The 2008 HMD Survey: Are We There Yet?

Results of the second annual worldwide survey of head-mounted display requirements.

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Executive Summary

In February, 2008, Sensics conducted its annual survey, exploring the use of and requirements from head-mounted displays (HMDs) amongst a worldwide academic audience. The survey was designed to understand user perceptions of HMD technology as well as desired performance characteristics of what was termed a 'good-enough' HMD. A summary of these results is presented in this report.

In general, user requirements from HMDs in 2008 did not change much from 2007. One area where change was evident is in the expectation of resolution: users today want higher and higher resolutions, often HD 1080 or above, for their HMDs compared with a typical requirement of 1024x768 just a year ago.

According to our findings, users still focus on three critical needs: ease of use, the need for panoramic and high-definition systems, and the need for HMDs to be built with superior display components.

We believe the commercially-available HMDs are moving closer towards delivering HMDs that will be considered 'good enough' by the mainstream. Products such as the Sensics piSight™ (offering panoramic field of view and high definition image) already deliver many of the desired attributes, and Sensics as well as other vendors continue to make important product improvements.

Methods

Survey invitations were sent via e-mail to 1,381 academics worldwide based on their prior interest in virtual reality display and visualization technologies. The survey contained 29 questions on various technical, commercial and usage aspects of virtual reality technologies in general and head-mounted displays in particular. Participants were promised that no personally-identifying information will be included in the survey report, and that participants would be among the first to receive the final report. From Feb 5th to Feb 29th, 2008, a total of 84 responses were collected via a Web-based survey tool. Participants were not guaranteed monetary compensation for participation, though Sensics provided gift certificates to 5% of participants after data collection was completed.

Results were analyzed using Web-based tools as well as Microsoft Excel. All survey results were included in the analysis. Results were then compared with a similar survey conducted by Sensics in the spring of 2007.

Results

Participant profile and research interests

Participants were asked to identify the continent in which they primarily work. Results were:

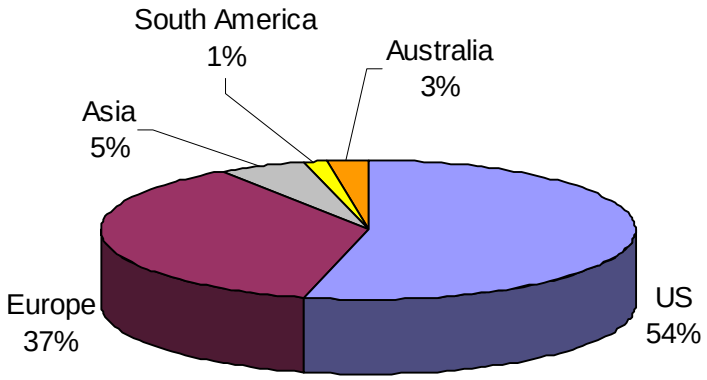

Figure 1 - Responses by Geography

Participants were asked if they are using virtual reality or immersive display technologies in their research, and then if they are using head-mounted displays (HMDs) in their current work or research. Results were:

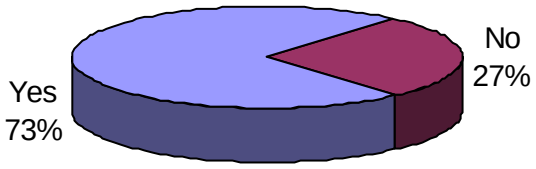

Figure 2 – Using Immersive Technologies?

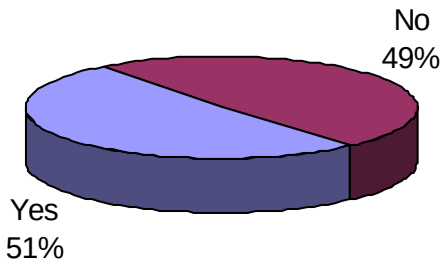

Figure 3 – Using Head-Mounted Displays?

Participants were asked to identify their current areas of research interests. Each participant was able to select more than one option. Results were:

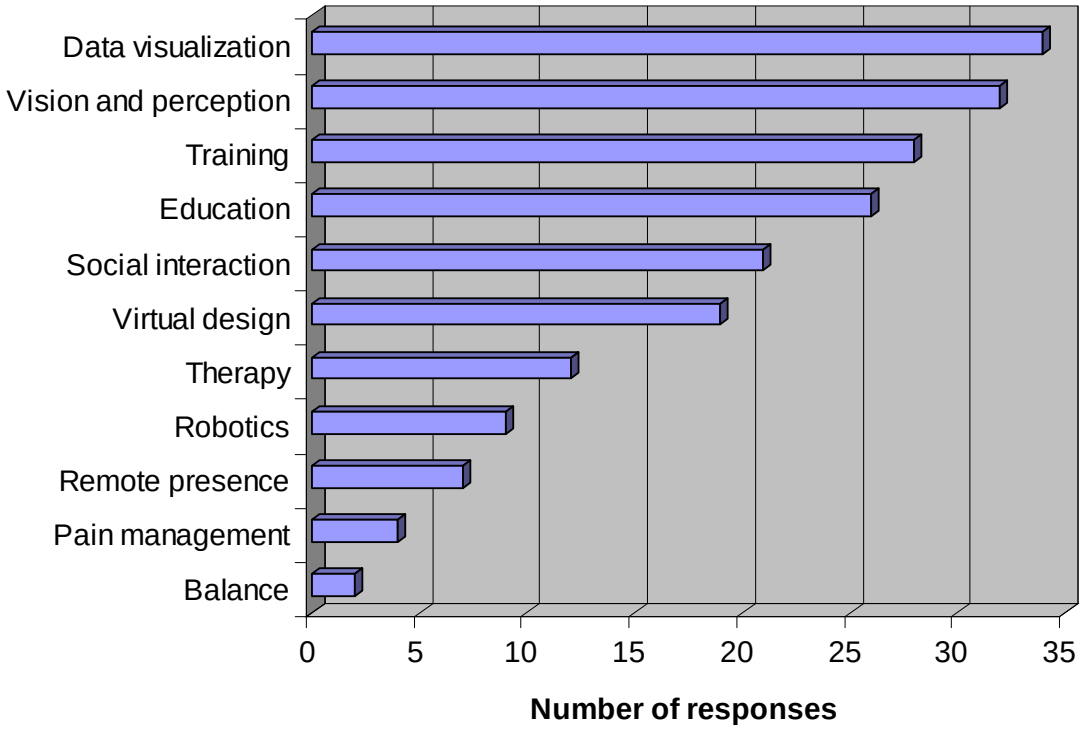

Figure 4 - Research Interests

Usage Characteristics

We asked the 51% of participants who are using HMDs (see figure 3), how often do they use the HMD:

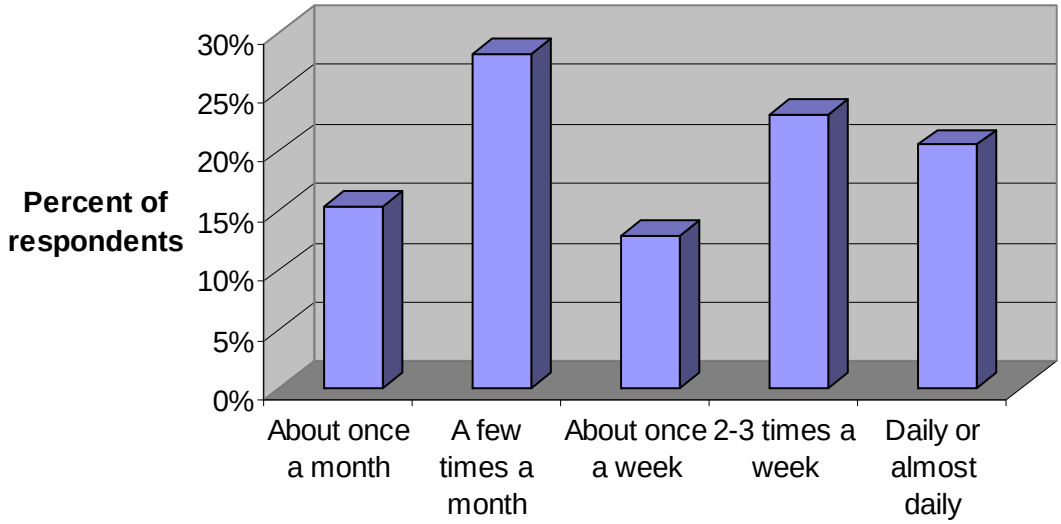

Figure 5 – Frequency of HMD Use

We also inquired about the length of each usage session:

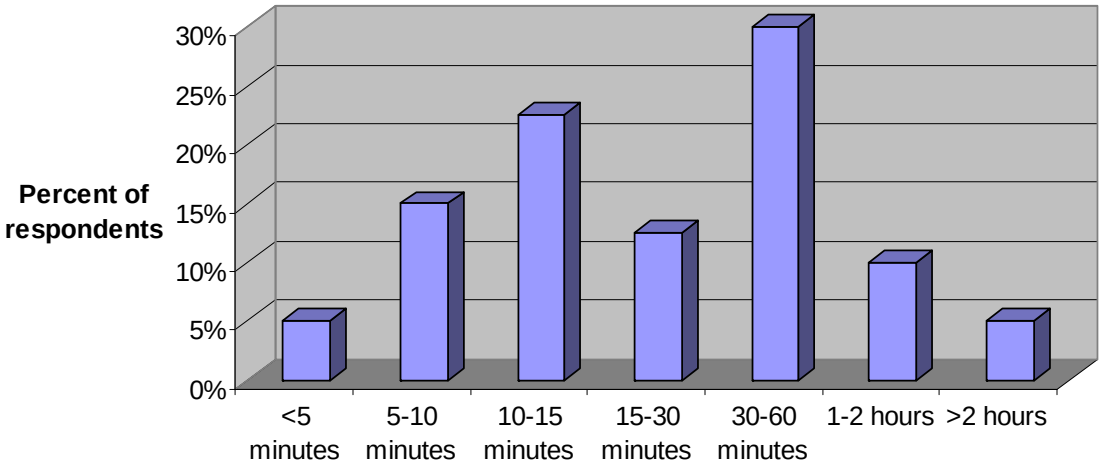

Figure 6 – Duration of HMD Use Per Session

HMD Attributes that are Important to Users

We asked respondents to indicate the importance of several HMD attributes. Each feature was given an importance score on the following scale:

1: Completely unimportant

2: Unimportant

3: Somewhat unimportant

4: Somewhat important

5: Important

6: Very important

This question was asked for many attributes with typical results of the following format:

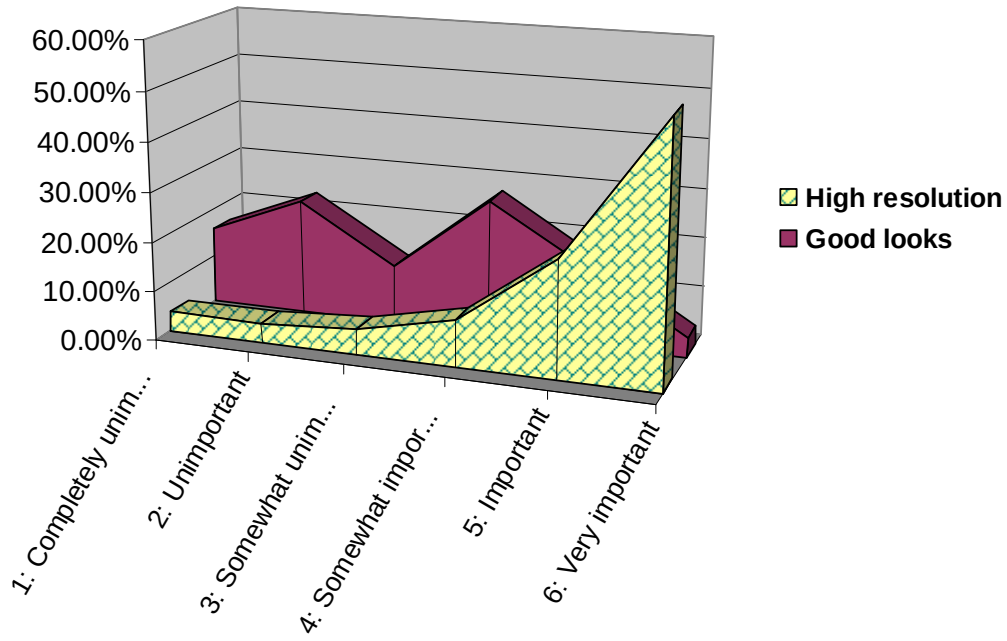

Figure 7 – Typical Importance Rating Scale

However, in the interest of space, we decided to summarize the rating scale for each attribute by reporting the most common value (1 through 6) as well as the average response. We have sorted these findings by the most common response and then by the average rating:

Most common rating	Attribute	Average rating
6: very important	A lightweight design	5.43
	The ability to very quickly wear and adjust the HMD	5.14
	A display that has very fast dynamic response (no smear or fade effects)	5.11
	Cables that are easy to manage	5.08
	High resolution display	5.07
	A panoramic field of view (over 100 degrees horizontal)	5.05
	A portable system	5.03
5: important	A large vertical field of view (50 degrees or more)	4.87
	High-contrast display	4.79
	A display that is close to eye-limiting resolution	4.52
	A head-mounted design that does not warm the head	4.51
	Large color gamut	4.46
	A design that has minimal contact with the head	4.16
	The ability to morph (rotate, transform) images in real time to correct for any artifacts in the source image	3.53
4: somewhat important	An HMD what can be used wirelessly	4.51
	The ability to use the HMD a long-distance from the image-generating computer	4.21
	The ability to use a battery to power the HMD	4.16
	Ability to incorporate live video into the HMD	3.77
	A design that looks good	3.16

Table 1 - Most Important Attributes

“How good is good enough?”

We asked survey participants a series of questions to determine what they would consider a ‘good enough HMD’. While we realize that most people would say “wide field of view is better than tunnel vision”, “high resolution is better than low resolution” and “lightweight is better than heavy”, we still wanted to understand ‘how good is good enough’ in quantitative terms.

When asked “What would be a 'good enough' horizontal field of view?” we received the following distribution:

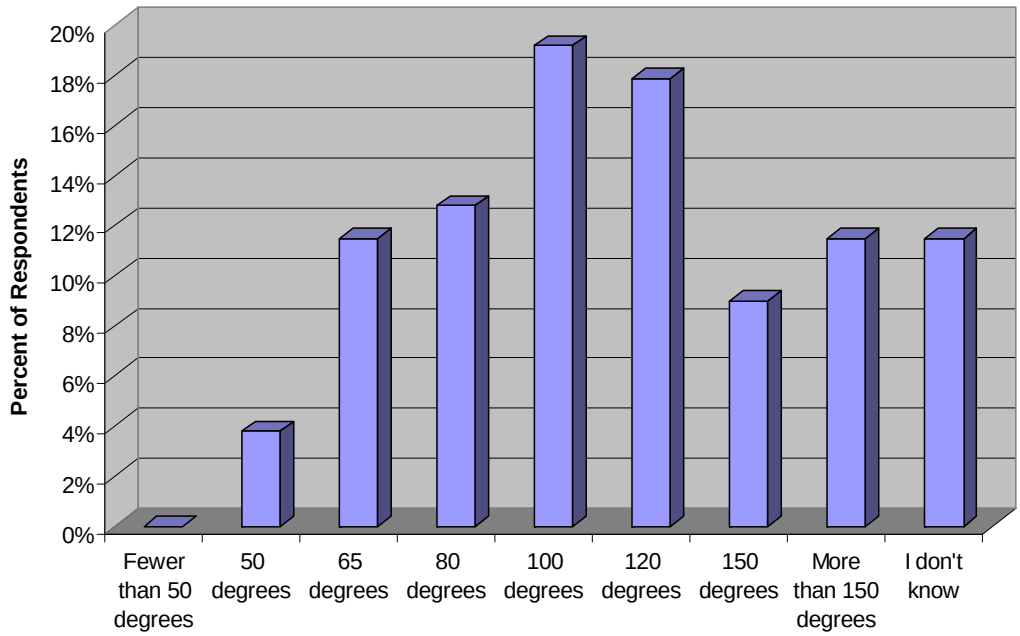

Figure 8 - ‘Good Enough’ Horizontal Field of View

When asked “What would be a 'good enough' vertical field of view?” we found:

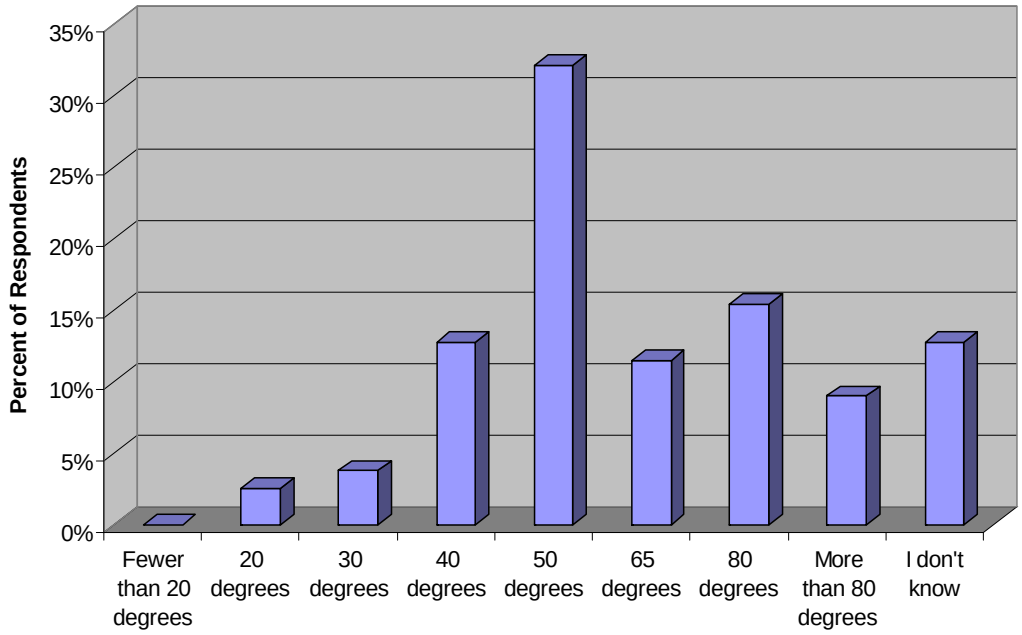

Figure 9 - ‘Good Enough’ Vertical Field of View

We then asked about ‘good enough’ resolution. The results were:

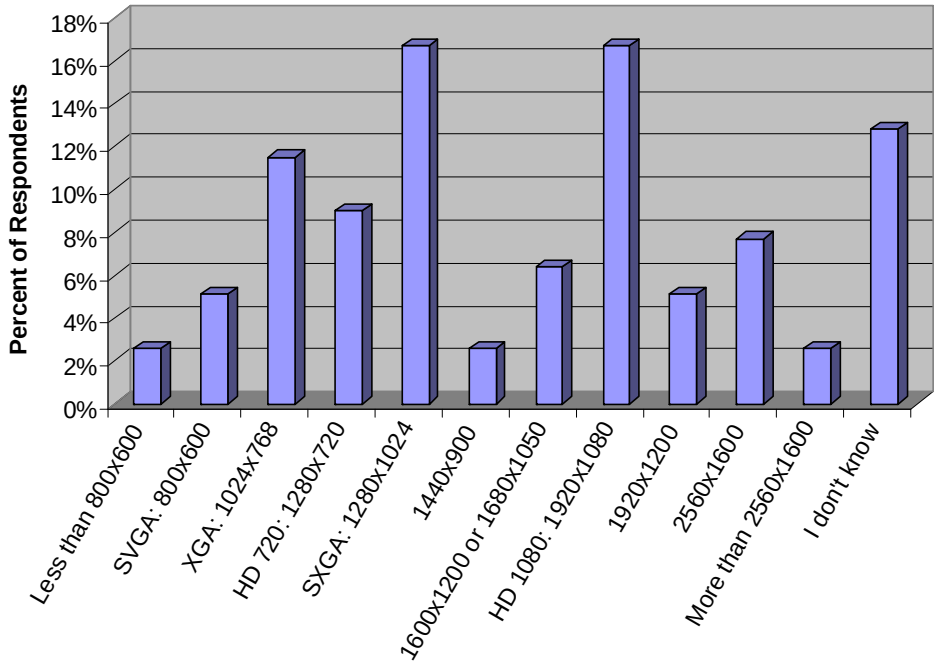

Figure 10 - ‘Good Enough’ Resolution

Last, we asked about 'good enough' weight for the head-mounted display. The results were:

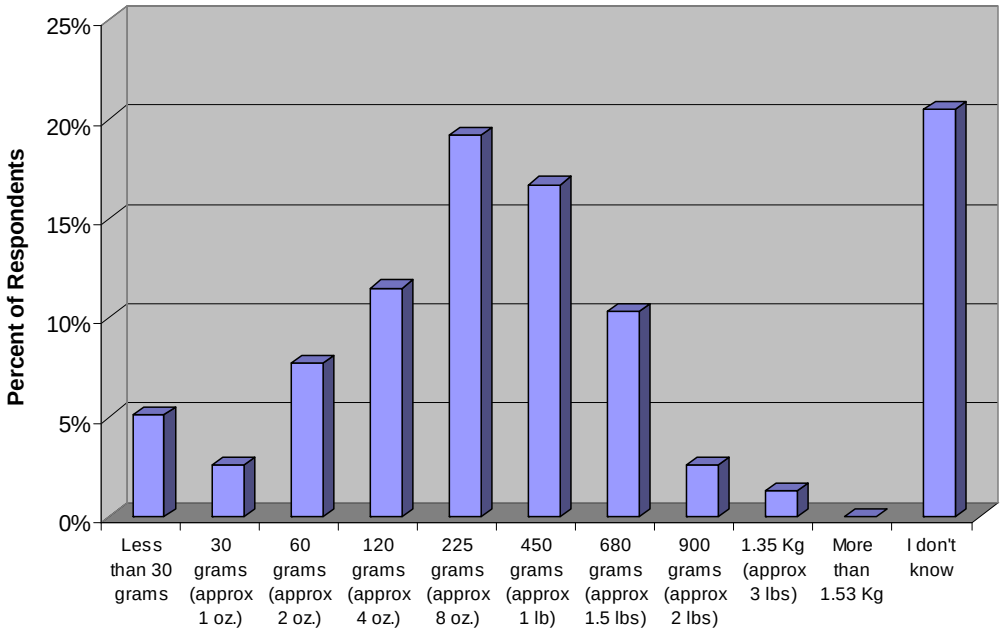

Figure 11 - 'Good Enough' Weight

Changes from 2007 to 2008

We compared the changes in the key requirements as captured in our previously-published 2007 survey to those uncovered in the existing survey. Note: the 2007 survey covered many market segments – not just academics – but participants in 2007 were asked to identify the type of organization, thus allowing us to "compare apples to apples" to considering only the responses from academic participants in both surveys.

'Good enough' value	2007 Survey	2008 Survey
Horizontal FOV		
• Less than 100°	30%	33%
• 100°	27%	22%
• 120°	18%	21%
• More than 120°	35%	24%
Vertical FOV		
• Less than 50°	19%	22%
• 50°	34%	37%
• 65°	31%	**13%**
• More than 65°	16%	**28%**
Resolution		
• Most popular	1024x768 (32%)	1280x1024, 1920x1080 (17% each)
• Less than 1600x1200	67%	**47%**
• HD 1080 or higher	20%	**32%**

Table 2 - FOV and Resolution Trends

We also examined whether the importance of key attributes (see table 1) has changed between 2007 and 2008 and found no significant change in the importance assigned to each attribute by the participants.

Analysis

Desired HMD attributes

Horizontal FOV:

The two most common choices for 'good enough' horizontal FOV were 100 and 120 degrees. We've seen research that shows that using HMDs with "tunnel vision" FOV (60 degrees or fewer) forces the user to use head movements in situations where eye movements would normally suffice.

Many HMD products on the market have narrow field of view and offer 50 degrees or less. Note that it is common practice in the HMD industry to specify *diagonal* field of view as the lead field of view characteristic. The horizontal and vertical field of view also depend on the aspect ratio of the display, but as an example, an HMD reporting 50 degrees diagonal field of view will typically have about 42 horizontal field of view and 25 degrees vertical field of view. The following table shows typical diagonal, horizontal and vertical FOV for popular configurations on the market

Monocular diagonal FOV (degrees)	Monocular horizontal FOV	Vertical FOV	Notes
40°	33°	22°	4:3 aspect ratio
50°	42°	25°	
60°	49°	33°	
80°	63°	53°	
95°	85°	45°	17:9 aspect ratio

Table 3 - Typical Monocular FOV Values

The table above shows values for a monocular display (e.g. one eye). HMDs use two such displays to create a binocular unit. Many HMDs on the market have 100% overlap between left and right eye (called binocular overlap), meaning that the binocular FOV is identical in all aspects to the monocular FOV. For instance, 100% overlap in a product reporting 50° diagonal FOV means that the combined horizontal FOV is still 42°. Newer products with wide horizontal FOV typically create binocular versions that have substantial binocular overlap but not 100%, thereby creating a larger total horizontal and diagonal FOV. For instance, a popular product with 95° monocular diagonal FOV is marketed in two versions: one with 132° total diagonal FOV (and 53° binocular overlap) and the other with 105° diagonal FOV (and 74° overlap).

Based on the results shown in Figure 9, the common 50° horizontal FOV is hardly considered 'good enough': only 4% of respondents thought that a horizontal field of view of 50 degrees or less would be good enough for them.

From these results it would seem that HMDs with 120 degrees FOV would satisfy the 'good enough' needs of 76% of those that had an opinion about how much horizontal FOV is required. This requirement has not noticeably changed between 2007 and 2008 (see table 2)

50% of respondents who mentioned that they require 150° or higher vertical field of view identified at least one of their research interests to be "vision and perception".

Vertical FOV:

The most common response for vertical FOV was 50 degrees. 59% of respondents would be satisfied with a product that has 50 degrees vertical FOV, whereas 72% would be satisfied with 65 degrees FOV. Key applications requiring very tall vertical FOV (80 degrees or higher) were "vision and perception" (47%), training and education.

Most HMD products on the market offer a vertical field of view of 30 degrees or lower. This is found to be 'good enough' by just 7% of respondents.

Examining the trends between 2007 and 2008 (table 2) reveals an interesting finding: the number of respondents that are satisfied with 50 or lower FOV has stayed about the same, but those respondents that ask for higher performance are requiring very tall FOV (80 or higher) in 2008, as opposed to satisfaction with 65 degrees in 2007.

Resolution:

The two most common responses for required resolutions were 1280x1024 and 1920x1080 (HD 1080). This was a notable change from 2007, where the most popular resolution was 1024x768. 32% of respondents asked for HD 1080 or higher resolution, whereas only 20% of the 2007 survey respondents asked for high resolution. Clearly, there is a shift in the market towards requiring higher and higher resolutions. We believe that this shift is attributed to several reasons:

- Hi-def consumer televisions are being heavily advertised, and there is a mainstream understanding about the relationship between resolution and viewing experience.
- Wider HMDs are now in the market, and users understand that beyond field of view, the total number of pixels (or the number of pixels/degree) is also very important. Most users report a very dramatic improvement when going from 10 to 20 pixels/degree.
- Applications such as data visualization (the most popular topic in Figure 4), greatly benefit from higher resolutions between greater amounts of data can be presented.

Important Attributes:

Table 1 shows key HMD attributes as ranked by the survey respondents. Our interpretation of the results is that there are three important topics:

- **Ease of use** which manifests itself in light weight, easy cable management, easy process of properly wearing/removing the HMD and portability.
- **Panoramic, high-definition.** A high-resolution display and panoramic field of view (100 degrees of more) consistently rank very high in important attributes. Our interpretation is that both high resolution and wide field of view need to be present for the desired usage experience. High pixel count with narrow field of view is not satisfactory ("tunnel vision") and neither is low pixel count with wide field of view (excessive pixel magnification).

- **Underlying display element technology**. Users ranked "a display that has a very fast dynamic response (no smear or fade effects)" as the third most important attribute. "High contrast" and "large color gamut" also ranked highly. These attributes are not determined by the optical or mechanical design of the HMD, but rather by the underlying micro-display technology being used. Currently, the most popular technologies are LCOS (Liquid Crystal on Silicon) and OLED (Organic Light-Emitting Displays). LCOS chips are currently offered in higher resolutions, but suffer from the need for back-lighting (which reduces contrast), and "motion blur" effects that cause smear when viewing rapidly-changing images. Tiled designs (such as Sensics) attempt to obtain the best of both worlds: use OLEDs for their excellent contrast, brightness, and color gamut, while tiling them together to achieve total resolutions higher than available LCOS designs.

An attribute that – perhaps surprisingly – was not ranked as particularly important was non-standard connectivity (wireless operation, long distances from image generator, battery operation) and looks. Perhaps this attribute is very important to some users but, on average, it is not important to all users.

It also is consistently apparent that academic users do not particularly value the looks of an HMD, unlike many commercial applications.

Summary: the 'good enough' HMD

The choice of an optimal HMD is just as complex as choosing the optimal cars. This is often an individual choice that needs to factor in the specific needs and wants (e.g. a sports car that allows a flip-down top vs. a minivan that can comfortably transport a fairly large family). Budget, of course, is also an important factor.

Having said that, it appears that at least on average, a "good enough" HMD would have the following attributes:

- A field of view of at least 120x50 degrees.
- At least 1600x1200 resolution, but preferably HD 1080.
- Bright displays with a very fast dynamic response.
- No more than 250 grams (8-10 oz) in weight.
- Easy user interface and cable management.

While a commercial product that meets all these requirements may not be available yet, we believe that a lot of progress has been made in the last 12 months towards this goal.

About Sensics

Sensics, Inc., the panoramic head-mounted display company, offers a comprehensive line of panoramic, upgradeable, high-definition head-mounted displays. Unlike other HMDs that feature narrow field of view, limited resolution or both, Sensics offers fully-immersive displays with up to 10 million pixels per eye. Over 35 different upgradeable models are offered, designed to meet a wide range of performance and budget specifications. Sensics products are used worldwide to enable new and improved virtual reality applications for training, virtual prototyping, visualization and remote presence. Sensics is headquartered in Baltimore, Maryland and offers its products with the help of a global reseller network.

The company's flagship product, the Sensics piSight™ line of panoramic, high-definition, HMDs offers substantial benefits over alternative HMD solutions:

- **Dramatically larger field of view**. By delivering imagery in the peripheral vision area, the piSight enhances situational awareness and provides a natural-feeling experience without unnecessary head movements.
- **Higher resolution**. HD 1080P images or better (with high pixel density - 20 pixels/degree) increases realism and heightens the sense of immersion.
- **Superior display quality**. Unlike traditional LCOS chips, The OLED displays in the piSight present an image that does not smear when the scene changes rapidly, provide high-contrast, are power efficient, yet require no backlight.
- **Upgradeability**. The upgradeable piSight design mitigates the risk of "technology dead end" once the field of view or resolution needs exceed the performance delivered by the existing product.

To learn more about the Sensics products or schedule a demo, visit www.sensics.com, or contact us at:

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