



crease the number of options to, say, seven, but the basic problem remains.

This restriction isn't necessary when surveys are computerized. A program could let respondents choose any point on the scale they wish, even those between the semantic anchors. Since data is captured automatically, there is no reason to economize on scale points.

Fine-grained items are somewhat more complex to implement in software than the simple coarse-grained items shown in Figure 2. Is the extra complexity worthwhile? Some research suggests it might be (Cox, 1980). Studies generally conclude that finer scales reduce bias (Krieg, 1999), and improve correlation estimates among variables (Bollen and Barb, 1981). Information loss from coarse scales reduces power when assessing the effects of moderating variables in regression (Russell and Bobko, 1992; Aguinis, 1995). It has also been shown that computer-administered questionnaires can improve power in detecting moderating effects (Aguinis, Bommer, and Pierce, 1996).

This research has three specific goals:

1. To create an effective technique for delivering coarse-grained Likert scales in Web-based surveys.
2. To extend past research on the effect of scale granularity on power.

3. To determine whether respondents will actually use scale points that are not on the semantic anchors.

### 3. Implementing Fine-Grained Items

Ideally, the code for a fine-grained Likert control for the Web should run on most browsers, should not require browser plugins, and should be easy to create and use. It's also desirable to have a program automatically generate the code for the control, rather than having a person write the code manually. This means that survey designers could store scale definitions in a file or database. They could add, change, or delete scales by updating values in, say, a database, and a program would translate their specifications into working code.

Our implementation of a fine-grained control uses simple HTML, with a little straightforward JavaScript. It was inspired by McFarlane (2002), though substantially modified. Figure 3 shows what a scale looks like before use. Respondents click anywhere on the scale to record their opinion. The control then shows a red mark (see Figure 4). To change their answer, respondents click on a different point, and the red mark moves. Note that the scale starts out empty, making it easy to see whether it has been used.

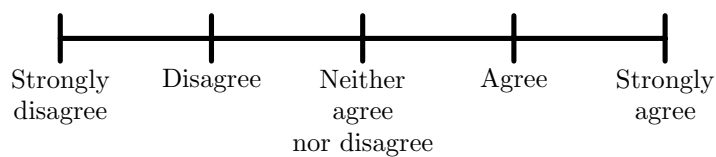


Figure 3: Initial State of a Fine-Grained Likert Scale

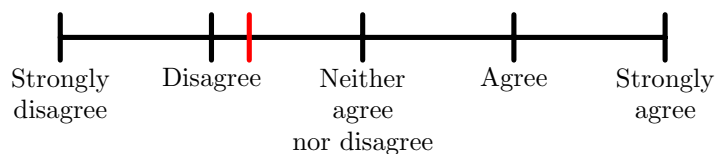


Figure 4: Initial State of a Fine-Grained Likert Scale

Figure 5 shows an HTML code sample. The scale is an HTML table, with a cell for each point. The first cell is a spacer to correctly position the scale relative to the anchor text. The next cell (named `tick0`) shows the scale mark for the first anchor point (the leftmost vertical black line on the scale). It contains the image `1x1_black.gif` which, as its name suggests, is a one-pixel black image. The file for this image is only 43 bytes long. The image is resized to occupy the desired amount of screen space. Cells `tick1` to `tick29` are cells for each clickable point on the scale between the scale marks for the first and second anchor points. They contain the image `scale.gif`, which renders the scale marks between the anchor points. This file is 52 bytes long. Cell `tick30` is the second anchor point. The sequence continues until the last anchor point and

then another spacer are drawn. The second HTML table in Figure 5 shows the anchor points.

Figure 6 shows the accompanying JavaScript. The script draws a red mark in the clicked table cell, after storing the cell's original image in case the user clicks on another cell and the original image needs to be restored.

The HTML in Figure 5 is generated by the ASP script shown in Figure 7. For simplicity, the code uses constants for the scale values, labels, and so on. The values are read from a database in practice. Andrew Perrin of the University of North Carolina ported the code to PERL. It is available at <http://www.unc.edu/~aperrin/tips/>.

```
<FORM name="f">
<TABLE cellSpacing="0" cellPadding="0">
<TR>
<TD><IMG height="21" src="1x1_trans.gif" width="45" /></TD>
<TD><IMG onclick="makeTick(0)" height="21" src="1x1_black.gif"
width="3" border="0" name="tick0" /></TD>
<TD><IMG onclick="makeTick(1)" height="21" src="scale.gif"
width="3" border="0" name="tick1" /></TD>
<TD><IMG onclick="makeTick(2)" height="21" src="scale.gif"
width="3" border="0" name="tick2" /></TD>
. . .
<TD><IMG onclick="makeTick(29)" height="21" src="scale.gif"
width="3" border="0" name="tick29" /></TD>
<TD><IMG onclick="makeTick(30)" height="21" src="1x1_black.gif"
width="3" border="0" name="tick30" /></TD>
<TD><IMG onclick="makeTick(31)" height="21" src="scale.gif"
width="3" border="0" name="tick31" /></TD>
. . .
<TD><IMG onclick="makeTick(119)" height="21" src="scale.gif"
width="3" border="0" name="tick119" /></TD>
<TD><IMG onclick="makeTick(120)" height="21" src="1x1_black.gif"
width="3" border="0" name="tick120" /></TD>
<TD><IMG height="21" src="1x1_trans.gif" width="45" border="0" /> </TD>
</TR>
</TABLE>
<TABLE cellSpacing="0" cellPadding="0">
<TR>
<TD valign="top" align="middle" width="90">Disagree</TD>
<TD valign="top" align="middle" width="90">Somewhat<BR>disagree</TD>
<TD valign="top" align="middle" width="90">Neither agree nor
disagree</TD>
<TD valign="top" align="middle" width="90">Somewhat<BR>agree</TD>
<TD valign="top" align="middle" width="90">Agree</TD>
</TR>
</TABLE>
<INPUT name="val" type="hidden" />
</FORM>
```

Figure 5: HTML Code for a Scale

```

<SCRIPT>
var oldImage;
var oldTickNumber;
var bFirstTimeThru = true;
function makeTick(tickNumber) {
var tickName;
document.f.val.value = tickNumber / 30 + 1;
tickName = 'tick' + tickNumber;
if (!bFirstTimeThru) {
eval('document.f.tick' + oldTickNumber +
'.src = oldImage');
}
oldImage = eval('document.f.'+tickName+'.src');
oldTickNumber = tickNumber;
bFirstTimeThru = false;
eval('document.f.'+tickName+'.src="1x1_red.gif"');
}
</SCRIPT>

```

Figure 6: JavaScript for Storing Respondent's Choice

```

<%
option explicit
dim iTickWidthPixels 'Pixels per tick on the scale
dim iCellHeightPixels 'Height of the scale
dim sMinValue 'Minimum scale value
dim sMaxValue 'Maximum scale value
dim iValueRange 'Scale range
dim iTicksPerUnitValue 'Ticks per unit
dim tLabels() 'Anchors
dim i,j
iTickWidthPixels = 3
iCellHeightPixels = 21
sMinValue = 1
sMaxValue = 5
iValueRange = sMaxValue - sMinValue
iTicksPerUnitValue = 30
redim tLabels(iValueRange)
tLabels(0) = "Disagree"
tLabels(1) = "Somewhat<br>disagree"
tLabels(2) = "Neither agree nor disagree"
tLabels(3) = "Somewhat<br>agree"
tLabels(4) = "Agree"
%>
<html>
<head>
. . .
<form name=f>
<table cellpadding=0 cellspacing=0>
<tr>
<%
'Write out the first table - the scale
'Write out a cell that is half a scale unit value
response.write "<td><img src='1x1_trans.gif' width=" & _
iTicksPerUnitValue/2*iTickWidthPixels & _
" height=" & iCellHeightPixels & "></td>" & vbCRLF
'Write out each scale interval
for I = 0 to iValueRange-1
'Black tick to start it
response.write "<td><img src='1x1_black.gif' name='tick' & _
I*iTicksPerUnitValue & "' height=" & iCellHeightPixels & _
" width=" & iTickWidthPixels & _
" border="0" onclick='makeTick(" & I*iTicksPerUnitValue & _
")'></td>"

```

```

'Now regular ticks for the rest of the scale interval
for j = 1 to iTicksPerUnitValue-1
response.write "<td><img src='scale.gif' name='tick" & _
I*iTicksPerUnitValue+j & "' height=" & _
iCellHeightPixels & " width=" & iTickWidthPixels & _
" border="0" onclick='makeTick(" & _
I*iTicksPerUnitValue+j & _
")'></td>"
next
next
'Write out final tick
response.write "<td><img src='1x1_black.gif' name='tick" & _
iValueRange*iTicksPerUnitValue & "' height=" & _
iCellHeightPixels & " width=" & iTickWidthPixels & _
" border="0" onclick='makeTick(" & _
iValueRange*iTicksPerUnitValue & "')></td>"
'Write out a cell that is half a unit value
response.write "<td><img src='1x1_trans.gif' width=" & _
iTicksPerUnitValue/2*iTickWidthPixels & _
" height=" & iCellHeightPixels & " border="0"></td>" & vbCRLF
%>
</tr>
</table>
<table cellpadding=0 cellspacing=0>
<tr>
<%
'Write out the label table
for I = 0 to iValueRange
response.write "<td align='center' valign='top' width=" & _
iTicksPerUnitValue*iTickWidthPixels & ">" & _
tLabels(i) & "</td>"
next
%>
</tr>
</table>
<input type='hidden' name='val'>
</form>

```

Figure 7: ASP Code for Generating the Item

#### 4. Effects on Power

We suspected that tests of means with data gathered using fine-grained scales would be more powerful than tests with data from coarse-grained scales. We wrote a simulation in Java that:

- Created  $n$  pairs of normally distributed samples from two populations with possibly different means but common variances, i.e.,  $n$  samples from  $N(\mu_1, \sigma)$  and  $N(\mu_2, \sigma)$
- Moved each data point to the nearest value on a five-point Likert scale to simulate a coarse-grained scale, and computed  $t$  statistics and  $p$  values for a test for equality of two means.
- Moved each data point to the nearest 100<sup>th</sup> part of the scale to simulate a fine-grained scale, and

computed  $t$  statistics and  $p$  values for a test for equality of two means.

- Repeated steps 1 to 3 for 1,000 experiments.

We fixed the standard deviation at 0.5 and alpha at 0.05. We varied the true differences between sample means from 0 to 2 in steps of 0.1 for 10, 20, 50, and 100 data pairs. The simulation thus yielded 2,600,000 data pairs.

Figure 8 shows the results. Although we used two-tailed  $t$  tests, we show only the right half of each power curve. The results confirmed our expectations. Analyses of data gathered using the fine-grained scale were more powerful. The differences in power were greatest when the sample size and the true difference between means were relatively small, as is often the case in

business and social science research. Figure 9 shows the fine-grained scale's gain in power over the coarse-grained scale for different sample sizes.

### 5. Would Respondents Use the Scale?

So far, we have code to implement the scale, and evidence that its use increases a statistical test's power. However, while coarse-grained scales are familiar to respondents, fine-grained scales are not. Would respondents take advantage of the scale's precision? That is, would they choose points other than those corresponding to the semantic anchors?

We used the scale in a study of the way students define "philosophy of life." The survey was delivered over the Web using the code given above. Respondents read about the new scale in the study's introduction. They were given a sample item, and encouraged to experiment with it. The sample item was "I like chocolate," with a scale from "Strongly agree" to "Strongly disagree."

Eighty seven respondents completed 11 items using the fine-grained scale, for a total of 764 responses after missing data was removed. Each scale had seven anchor points, that is, seven points with vertical ticks and text labels (see Figure 3). There were a total of 150 clickable points on each scale, most between the anchor points.

Of the 764 responses, 434 (57%) were not on one of the anchor points, that is, they were between the vertical ticks in Figure 3. These responses could not have been precisely measured with a traditional coarse-grained Likert scale. It seems that respondents are willing to use the entire scale, and not just the anchor points.

While most of the responses were off the anchor points, a substantial minority *were* on the anchor points. Since each scale had 150 clickable points, there were many more responses on the anchor points than would have been predicted by chance, if the prob-

ability of selecting each point was equal. It seems that, although there is substantial use of the points between the anchors, respondents are still attracted to the anchor points.

This is not too surprising, given that coarse-grained Likert scales (on which only the anchor points are clickable) are familiar, while fine-grained scales are not. We had hoped to counteract this effect by giving respondents a practice fine-grained item, and encouraging them to experiment with it. We may not have been as successful as we had hoped.

However, further analysis showed an interesting effect. We divided respondents into two groups based on their response to the practice item: (1) those who selected an on-anchor point for the practice item, and (2) those who selected an off-anchor point. Then we examined their responses to other fine-grained items in the same survey. For each group, we computed the number of responses to other items that were on-anchor or off-anchor. Table 1 shows the resulting contingency table (because of missing data and the separation of practice items from the others, the totals are not the same as those presented earlier). Responses are unevenly distributed ( $\chi^2 = 59.2$ , d.f = 1,  $p < 0.001$ ). So, respondents who chose an on-anchor point for the practice item tended to use on-anchor points for the rest of the items. Those who chose an off-anchor point for the practice item tended to use more off-anchor points for the rest of the items.

The analysis suggests an explanation for the large number of on-anchor responses in the data. It could be that respondents who consistently chose on-anchor points did not read the instructions given with the practice item, and therefore did not know they could choose off-anchor points. Perhaps the problem could be avoided if the survey software forced them to choose an off-anchor point for the practice item. For example, the software might refuse to proceed to the next screen, unless an off-anchor point was chosen.

Practice item	Off-anchor	Other items		
	On-anchor	267	125	392
Totals		81	143	224
		348	268	616

Table 2: Off-and On-Anchor Responses

### 6. Conclusions

Limiting the granularity of Likert scales is reasonable for paper surveys, because it simplifies data coding. However, this is less important for computer-based surveys since data capture is automatic. Fine-grained Likert scales can be implemented fairly easily for Web-based surveys. Analyses using fine-grained scales are more powerful than those using coarse scales, particularly for the smaller sample and effect sizes that are often encountered in business and social

research. Further, respondents will use the off-anchor points on the scale.

The implications for businesses and researchers are clear. Fine-grained scales are relatively easy to implement. Further, the software that delivers the items can be reused at little cost. Given the total costs of running surveys, and the value of the decisions that may hang on their results, fine-grained Likert scales are a worthy investment.

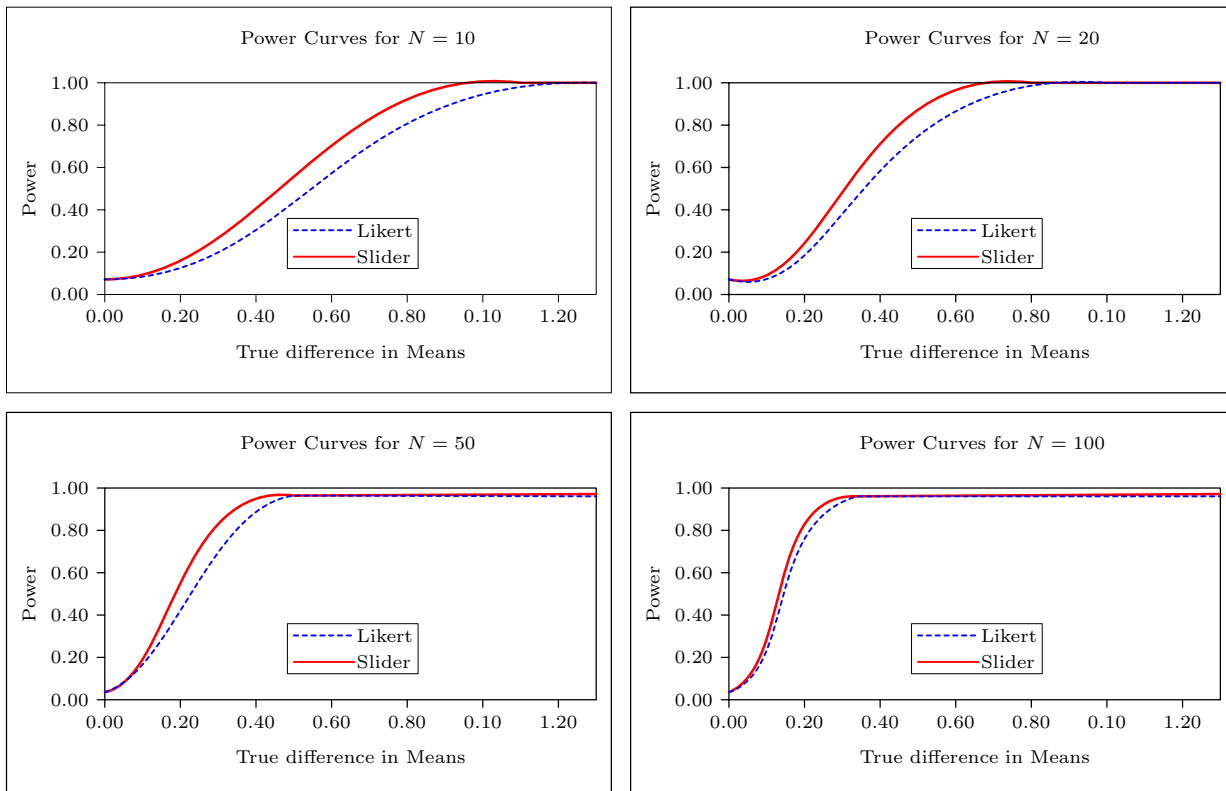


Figure 8: Power Curves for Different Sample Sizes



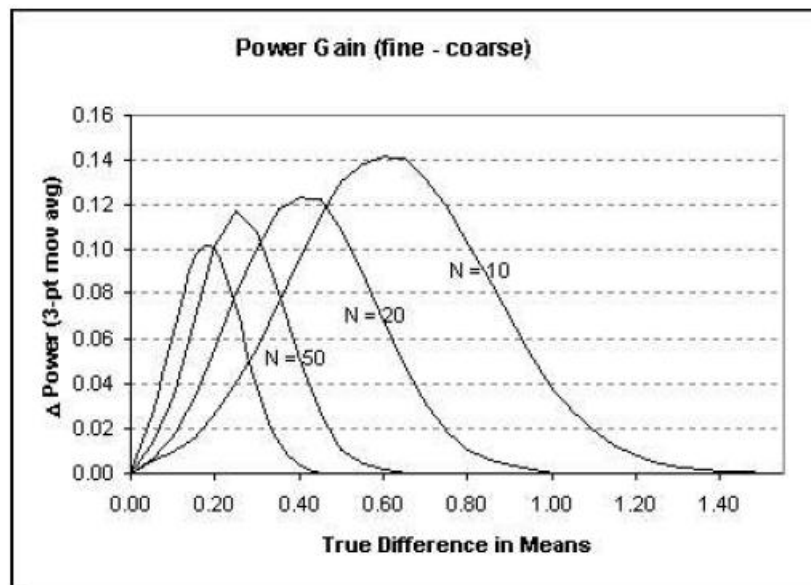


Figure 9: Power Gains for Different Sample Sizes

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