Interaction of Senses: The Effect of Vision versus Touch on the Elongation Bias

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We highlight the role of interacting senses on consumer judgment. Specifically, we focus on the role of the visual and haptic (touch) senses on the elongation bias, which predicts that the taller of two equi-volume objects will appear bigger.

We show that sensory modality will affect the extent (and even direction) of the elongation bias—with visual cues alone and with bimodal “visual and haptic cues” (seeing and handling the objects), we obtain the elongation bias; however, with haptic cues alone (handling the objects blindfolded) and in bimodal judgments with visual load, we obtain a reversal of the elongation bias.

In 1709, George Berkeley stated that “it must be acknowledged that we never see and feel one and the same object. That which is seen is one thing, and that which is felt is another” (1709, sec. 49). This distinction in the perception from different senses seems to have led psychologists to study senses in isolation. However, recently, there is a growing interest on the interaction between senses (e.g., Jones 1986; Power 1980). In this article, we want to introduce this literature to marketing with the hope that it will encourage research on interacting senses within marketing. We also add to this body of literature, by focusing on the effect of vision and touch on the elongation bias.

Much research has shown that taller containers appear to be more voluminous than shorter ones of equal volume, the effect being labeled the “centration hypothesis” (Piaget 1968) or the “elongation effect” (Holmberg 1975). The elongation effect has also been replicated by consumer behavior researchers using frequently purchased packages (Raghubir and Krishna 1999; Wansink and van Ittersum 2003). Raghubir and Krishna (1999) also show that the elongation bias reverses when participants pick up the containers and consume liquid from them, so that perceived consumption from the shorter container appears to be greater than that from the taller one. They suggest that this reversal is because of expectation disconfirmation—vision displays a judgment bias and sets up an (illusory) expectation, which is disconfirmed by consumption and makes the final judgment go in the opposite direction of the original, creating the reversal.

In Raghubir and Krishna’s (1999) research, the focus is not on sensory input. In fact, many different senses could have contributed to the reversal and to the perceived consumption estimates: vision, proprioceptive sense (including stomach and esophagus), proprioception (muscle), and the haptic sense (touch). Raghubir and Krishna’s experiments do not allow for the separation of these effects. In other words, their results assume that the effect of proprioception and haptics on size judgment is unbiased. In fact, we know from the size-weight illusion (Charpentier 1891) that vision and proprioception can interact so that bigger objects of the same weight feel lighter. Thus, the visual-proprioceptive effect on size judgments may indeed be biased. In this article, we focus specifically on the visual-haptic interaction and its effect on the elongation bias.

We contend that the elongation effect is a visual bias and may not sustain without vision when other senses, namely, haptic inputs, are used instead to make the same volume judgment. In this case, we show that the elongation bias may be reversed and could also conceivably explain Raghubir and Krishna’s (1999) results. We argue that the reversal may occur because different spatial dimensions may be more salient to different senses—“height” for vision and “width” when one handles the objects and uses the haptic sense to make the judgment.

We further propose that when multiple inputs (visual and haptic) are used to make the same (volume) judgment, one input may be more dominant for that judgment. We show that when both vision and touch are used for volume judgment, vision dominates touch. We also show that when a person is otherwise (visually) occupied, then perceptions of volume for things one picks up are based more on haptic input than when one is not visually occupied. Thus, if one reflects on a cocktail party or a business dinner, then per-

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ceptions of volumes for drinking glasses may depend on haptic input to a larger extent than if one were mixing a drink for oneself leisurely at home. In the former situation, the diameter of the glass would have a larger role in volume perception of the glass than in the latter situation.

We do three laboratory experiments to explore our research question. In the first two experiments, we use two containers of equal volume, one taller than the other, to test the elongation bias. We find that vision dominates touch so that the elongation bias is obtained when participants only see the objects, and also when they see the objects and handle them. However, when we blindfold the participants and make them handle the glasses, we get an astonishing result. The elongation bias "flips"—the shorter, wider glass is perceived to be more voluminous.

In the second experiment, we show that the elongation-reversal effect is not a function of blindfolded participants not feeling the glass all over and hence not ascertaining the height; it is obtained even when "height" is made salient to these participants. In the third experiment, we introduce visual load and let participants see and handle the containers to judge their volume. The volume judgment task here is memory based so that volume judgments are more incidental than deliberate. We find that, under visual load, reliance on haptic input increases and that we obtain elongation bias reversal.

Throughout this article, when we talk of "bias," we talk of judgment bias, that is, a systematic deviation from the "truth." There is much research by decision theorists and consumer behavior researchers on systematic judgment biases. However, decisions theorists have focused little on the role of interacting senses in judgment biases. The article directs attention to the fact that sensory modality can affect the extent (and direction) of the elongation bias. As such, it suggests that there is much opportunity for people studying judgment biases to direct some attention to sensory inputs.

We first provide a brief background on sensory interaction and on the elongation bias and then propose our hypotheses. This discussion is followed by the three studies. We end with conclusions, limitations, and topics for future research.

PRIOR RESEARCH AND HYPOTHESES

We present here a brief summary of prior research on vision-touch interaction and then on the elongation bias.

Vision-Touch Interaction

The earliest known experiment on intersensory conflict, by Brewster in 1839, is on vision-touch conflict (reported in Epstein 1971). Brewster found that when an indented engraved seal is optically right-left reversed and is seen and felt, the concavities appears as protuberances and feel as such, even though the felt experience contradicts the information provided by the haptic sense, that is, vision dominates touch.

A century after Brewster’s experiments, Gibson (1933) demonstrated that if a subject moved his or her hand along a straight surface while looking through a prism that made the surface look curved, it felt curved as well. Gibson’s experiment and results are similar to those on spatial location (vision-proprioception conflict) where the subject sees a laterally displaced (through a prism) image of one’s own hand and subsequently uses the other hand to judge where it is (e.g., Hay, Pick, and Ikeda 1965). In these studies, participants are more likely to believe the apparent visual location of their own body part (estimates are closer to—but not the same as—those of vision alone than of proprioception alone), even though it conflicts with its actual location.

There have also been experiments where visual and tactile (haptic, or touch based) images of a figure were at odds and participants had to judge the figure shape. Participants saw the figure through a prism that distorted the visual image. Then they had to reach behind the prism and under a cloth to feel the object. In these experiments, typically, standard geometric shapes, for example, square or parallelograms, were visually distorted so that, for instance, the sides of square were “seen” in the ratio 1 : 1.5 or 1 : 1.8. Rock and Victor (1964) demonstrated that vision dominates touch in these tasks. Power (1980) further showed that when the discrepancy between vision and touch is large, vision still dominates touch, but the magnitude of dominance is reduced, that is, judgments using both touch and vision are still closer to those using vision alone than to those using touch alone but not as close.

In a different sort of visual distortion, Kinney and Luria (1970) demonstrated that when submerged divers matched circular disks in size with remembered coins, objectively undersized disks were picked, even when the divers could feel the disks. Many other studies have also examined vision-touch discrepancy and found strong or complete dominance of vision over touch (e.g., Miller 1972).

Thus, across many studies on dominance of vision versus touch, it appears that in some situations, vision completely dominates touch, whereas in others vision is still dominant but not completely so, with the level of vision dominance being task, object, and context dependent. Touch does not appear to dominate vision in these studies. We discuss next the elongation bias and how the visual-haptic sensory interaction can play a role in it.

Elongation Bias

In Piaget’s (1968) experiments demonstrating the centration bias, colored liquid was poured from a tall cylinder into a shorter, wider cylinder, so that the height of the liquid in the second cylinder was smaller. Children were asked whether the volume of the liquid had remained the same or been reduced—most believed the latter, exhibiting the use of a single dimension, height, to make three-dimensional judgments.

Building on Piaget’s experiments, Holmberg (1975) conceptualized height not in absolute terms but in units of width. He suggested and found support for the elongation bias whereby containers with greater height-to-width ratios were estimated as having larger volumes. In Holmberg’s exper-
iments, participants had to turn a knob to raise or lower a
cylinder through a hole in a plane to match the volume of
a given object. In consumer behavior studies, Krider, Ra-
ghubir, and Krishna (2001), Raghubir and Krishna (1996,
1999), and Wansink and van Itersum (2003) also show the
centration bias (use of a single dimension) to operate in
spatial (length, area, and volume) judgments.

Krider et al. (2001) suggest that the centration bias is due
to the perceptual salience of one of the dimensions, which
results in objects larger on this salient dimension appearing
bigger—they show that squares appear smaller than equal
sized circles but larger when placed on a corner so that they
appear like a diamond. The psychological reasoning for
these effects relies on consumers simplifying a difficult cog-
nitive task by using a single piece of information as a proxy
for a more complex analysis (Einhorn and Hogarth 1981).

In prior tests of the elongation bias, visual input has al-
ways been used, and it has been implicitly assumed that the
elongation bias is visual. However, the bias has not been
tested without vision, which we do in this research. We
propose that in visual perception tasks where one judges the
volume of two glasses, height will be the salient dimension
(as proposed by Raghubir and Krishna 1999); however, if
one handles the containers (but does not see them), width
will be the salient dimension. This is because information
on diameter is haptically obtained merely by picking up an
object (called the “enclosure” exploratory procedure by
Klatsky, Lederman, and Matula [1993]); however, informa-
tion on height is haptically obtained by “contour follow-
ning” (Klatsky et al. 1993); the latter, contour following, is
a less natural and more deliberate haptic exploratory pro-
cedure as opposed to the more natural “enclosure” haptic
exploratory procedure.

As such, with visual input, one will obtain the elongation
bias, but, with haptic input (and no visual input), one will
not obtain the elongation bias. In fact, with haptic input,
one will obtain a reversal of the elongation bias, since the
signals from vision and touch are totally at odds—with vi-
sion, the taller, thinner object being bigger, and with touch,
the shorter, wider object being bigger. This leads us to pro-
spose that:

**H1:** When vision (alone) is used to judge volume, one
will obtain the elongation bias, whereby tall-thin
objects are perceived to be larger than short-fat
ones of equal volume.

**H2:** When the haptic sense (alone) is used to judge
volume, one will obtain the “reverse-elongation bias,”
whereby the short-wide objects will be per-
ceived to be bigger than the tall-thin geometric
object.

Hypothesis 1 is more in the nature of a replication since the
elongation bias with vision has been demonstrated many
times before.

As discussed earlier (e.g., Jones 1986; Power 1980; Rock
and Victor 1964), prior studies suggest that in some situa-
tions, visions completely dominates touch, whereas in others
vision is still dominant but not completely so. Hence, we
hypothesize that:

**H3:** Vision will dominate touch, so that when both
senses are used for volume judgment, the elonga-
tion bias (perceived difference in volume of tall
vs. short glass) will be closer to that for vision
alone versus that for touch alone.

Based on research previously discussed, increasing the
salience of a dimension increases its use (Krider et al. 2001;
Lauer 1929). Thus,

**H4:** Making height (width) more salient will increase
the elongation bias (decrease the elongation bias).

When one sense is taxed (has cognitive load on it), then
the other sense should be relied on more for volume judg-
ment. This is consistent with the sensory-conflict and at-
tention argument (Kelso et al. 1975; Warren and Schmitt
1978), whereby weights given to each modality in bimodal
judgments are related to the attention that is directed to each
modality. Cognitive load affecting relative reliance on sen-
sory inputs is even more likely if the loaded sense is the
dominant sense; if the loaded sense is the dominated sense,
load should make little difference to relative use of alternate
sensory inputs. Thus if, consistent with hypothesis 3, vision
indeed dominates the haptic sense (even if not completely),
then load on visual resources should increase the weight
given to haptic resources in the judgment. Hence, we also
propose that:

**H5:** Vision dominates the haptic sense in volume judg-
ment, so that haptic input will be used more when
there is cognitive load on vision, reducing the
elongation bias (vs. when there is no load on
vision).

We now elaborate on our three studies.

**STUDY 1: SENSORY INPUTS AND
ELON GATION BIAS**

We examine how the elongation bias for judging relative
volume of two glasses is affected when the relative volume
is judged by visual cues alone, visual cues along with haptic
cues, and haptic cues alone (handling the glasses blind-
folded).

**Design**

Participants were 66 undergraduate nonbusiness students
who completed the experimental task for payment. The de-
sign was a one-way between-subjects ANOVA with three
conditions ("vision" only, "vision and touch," and "touch" only—i.e., participants are blindfolded).
TABLE 1
STUDY 1: VOLUME ESTIMATES FOR TALL AND SHORT GLASSES AS A FUNCTION OF SENSORY INPUT

<table>
<thead>
<tr>
<th>Sense</th>
<th>Tall glass</th>
<th>Equal</th>
<th>Short glass</th>
<th>$F(1,59)$ for contrast of tall versus short glass (elongation bias)</th>
<th>$F(1,59)$ for contrast of elongation bias in this row versus next row</th>
</tr>
</thead>
<tbody>
<tr>
<td>Vision:</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mean volume (fl. oz.)</td>
<td>7.30</td>
<td>6.27</td>
<td></td>
<td>9.58*</td>
<td>.42</td>
</tr>
<tr>
<td>SD (fl. oz.)</td>
<td>(2.20)</td>
<td>(1.40)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Which glass is bigger (n)</td>
<td>14</td>
<td>4</td>
<td>3</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Vision and touch:</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mean volume (fl. oz.)</td>
<td>6.96</td>
<td>6.23</td>
<td></td>
<td>5.55*</td>
<td>14.96*</td>
</tr>
<tr>
<td>SD (fl. oz.)</td>
<td>(1.44)</td>
<td>(1.70)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Which glass is bigger (n)</td>
<td>13</td>
<td>7</td>
<td>4</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Touch:</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mean volume (fl. oz.)</td>
<td>6.11</td>
<td>7.24</td>
<td></td>
<td>9.43*</td>
<td></td>
</tr>
<tr>
<td>SD (fl. oz.)</td>
<td>(1.71)</td>
<td>(1.30)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Which glass is bigger (n)</td>
<td>2</td>
<td>5</td>
<td>10</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Note.—The table can be read as follows. For the vision condition, the mean volume estimate for the tall glass is 7.3 fl. oz., and the standard deviation is 2.2 fl. oz.; for the short glass, it is 6.27 fl. oz., and the standard deviation is 1.4 fl. oz. Fourteen participants estimate the tall glass as bigger, three estimate the short glass as bigger, and four estimated them to be equal in volume. The contrast test of the tall vs. short glass estimate (i.e., the elongation bias) in the vision condition has an $F(1,59)$ value of 9.58. The contrast test for elongation bias in “vision” vs. the sense in the next row, “vision and touch,” has an $F(1,59)$ value of 0.42.

*The $F$-value for the contrast test is significant at $p < .01$.

Method

We used two transparent plastic glasses of the same volume (7 fl. oz.) with one glass taller than the other. The glasses were of the lightweight, disposable kind so that “weight” was not a concern. In the blindfolded condition, at no point did the participants see the glasses—the glasses were hidden and were taken out only after the participants had been blindfolded. In handling the glasses, blindfolded participants were free to feel the glasses all over, and in fact they felt the top, bottom, and sides, that is, all dimensions of the glasses. One would expect them to feel the glass all over since it is difficult to make a volume judgment blindfolded without doing so. As such, participants had both height and diameter information. The order of presentation of glasses was counterbalanced. In all three conditions, glasses were presented one at a time, the participants orally answered the perceived volume for the two glasses, and the experimenter wrote down the answers. As a reference, all participants were informed that a Coke can is 12 fl. oz.

There were no significant (main or interaction) order effects ($p > .5$), and these are not discussed further. Four outliers were removed using a cutoff of three standard deviations from the mean, two from “vision,” one from “vision and touch,” and one from “touch” conditions.

Results

**Perceived Relative Volume.** The analysis was a repeated-measures ANOVA treating the two volume estimates (tall glass, short glass) as a within-subjects factor and the three conditions as a between-subjects factor. We call the within-subjects factor “elongation” and the between-subjects factor “sense.”

Neither elongation nor sense were significant ($p > .2$), but their interaction was ($F(2,59) = 10.91, p < .001$; see table 1). A significant interaction between elongation and sense is consistent with hypotheses 1–3, but further contrast tests are needed to support these hypotheses. Follow-up simple effects tests show that the elongation bias is significant for all three conditions, but its effect is very different across the conditions. In the “vision” condition, mean perceived volume for the tall glass is 7.30 oz. versus 6.27 oz. for the short glass ($F(1,59) = 9.58, p < .01$). In the “vision and touch” condition, mean perceived volume for the tall glass is 6.96 oz. versus 6.23 oz. for the short glass ($F(1,59) = 5.55, p < .05$). Both these results are consistent with the elongation bias. In the “touch” condition, however, mean perceived volume for the tall glass is 6.11 oz., significantly less (and not more) than the short glass (7.24 oz.; $F(1,59) = 9.43, p < .01$)—this is in the opposite direction of the elongation bias.

Thus, hypotheses 1 and 2 are supported—elongation bias needs visual input and is not supported by haptic input alone. When haptic input is used, we obtain the reverse-elongation bias. Hence, the elongation bias flips when “touch” as opposed to “vision” is used for the judgment.

Hypothesis 3 argues that vision will dominate touch so that the estimate in the bimodal (“vision and touch”) condition will be closer to the “vision” versus the “touch” condition. The simple effects tests described earlier showed that the elongation bias was significant for the “vision and touch” condition. To directly compare the “vision” and “vision and touch” conditions, we did interaction contrasts comparing the magnitude of the elongation bias in these two conditions ($F(1,59) = 0.42, p > .5$). We also did similar interaction contrasts for “vision” versus “touch” ($F(1,59) = 18.95, p < .01$) and for “vision and touch” versus “touch”
INTERACTION OF SENSES

\(F(1,59) = 14.96, p < .01\). These tests indicate that the magnitude of elongation bias is similar in the “vision” versus “vision and touch” conditions but is significantly different in the “vision” versus “touch” conditions. Thus, “vision” seems to dominate “touch,” and the elongation bias in the “vision and touch” condition is in the direction of “vision,” supporting hypothesis 3.

Which Glass Is Perceived to Be More Voluminous?
This question was not asked directly but was inferred from the volume estimates. Table 2 also reports the proportion of participants who thought that the taller glass was bigger, smaller, or equal to the shorter glass for the three sense conditions. One can see that while more people think the tall glass is bigger in the “vision” and “vision and touch” conditions, more think that the short is bigger in the blindfolded condition (all \(p's < .05\)). Systematic differences in these proportions across (sense) conditions are tested with a larger sample size in study 2.

Discussion

We show in study 1 that the elongation bias is in fact a visual bias and that it reverses when the sensory input is not visual but haptic. There remains one concern that, in the blindfolded condition in this study, participants may not have felt the height properly but only felt the diameter. Also, study 1 had a relatively small sample size for the categorical data analysis. In the next study, we test whether elongation bias can be moderated by making specific dimensions more salient, and if this result is sensory-input specific. We also use a larger sample size.

STUDY 2: DIMENSION SALIENCE AND SENSORY INPUTS

We focus on the effect of salience of different dimensions on the elongation bias when different sensory inputs are used for the judgment.

Design

Participants were 260 undergraduate business students who completed the experimental task as part of a subject pool requirement. The design was a 3 x 3 between-subjects ANOVA with three sensory input conditions (vision only, vision and touch, and touch only—i.e., participants are blindfolded) and three salience of dimension conditions (no dimension salient, height salient, and diameter salient).

Method

The method was the same as in study 1. Participants gave their volume estimate for two transparent, plastic glasses (one taller and thinner and one shorter and wider, both of equal volume—16 fl. oz. or approximately 473 ml). As a benchmark, participants were told that a Coke can is 330 ml. The order of presentation of glasses was counterbalanced. A particular dimension was made salient by specifically asking participants their estimate of that dimension. Thus, for instance, in the height-salient condition, participants were asked for their estimates of height of the glass before they were asked for their volume estimate of the glass. As in study 1, the two estimates were asked separately (i.e., subject saw only one glass at a time). In addition, in

| TABLE 2 |
| STUDY 2: VOLUME ESTIMATES FOR TALL AND SHORT GLASSES AS A FUNCTION OF SENSORY INPUT AND DIMENSION SALIENCE |

<table>
<thead>
<tr>
<th>Sense</th>
<th>Dimension salience</th>
<th>None salient</th>
<th>Diameter salient</th>
<th>Height salient</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Tall glass</td>
<td>Equal</td>
<td>Short glass</td>
<td>Tall glass</td>
</tr>
<tr>
<td>Vision:</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mean volume (ml)</td>
<td>403.7</td>
<td>357.9*</td>
<td>360.7</td>
<td>303.0**</td>
</tr>
<tr>
<td>SD (ml)</td>
<td>(115.0)</td>
<td>(109.3)</td>
<td>(92.4)</td>
<td>(81.9)</td>
</tr>
<tr>
<td>Which glass is bigger (n)</td>
<td>15</td>
<td>0</td>
<td>9</td>
<td>16</td>
</tr>
<tr>
<td>Vision and touch:</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mean volume (ml)</td>
<td>364.1</td>
<td>319.5*</td>
<td>364.8</td>
<td>337.9</td>
</tr>
<tr>
<td>SD (ml)</td>
<td>(81.4)</td>
<td>(86.2)</td>
<td>(92.6)</td>
<td>(117.3)</td>
</tr>
<tr>
<td>Which glass is bigger (n)</td>
<td>16</td>
<td>1</td>
<td>5</td>
<td>17</td>
</tr>
<tr>
<td>Touch:</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mean volume (ml)</td>
<td>305.5</td>
<td>350.3*</td>
<td>313.7</td>
<td>365.8**</td>
</tr>
<tr>
<td>SD (ml)</td>
<td>(111.0)</td>
<td>(109.6)</td>
<td>(68.6)</td>
<td>(92.1)</td>
</tr>
<tr>
<td>Which glass is bigger (n)</td>
<td>10</td>
<td>2</td>
<td>18</td>
<td>4</td>
</tr>
</tbody>
</table>

Note.—The table can be read as follows. For the vision and none salient conditions, the mean volume estimate for the tall glass is 403.7 ml, and the standard deviation is 115.0 ml; for the short glass, it is 357.9 ml, and the standard deviation is 109.3. Fifteen participants estimate the tall glass as bigger, nine estimate the short glass as bigger, and none estimate them be equal in volume.

*Elongation bias in this cell (estimated volume of tall glass – estimated volume of short glass) is significant at \(p < .01\).

**Elongation bias is significant at \(p < .05\).
this study, the two tasks (i.e., the two glasses) were separated by an unrelated filler task.

In all nine conditions, the participants orally gave their perceived volume estimates for the two glasses and the experimenter wrote these down. There were no significant (main or interaction) order effects (p > .2), and these are not discussed further. Six outliers, occurring in five of the nine conditions, were deleted.

Results

Perceived Relative Volume. The analysis was a repeated-measures ANOVA treating the two volume estimates (tall glass, short glass) as a within-subjects factor (“elongation”) and “sense” and “dimension salience” as between-subject factors. Table 2 reports means and standard deviations for all nine conditions.

Elongation (F(1,245) = 9.87, p < .01) and its interaction with sense (F(2,245) = 29.85, p < .01) were both significant. No other effect was (p > .2). A significant interaction between elongation and sense is consistent with hypotheses 1–3, but further contrast tests are needed to support these hypotheses. Follow-up simple effect tests show that the elongation bias is significant for all three conditions (all ps < .01). However, as one can see from table 2, whereas, in the “vision” condition and the “vision and touch” condition, mean perceived volume for the tall glass is larger than for the short glass (for all dimension-salience conditions), in the “touch,” it is the opposite. This supports hypotheses 1 and 2 that elongation bias needs visual input and that one obtains a reversal with haptic input alone.

Hypothesis 3 argues that vision will dominate touch in the “vision and touch” condition. Table 2 shows that, pooled across the three dimension-salience conditions, volume estimates in the “vision” and “vision and touch” conditions are in fact very similar—378.3 (tall) and 318.0 (short) ml in the “vision” condition and 367.2 (tall) and 318.7 (short) ml in the “vision and touch” condition. Interaction contrasts comparing the elongation bias in these two conditions show that the difference is not significant (F(1,245) = 0.44, p > .5). However, given the elongation reversal, the elongation bias is clearly significantly different in the “vision” versus “touch” conditions (F(1,245) = 48.5, p < .01) and also in the “vision and touch” versus “touch” conditions (F(1,245) = 37.89, p < .01). Thus, vision seems to dominate touch so that volume estimates in the vision and touch condition are close to those in the vision (only) condition, supporting hypothesis 3.

Hypothesis 4 argues that the elongation bias will increase (decrease) when height (diameter) is made salient. None of the effects involving dimension salience are significant (p > .2). This would indicate that one dimension is intrinsically strongly salient depending on sensory input—height when vision is present and diameter when only haptic input is present. The null effect also provides support that the elongation reversal effect in the “touch” condition is not because participants do not notice the height.

Yet, there is other information in the data. Table 2 also shows that the elongation bias (reverse elongation bias for “touch”) is significant in eight of the nine cells but not in the “vision and touch” cell when diameter is made salient. Thus, it appears that the addition of touch (to vision) is not enough to decrease the elongation bias; nor is diameter salience alone enough; however, “touch” together with “width salience” is—in this case, elongation bias ceases to exist. One could argue that hypothesis 4 is only partly supported.

Between-Subjects Analysis. A between-subjects analysis was also conducted using only half the data, that is, only the first volume estimate of each subject. Given that we had no order effects, as one would expect, we obtained similar results with this analysis. This suggests that our results do not only manifest themselves when comparative judgments are made. This is further tested in study 3, which uses a between-subjects analysis. We revert back to the within-subjects (full data) analysis to do the categorical data analysis.

Which Glass Is Perceived to Be More Voluminous? This question was not asked directly but was inferred from the volume estimates. Table 2 shows that in all “vision” and “vision and touch” conditions, the proportion of participants perceiving the tall glass to be bigger is larger than that thinking the short glass is bigger. In the “touch” condition, however, the proportion of participants perceiving the tall glass to be bigger is smaller than that thinking the short glass is bigger. If we pool across the three dimension-salience conditions, then, in the “vision” condition, more participants found the tall glass bigger (52/82 or 63.4%) than the short glass bigger (17/82; p < .01; 13/82 thought they were equal). In the “vision and touch” condition too, more participants found the tall glass bigger (55/77 or 71.4%) than the short one (21/77; p < .01; 1/77 thought they were equal). In the “touch” condition, there is a reversal, and more participants think the short glass is bigger (69/95 or 72.6%) than the tall one (24/95; p < .01; 2/95 think they are equal).

An additional binary logit analysis tested for systematic differences between the three sense conditions for people believing that the tall glass is bigger versus those believing that the short is (thus dropping participants who thought the two glasses were equal in volume). This analysis therefore tests directly for the difference in elongation bias among the three conditions. This is done in a manner similar to simple contrast tests in MANOVA, but since the dependent variable is categorical (tall glass bigger, short glass bigger), we use a logit analysis. The analysis also includes dimension salience as another independent variable (consistent with the MANOVA tests reported earlier) and tests for elongation bias across the three dimension-salience conditions. The analysis reveals that the proportion of people believing that the tall glass is bigger than the short glass was not significantly different between “vision” and “vision and touch” (Wald chi-square = .11, p > .5) but was significantly different between “vision” and “touch” (Wald chi-square = 35.88,
INTERACTION OF SENSES

$p < .01$). Dimension salience was not significant—elongation bias was not different when no dimension was made salient versus when diameter or height were made salient (both $p's > .2$).

If one pools the results across the three dimension-salience conditions (i.e., omits dimension salience as an independent variable), the results are still similar—there is no significant difference between the "vision" and "vision and touch" conditions (Wald chi-square = 1.67, $p > .5$) and a significant difference between "vision" and "touch" conditions (Wald chi-square = 35.22, $p < .01$).

Discussion

A concern with study 1 was that blindfolded participants may not have felt the height properly but only the diameter. In study 2, we find that making height or diameter salient has little effect on the extent to which elongation bias (or its reversal) associated with different senses. The reversal is obtained even when height is made salient to blindfolded participants. This suggests that one dimension may be intrinsically strongly salient depending on sensory input—height when vision is present and diameter when only haptic input is present.

In both studies 1 and 2, we also find that elongation bias in the "vision and touch" condition is closer to that in the "vision" condition than in the "touch" condition. Per the sensory-conflict and attention argument (Kelso et al. 1975; Warren and Schmitt 1978), this would suggest that in the bimodal judgment (vision and touch) situation, most (or all) of the participants' attention is directed to vision.

In study 3, we manipulate the attention given to vision. We examine the effect of visual load on relative use of sensory input.

STUDY 3: VISUAL LOAD, MEMORY, AND USE OF SENSORY INPUTS

If visual load increases the use of the haptic (vs. the visual) sense in making judgments, then the elongation effect should be smaller in the load versus no-load condition. Additionally, this will demonstrate that vision dominates touch in volume judgments.

Design

Participants were 124 undergraduate business students who completed the experimental task for payment. The design was a $2 \times 2$ (load: visual load vs. no load) \times (height of glass: tall or short) between-subjects ANOVA.

Method

Participants gave their volume estimate for one of two transparent, plastic glasses (one taller and thinner and one shorter and wider, both of equal volume—16 fl. oz. or approximately 473 ml). Participants were told that they would be doing a tasting for new bottled water. One fl. oz. of water was poured into each glass. Participants were instructed to sip the water from each glass given to them really slowly ("so as to really perceive its true taste") and answer some questions. More specifically, participants were asked, in order, how many bottles of water they bought each week, their favorite bottled water (then told to eat a water cracker to refresh their taste buds followed by exactly four small sips of water drunk very slowly—so as to get the true taste of the water), and how the water compared with their favorite water based on two questions (a nine-point scale anchored at definitely better tasting and definitely worse tasting; a nine-point scale anchored at definitely more refreshing and definitely less refreshing).

For the visual load condition, participants had to answer the questions listed earlier while watching six 30 sec. advertisements. They had been told that we would ask them ad recall questions later, and they had to do another task (a tasting) while watching the ads. In this condition, after the ads were over and the glass was taken away, we asked them to estimate the volume of the glass in which the water was served (a Coke can being 330 ml) and also asked them the ad recall questions (we asked them to list unaidered the name of all the products that they saw ads for; we also had some other questions). In the no-load condition, no ads were shown; after the questions above, the glass was taken away, and participants were asked to estimate the volume of the glass they had just been drinking from.

The judgment task was memory based so that volume estimates were more incidental than deliberate. This was done because, in a deliberate task where participants know that they will be asked for volume judgments later, there is a high likelihood that, at the time of judgment, they will again rely on visual input (even though there was visual load during the task).

Two outliers were deleted from the data using a cutoff of three standard deviations from the mean. These occurred in the load-tall and no-load-short conditions.

Results

The analysis was an ANOVA with load and height (of glass) as the two independent variables and perceived volume of glass as the dependent variable. The interaction of load and height was significant ($F(1,118) = 8.39, p < .01$), whereas the main effects for load and height were not ($p > .2$). In the no-load condition, participants estimated the tall glass ($M = 375.8$ ml, SD = 90.0, $n = 30$) as being bigger than the short glass ($M = 326.5$, SD = 72.0, $n = 30$), whereas in the visual-load condition, it was the opposite—participants estimated the short glass ($M = 363.33$, SD = 99.51, $n = 30$) as being bigger than the tall glass ($M = 311.72$, SD = 116.4, $n = 32$). Follow-up simple effect tests show that the differences are significant in both conditions ($F(1,118) = 3.94, p < .05$ for no load; $F(1,118) = 4.46, p < .05$ for load), supporting hypothesis 5 that haptic input will be used more when there is cognitive load on vision, reducing the elongation bias ($F(1,118) = 3.94, p < .05$ for no load; $F(1,118) = 4.46, p < .05$ for
Discussion

Results from study 3 suggest that vision does indeed dominate touch for volume judgment, such that when a stimulus is experienced under visual load, for example, when watching a movie or talking to colleagues at a work-related social function, then reliance on haptic input for volume judgment of the stimuli increases. In that case, when one reflects on the experience, we obtain elongation bias reversal.

We used a between-subject design in study 3 and obtained the elongation bias with "vision and touch" and reverse elongation with "vision and touch," but with visual load. Along with studies 1 and 2, this suggests that our results do not hold only when relative judgments are made.

Per Raghubir and Krishna (1999), elongation reversal will not occur under visual load, since vision is needed to set up the expectation. Our results, however, show the opposite—that elongation reversal will be more likely to occur under visual load. Thus, our results cannot be explained by Raghubir and Krishna's theory. However, we can offer an alternative explanation for Raghubir and Krishna's (1999) elongation reversal—that participants have prolonged haptic contact with the glasses when they drink from them, causing the reversal. However, this needs to be explored further in future research.

CONCLUSION, LIMITATIONS, AND FUTURE RESEARCH

In this article, we examine how the elongation bias for judging relative volume of two stimuli is affected when the judgment is made by visual cues along with other sensory cues (through handling the object) and by the latter alone (handling the object blindfolded). Studies 1 and 2 show elongation bias needs visual input and is not supported by haptic (only) input. When haptic (only) input is used, we obtain a reversal in the elongation bias—the elongation bias flips when "touch" as opposed to "vision" is used for the judgment. We propose that reversal in the elongation bias occurs because, when blindfolded participants hold a glass, the natural exploratory procedure of enclosure (holding the glass) makes diameter of the glass the most salient dimension. Feeling the height of the glass requires a less natural "contour following" exploratory procedure and is therefore less salient. Since the shorter, wider glass has the bigger diameter, it is perceived to be bigger.

In study 1, blindfolded participants are free to feel the glasses as they wish; however, in study 2, we specifically manipulate salience of specific dimensions by asking participants their estimates for these dimensions (before volume judgment). We find that dimension salience has little effect on our results (elongation bias and its reversal). We suggest that one dimension may be is intrinsically strongly salient depending on sensory input—height when vision is present (even when touch is present) and diameter when only haptic input is present.

Study 2 also indicates that while making alternate dimensions salient can affect the extent of centration (focus on one salient linear dimension) for area judgments (as shown by Krider et al. 2001), this need not be the case for volume judgments. Thus, the effect of dimension salience on spatial judgment needs further research. Our results suggest that, when the visual sense is available to consumers for making volume judgments and larger objects are preferred by them, then managers should try to make taller containers in order for the containers to appear larger. Making a short fat container’s width salient (e.g., by drawing horizontal lines across it or building horizontal ridges into the container) is not likely to make it appear larger than an equivolume taller one.

We show, through studies 1–3, that vision does indeed dominate touch for volume judgment. In bimodal volume judgment, most (or all) of the participant’s attention is directed to vision, so that estimates are close to that of vision alone. With attention diverted away from vision (when we introduce visual load in study 3), and toward haptic input, we obtain the reverse elongation bias as would be predicted with dominance of haptic input. One could argue, however, that participants had more tactile contact with containers in the load condition, and this could have introduced a potential confound. This needs to be explored in future research. Findings across the three studies also indicate that our results are not dependent on comparative judgments of volume.

The elongation bias reversal that we obtain cannot be obtained by Raghubir and Krishna (1999), since their theory requires vision for the reversal (to set up an expectation), whereas we obtain the reversal when there is no vision or the visual sense is loaded. Our results, however, suggest that participants’ prolonged haptic contact with the glasses when consuming from them may cause the reversal in the Raghubir and Krishna experiments. But this needs to be explored further. One way we can test whether Raghubir and Krishna’s (1999) bias reversal is interoceptive and not proprioceptive or haptic is by having participants consume the drink through a straw with the glasses being stationary (rather than having participants pick up and drink from the two glasses).

Findings from study 3 that reverse elongation is obtained under bimodal judgment and visual load are independent of one’s consumption of the product. Thus, one can share the product with others (e.g., popcorn during movies) or take only a few sips from a glass, but the effect should still be obtained as long as one holds the product for some time. The volume judgment in this study is a memory-based task, and the ensuing managerial implications we draw from it rely on memory-based judgments. When one reflects upon a party or other visually loaded social/business occasion, for instance, perceptions of volumes for drink glasses may depend on haptic input to a larger extent than if one was idly having a drink. In the former situation, glass diameter would have a larger role in volume perception of glass than
in the latter situation. As such, managers of clubs catering to business parties may find customers thinking drinks were more generous if the drinks were served in wider versus taller containers, thereby earning this reputation of generous drink servings.

Similarly, in movie theaters where patrons eat popcorn while watching the movie, the visual sense is loaded watching the movie, whereas the haptic sense is occupied for a long time holding the popcorn container. In this situation too, shorter, wider plastic containers may be remembered as having more popcorn than taller, thinner ones. Of course, this does not imply that on the next purchase occasion, if the movie theater were to keep both taller, thinner and shorter, wider containers for purchase, the consumer would not choose the tall one (believing it to be bigger)—it is quite possible that the consumer’s memory of the last consumption experience may be overwhelmed by visual input of the two containers under this no-visual-load situation. However, if only one type of container is to be sold by the theater (as is the case with movie halls), the shorter, wider one may bring greater satisfaction to consumers.

In study 2, in the “vision and touch” condition, with width salience we did not obtain the elongation bias. This was when the upcoming judgment task was known. In study 3, when there was load on vision and the judgment task was incidental, then touch (and hence width) was used more, reversing the bias. Future research should check the effect of salience manipulation and of the amount of tactile contact on the elongation bias.

Study 2 indicates that participants are more likely to use tactile information from natural procedures (grasping) than from less natural procedures (contour-following) even when the latter are made more salient. One reason could be that natural procedures lead to lower variance in estimates, but we do not find that in our results. Hence, why information from natural procedures is more readily used is another area for future research.

As marketing researchers, we tend to focus primarily on physical product/service features and not so much on the sensory appeal of products and features. There has been a little research on visual/volume perception (Chandon and Wansink 2002; Wansink and van Ittersum 2003), aesthetics and color (Folkes and Matta 2004; Gorn et al. 2004), hearing/music (MacInnis and Park 1991), smell (Joy and Sherry 2003; Morrin and Ratneshwar 2003), and touch (Peck and Childers 2003). However, much more research on the effect of sensory inputs on consumer behavior is needed. Further, there are few studies in marketing on the interplay between sensory inputs. Thus, there is enormous scope for future research in marketing studying how different senses individually and through their interactions can affect consumer perceptions, behavior, and choice.

REFERENCES


[Dawn Iacobucci served as editor and Gita V. Johar served as associate editor for this article.]