Blood Pressure and Fitness and Dietary and…</td>
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<td>Limited analytics</td>
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<tr>
<td>Advanced Personal Analytics</td>
<td>Medium Simplicity and Accessibility</td>
<td>Combined data More analytics options ‘Whole person’ view</td>
<td>‘Self-service’ approach may disadvantage some users. Collection and normalization of data requires some skill</td>
<td>All of the above plus other environmental (e.g. weather, travel) and device data</td>
</tr>
<tr>
<td>ML/Predictive Analytics</td>
<td>Complex/ Inaccessible</td>
<td>Leverages large personal data sets to inform future decisions &amp; recommendations</td>
<td>Complex, beyond average consumer skill level</td>
<td>All of the above plus large cohort/ population datasets</td>
</tr>
<tr>
<td>Prescriptive Analytics</td>
<td>Complex/ Inaccessible</td>
<td></td>
<td></td>
<td>All of the above plus symptom/ treatment recommendations data</td>
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