Visual discrimination of hygiene tissue softness in the absence of haptic feedback

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ABSTRACT: Our perception of the softness of materials is dominated by the subjective interpretation of haptic stimuli — touch. Although softness is defined by the way a material deforms when force is applied, other sensorial inputs, such as vision and hearing, can be used to complement haptic feedback or when the material cannot be touched. Surface and bulk softness elements of hygiene tissue, such as surface roughness, embossing pattern, and bulk can be assessed visually. Softness is reported as the number one desired quality of hygiene tissue. So, it is of paramount importance to understand the criteria a consumer uses to judge softness visually. Consumers must rely on these other non-tactile senses at point-of-purchase or in e-commerce because they cannot interact with a product to judge the softness. This study proposes that a consumer can accurately gauge softness by sight alone, and that factors such as color tone, embossing, and image quality all affect the perception of softness. Stiffness and mechanical properties of the sheet cannot be observed by eye and can contribute to errors in visual judgement. We conducted an experiment using a complete pair ratio (round-robin) type comparison to evaluate the perceived softness of altered images of hygiene tissue with unaltered images. Images of hygiene tissue were altered to represent different lighting conditions or product color and digital image degradation. Our results suggest that yellow hygiene tissue is perceived as less soft than blue, and un-embossed tissue as less soft that embossed tissue. Reducing the image resolution to 10% of the original did not negatively affect the perception of softness.

Application: In product development, color and embossing pattern can be manipulated to influence the consumer's perception of product softness. Images displayed digitally can be optimized in a similar manner.

Softness is the most important quality in hygiene tissue, as judged by consumers who did not select price as the number one criteria in purchasing decisions [1]. Softness can be defined as "the subjective impression of the physical compressibility and deformability of objects" [2]. Thus, our perception of softness is dominated by the sense of touch. Surface softness of tissue paper can be influenced by the stiffness and coarseness of fibers [3], the number of fibers that stick out [4], the creping frequency and shape of the crepes [5,6], roughness profile [7], and characteristics of the embossing or sheet molding. Bulk softness is influenced by the density and stiffness of the sheet and can be inferred by the resistance to flexing or compressing the sheet. Stiffness is the in-plane resistance to bending and is influenced by the sheet strength via chemical bonding or mechanical modification of the fibers (refining) and fiber type.

Softness is the subjective interpretation by a human brain of a complex set of sensorial stimuli [8]. Haptics, the study of tactile stimuli, can explain much of the differences in human perception of softness of tissue products, yet we use a broad range of senses to judge the world around us. Vision, hearing, and touch work together to give a subjective representation of the materials with which we interact [9]. When we rub our hands over the surface of sandpaper, a sound is generated; the finer the grain, the quieter the sound produced. Likewise, crumpling a stiff tissue will produce a louder sound than a supple one. Vision and hearing have been calibrated with our tactile information through repeated interaction of soft and not soft materials.

In the absence of haptic feedback, as in an online context, customers can only rely on visual perception to evaluate softness. Global e-commerce sales are growing at a rate of 15% annually [10], and the ability for hygiene tissue manufacturers and distributors to make their product visually appeasing will be a key differentiator. To do so, it is crucial to develop a richer understanding of how images of hygiene tissue influence softness perception. Several studies have been conducted to understand the influence of vision on the sense of touch and how the two senses work together. For instance, Cellini et al. [11] found that the addition of visual information when pressing a button, greatly increased one's ability to estimate the softness or resistance of the object. Ernst and Banks [12] concluded that visual and haptic information work together to provide an accurate interpretation of physical characteristics of an object. Tiest and Kappers [13] found that subjects generally were good at estimating surface roughness of everyday materials, but that different subjects ordered the samples using different criteria. Norman et al. [14] found that vision and touch have functionally overlapping, but not necessarily equivalent, representations of three-dimensional shapes.

To our knowledge, no studies have yet to investigate the extent to which a consumer can visually discriminate hygiene tissue softness when they cannot physically interact with the product, or which image characteristics influence a customer's perception. Our hypotheses for this study were as follows:

1. A consumer can visually discriminate and correctly sort images of high, medium, and low softness hygiene tissues.
2. A consumer can differentiate between a large difference in softness and a small difference through visual observation.
3. The disparity in softness between two samples is inversely proportionate to the decision time.
4. A consumer interprets images of hygiene tissue that are yellowish as less soft than images with a pure white or bluish tone.
5. The quality (resolution) of the image of hygiene tissue is inversely proportionate to the subject's interpretation of softness.
6. The subject's inherent precondition for tactile interaction, known as need for touch, will influence their decision time to visually discriminate softness.

To investigate these issues, we conducted a laboratory experiment with 17 participants who visually examined altered and unaltered images of hygiene tissue and selected the softest looking image in pairs. Information from their selections was analyzed to test our hypotheses about the influence of color, image resolution, and embossing on the perception of softness and decision time.

METHOD

Experimental design

We used a within-subject experimental design to evaluate 14 different combinations of visual and physical stimuli. These included three softness ranges (high, medium, and low) combined with four resolutions (unaltered, blueish, yellowish, and low resolution), plus two un-embossed samples of high and low softness. **Table I** lists the images and corresponding characteristics. Paired-comparison (or round-robin) type experiments were used to assess the perception for each stimulus by each participant. The set of 91 pairs (each image displayed in a pair with every other image) was presented to participants twice for control purposes. Participants were asked to make a choice of which image appeared to be softest in each pair. They were then asked to qualify their response by indicating the relative magnitude of the difference in softness between the two presented stimuli. The softness selections and differences in magnitude were converted into a visual softness scale.

Experimental stimuli

Three embossed retail bath tissues were chosen to represent high, medium, and low softness (two national brands and one private label corresponding to two conventional sheets and one through-air-dried product). An away-from-home, flat sheet, un-embossed jumbo roll bath tissue was used as the medium softness un-embossed sample. A high softness facial tissue was used as the high softness un-embossed sample. Samples were selected to fit into one of three softness brackets, as determined by the handfeel value using the "TPII" algorithm from the tissue softness analyzer (TSA) from Emtec Electronic GmbH (Leipzig, Germany).

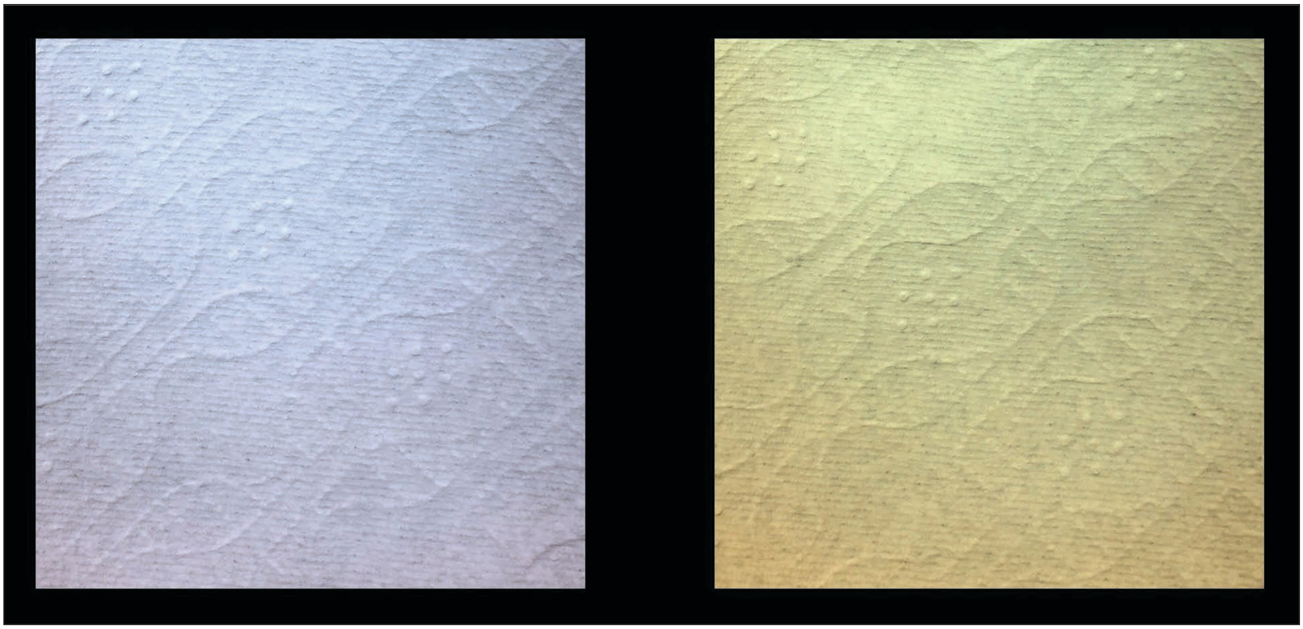
Sample Identifier	Sample Description
A	High softness – unaltered
B	High softness – low resolution
C	High softness – bluish
D	High softness – yellowish
E	Medium softness – unaltered
F	Medium softness – low resolution
G	Medium softness – bluish
H	Medium softness – yellowish
I	Low softness – unaltered
J	Low softness – low resolution
K	Low softness – bluish
L	Low softness – yellowish
M	High softness, un-embossed
N	Medium softness, un-embossed

I. Fourteen stimuli of high, medium, and low softness were presented to the participants.

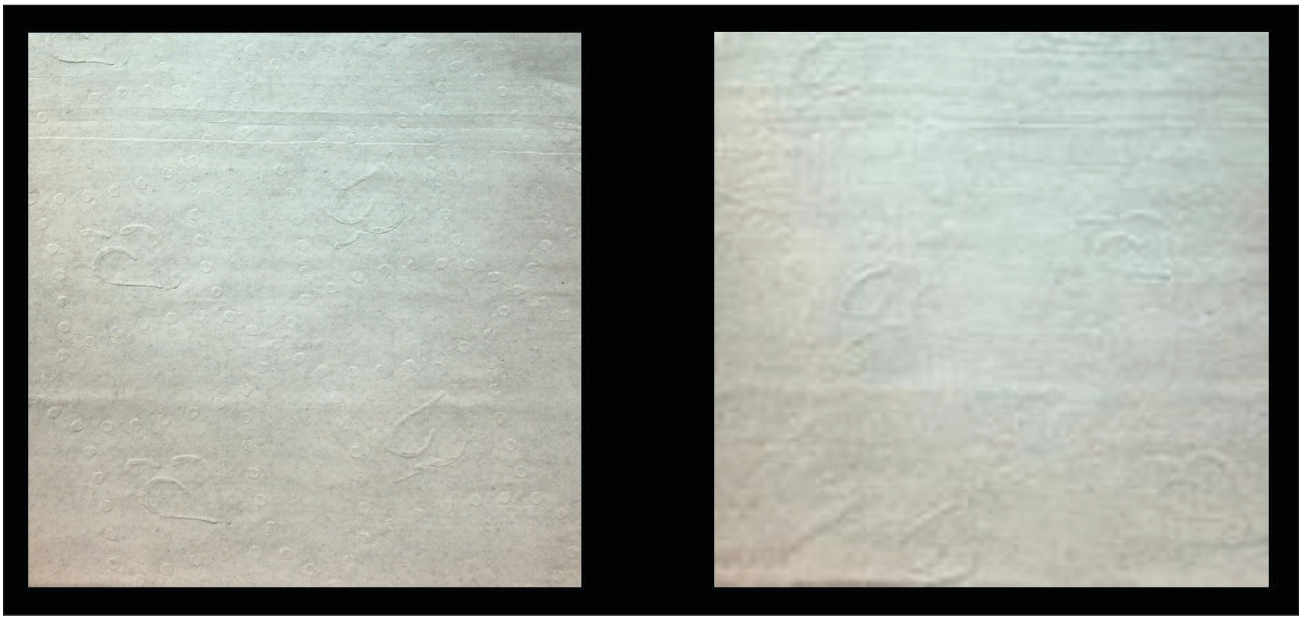
The advantage of presenting stimuli on a digital monitor instead of displaying the physical samples in front of the participants is that the images can be altered to reflect different conditions, such as lighting and image quality (resolution). The products were photographed on a black background with constant lighting conditions and then digitally altered in three ways:

1. The color tone was shifted to the blue region, as seen in **Fig. 1** (Adobe Photoshop's express temperature adjustment -15).
2. The color tone shifted to the yellow region (Adobe Photoshop's express temperature adjustment +15).
3. The image resolution was reduced ×10 by reducing the size of the image to 10% of the original size, as seen in **Fig. 2**.

The un-embossed samples were unaltered. The images were digitally cropped to 9 cm × 9 cm, with no edges or perforations visible, and presented two at a time, side-by-side on the monitor (**Fig. 3**).



1. Image altered to be more bluish on the left and yellowish on the right.



2. Original unaltered image on the left and 10% reduction in resolution on the right.

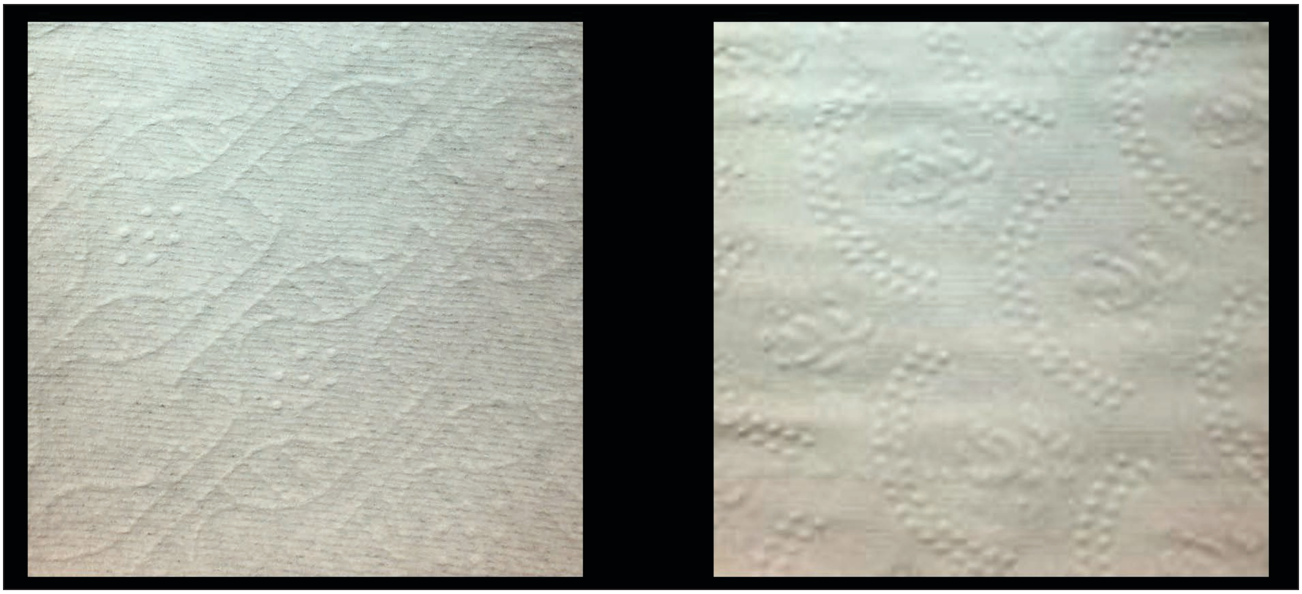
Participants

Participants were solicited from the research panel of our institution from among more than 3600 students, staff, and members of the public. Participants were compensated for their participation with a gift certificate of $20 for the university bookstore. To exclude confounding effects, the following exclusion criteria were used for subject recruitment:

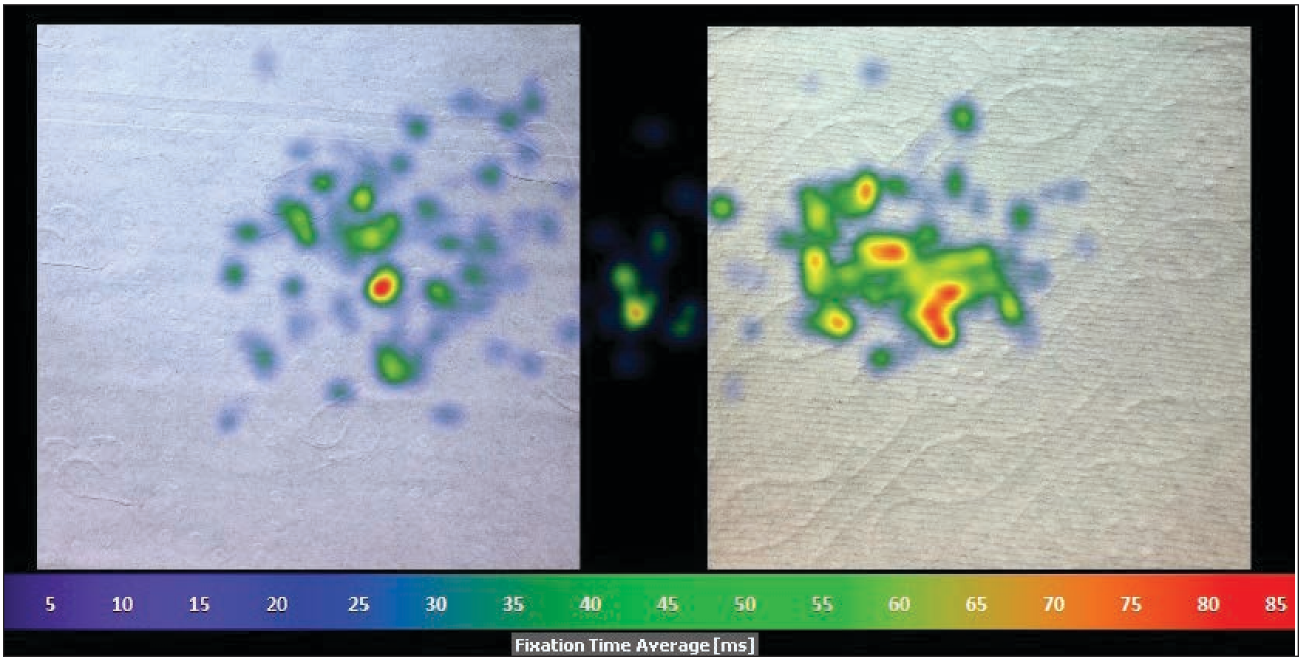
- The participant can work at a computer without the need of corrective lenses or contact lenses.
- The participant has not been diagnosed with color blindness.
- The participant does not have a cardiac stimulator.
- The participant has not been diagnosed with a neurological or psychiatric disorder.
- The participant has not undergone laser vision correction.
- The participant does not have astigmatism.
- The participant does not suffer from epilepsy.
- The participant has no diagnosed health problems.

Instruments and measures

We used oculometry (i.e., eye tracking) to track the attention of participants when presented with images of hygiene tissue. Oculometry records the eye position or point of gaze



3. Participants viewed all pair combinations of the 14 stimuli (91 pairs) arranged on a black background. Participants were asked to look at the images and then decided which image appeared to be the softest.



4. Heat maps were used to discover how much of the image the participants looked at before deciding. In this typical example, participants explored less than one quarter of the image before deciding about the softness. The concentration on fixation in the center between the two stimuli is an artifact of the gaze being directed to the center of the screen before each stimulus presentation.

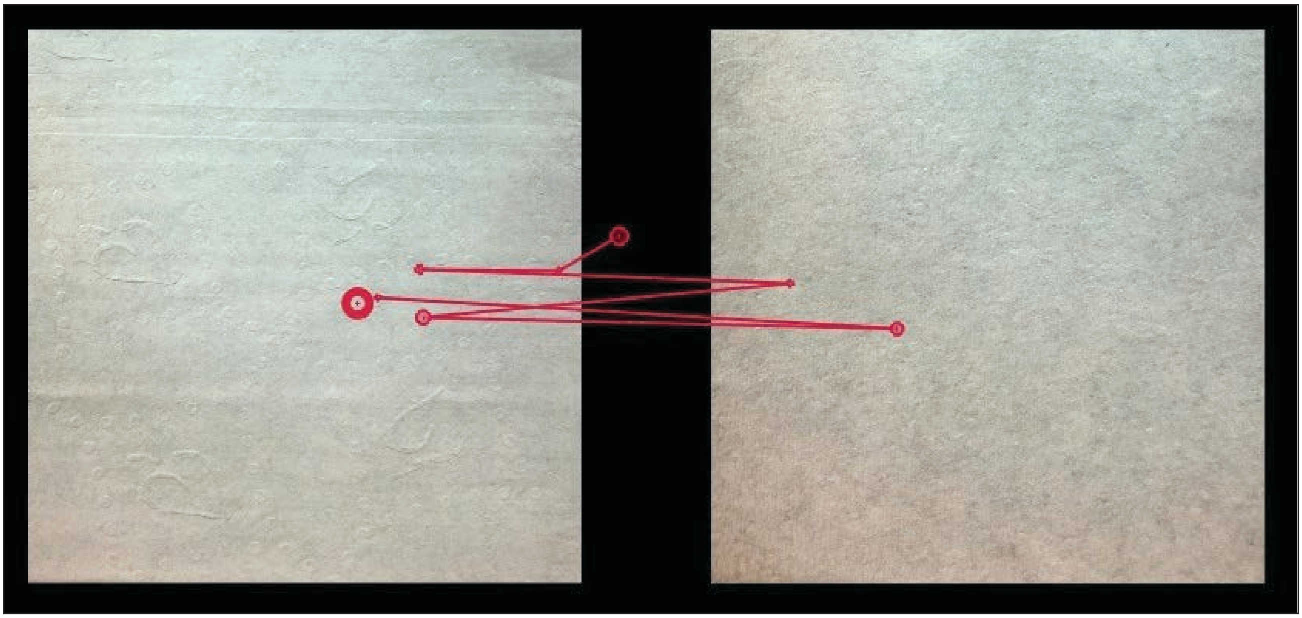
and movement on a monitor [15]. Near infrared light is shined into the pupils of the observer and the reflections off the cornea are tracked by a high-resolution camera. We used passive oculometry, where an instrument is mounted onto a monitor and the observer is stationary. We measured the amount of time a participant looked at each image, to identify what areas the participant spent the most time viewing, and to count how many times the participant scanned between images. **Figures 4** and **5** show the visual attention results of a typical pair of images.

PROCEDURE

The study was broken into five parts:

1. Calibration
2. Paired comparisons block 1
3. Break
4. Paired comparisons block 2
5. Questionnaire

To start, participants sat in front of a monitor fitted with an



5. This scan path image of a pair of stimuli is typical for all the pairs. Participants looked back and forth between the two images several times in the same areas before deciding.

SMI RED250 mobile oculometer (SensoMotoric Instruments; Berlin, Germany). The chair was positioned so that the participant's eyes were in the middle of the screen and 60-70 cm away from the oculometer. Positioning of the participant was aided by visual feedback displayed on the monitor. A pre-programmed eight-point calibration associated the position of the participant's cornea with their gaze on the screen. Calibrations were repeated until an error of less than 0.5° was noted in both eyes. Most participants required only one calibration, but two needed to repeat the exercise three times. The calibration is sensitive to the position of the participant's eyes; therefore, throughout the experiment, participants were observed and reminded to sit up straight in the chair, if required.

Participants were instructed to look at the images presented and indicate which image in each pair appeared softest. Participants were not given further instruction on how to identify the stimuli or given a definition of softness; therefore, each participant used a personal preference to guide their perception of softness. Participants were not presented the stimuli physically; their only interaction with the products was visual inspection. A participant indicated his or her choice by selecting a number on a numerical keypad provided. The participant selected 1 to indicate that the image on the left as the softest and 3 to select the image on the right as softest.

After selection of the softest image, a second screen was presented to the participant. For that, each participant was asked to qualify their answer by indicating the difference in softness between the two previously observed images. The options were: small, medium, and large. The participant selected 1 on the keypad to indicate there was a small difference in softness between the two previous images, a 2 for a medium difference, or a 3 for a large difference. The participants used the same keys on a number pad to select which image appeared softest (left or right with number keys 1 and 3) and to qualify the difference in softness (1 for small, 2 for medium, and 3 for large). Using the same set of keys eliminated the need for the participants to move their hands and look at the keyboard and then reposition their view for each screen. The effect of parity was accounted for in the qualifying step in which a response of 1 returned a null result for both stimuli. In the first block, 91 pairs of images were presented, followed by a short pause of 3 min, during which videos played and the participants could relax their eyes and arms. The pairs of images were then presented a second time, in random order, with the left and right orientation of the images reversed (block 2).

The procedure was followed by a questionnaire asking about participants' purchasing household habits and personal demographics. Responses were also used to assess the participant's "need for touch" (NFT). NFT is described as the "preference for the extraction and utilization of information obtained through the haptic system" [16,17]. Previous research has used this scale in an online context [18]. Participants report to what degree they agree with 12 statements about interacting and purchasing products. NFT is composed of two dimensions: autotelic and instrumental. The autotelic dimension relates to touch as the activity viewing shopping as a hedonic activity seeking sensory stimulation and enjoyment [19]. A person with a high autotelic NFT would agree with statements such as, "Touching products can be fun and I like to touch products even if I have no intention of buying them." The second dimension, instrumental, relates pre-purchase touch as a goal-oriented activity. A person who has a high instrumental NFT touches products to evaluate their quality and would agree with statements such as, "I place

x_{ij}	A	B	C	D	E	F	G	H	I	J	K	L	M	N	Geometric Mean $\bar{x}_1$	Ratio Geometric Mean RGM_i	Linear Non-standard ln RGM_i	Scaled Standard Values
A	1	1	2	1	1	2	1/2	1/2	1/3	1/3	1/3	1/3	1/2	3	0.75	0.050	-3.0	95.2
B	1	1	1	1	1/2	1/2	1/2	1/2	1/3	1/3	1/3	1/3	1/2	1/3	0.53	0.035	-3.4	114.4
C	1/2	1	1	1	1/2	1/2	1/2	1/3	1/3	1/3	1	1/3	1/2	1/3	0.53	0.035	-3.4	114.4
D	1	1	1	1	1/2	1/2	1/2	1/2	1/3	1/3	1/3	1/3	1/3	1/3	0.51	0.034	-3.4	116.0
E	1	2	2	2	1	1	1	1	1	1/2	1/2	1/2	1	1	1.00	0.066	-2.7	79.8
F	1/2	2	2	2	1	1	1	1	1/2	1/2	1/2	1/2	2	1	0.95	0.063	-2.8	82.5
G	2	2	2	2	1	1	1	1	1/2	1/2	1/2	1/2	1	1	1.00	0.066	-2.7	79.8
H	2	2	3	2	1	1	1	1	1/2	1/2	1/2	1/2	1	1	1.03	0.068	-2.7	78.3
I	3	3	3	3	1	2	2	2	1	1	1	1	1	1	1.59	0.105	-2.3	54.9
J	3	3	3	3	2	2	2	2	1	1	1	1	1	1	1.67	0.110	-2.2	52.2
K	3	3	1	3	2	2	2	2	1	1	1	1	2	1	1.62	0.107	-2.2	53.7
L	3	3	3	3	2	2	2	2	1	1	1	1	2	1	1.75	0.115	-2.2	49.5
M	2	2	2	3	1	1/2	1	1	1	1	1/2	1/2	1	1	1.08	0.071	-2.6	75.6
N	1/3	3	3	3	1	1	1	1	1	1	1	1	1	1	1.17	0.077	-2.6	71.4

II. Example of comparison matrix. The 14 image identification letters are inscribed in the columns and rows and the result of the difference magnitudes are entered into the matrix. An entry above 1 indicates that the row was selected as softer than the column; the inverse is true for numbers between 0 and 1. An insignificant difference between the softness of two stimuli results in an entry of 1. Note that columns and corresponding rows are reciprocals of each other. For the pair AC, the participant indicated that A was softest with a medium difference (2). For the pair CH, H was selected as softest with a large difference (3). The geometric mean or the nth root of the product of all entries in the row is inversely proportionate to the participant perceived softness. The ratio geometric mean normalizes the results to between 0 and 1 so the logarithm can be taken and produce a linear result. The final scaled standard values are achieved from the slope, m, and intercept, b, of a calibration curve between the scaled standard values and the tissue softness analyzer results.

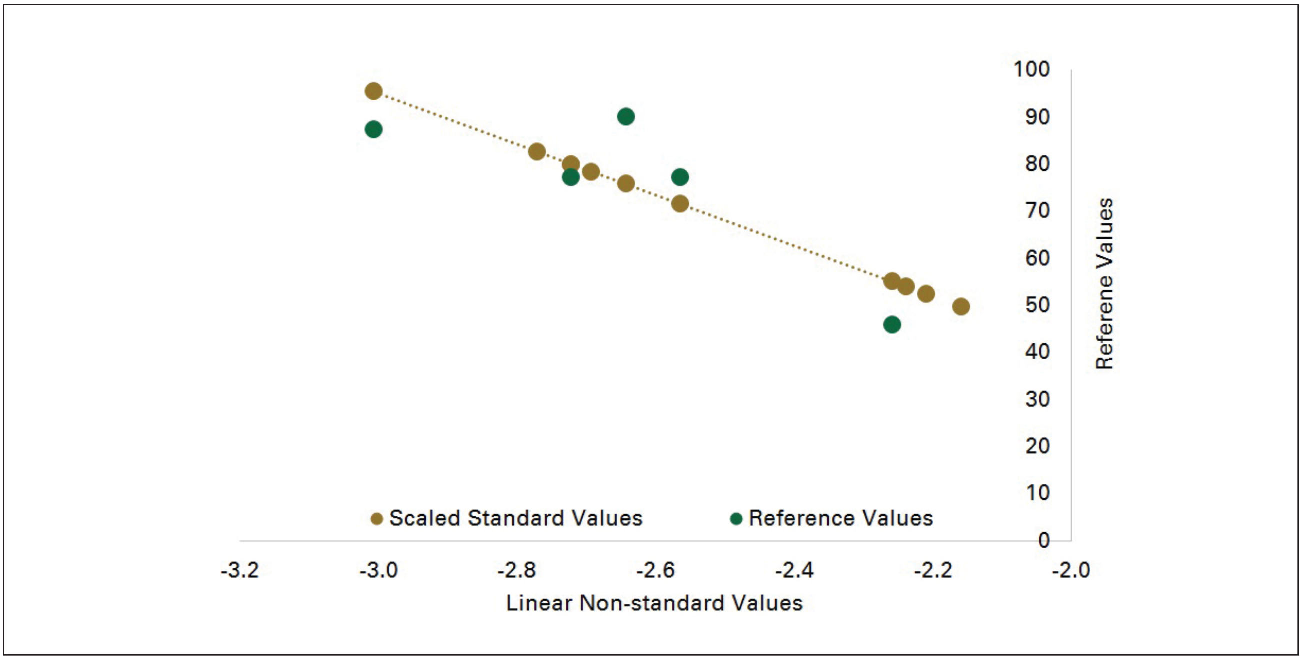
more trust in products that can be touched before purchase," and "If I can't touch a product in the store, I am reluctant to purchase the product" [20].

Measurement

We used numerical inputs to quantify the softness perceptions of each participant. We built a comparison matrix to calculate the visual softness of each image on a ratio scale. The analytic hierarchy process [21] was used on the scaled, paired comparisons [22]. An n × n matrix was built for each participant, where n is the number of stimuli (14 in this case). The 14 images were given codes A-N, corresponding to each row and column of the matrix. The softness preference selected by the participants was scaled by asking the participant to qualify his or her answer by announcing the degree of difference on a 3-point scale in the evaluated attribute (softness) [23]. The preference and magnitude estimation data x_{ij} are mapped into the n × n matrix. The diagonal is attributed the value of 1 because pairs of the same have minimum difference in softness. For each matrix entry, if the stimulus in the row was chosen as softest, the qualification rating was entered as is. If the column was selected as softest, the inverse fraction of the qualification was entered.

To convert the softness selection and magnitude estimations into the same scale as the TSA data, the geometric mean of the pair values was calculated, converted into a linear scale, and a calibration curve was built. The geometric mean of all the entries in a row was calculated by finding the n^{th} root of the product of the row.

The geometric mean of the participant selected preferences and difference magnitudes are used to convert the participant data into a visual softness scale (Eq. [1]):



6. Calibration curve to convert linear non-standard values to the 0-100 tissue softness analyzer scale. The slope and intercept are individual to each participant.

$$Geometric\ Mean = \bar{x}_i = \left(\prod_{j=1}^{14} x_{ij}\right)^{1/14}$$

The geometric means are then normalized between 0 and 1 by dividing by the sum of all the geometric means. (This can also be achieved by dividing by the maximum geometric mean in the series.)

The ratio of the geometric mean is used to normalize data to between 0 and 1 (Eq. [2]):

$$Ratio\ Geometric\ Mean = RGM_i = \bar{x}_i / \sum_{i=1}^{14} \bar{x}_i$$

The ratio geometric mean can then be converted into a linear scale by taking the natural logarithm. The linear scaled values are referred to as the linear non-standard values (see **Table II**). The linear non-standard values are converted to the same scale as the TSA data by building a calibration curve with the linear non-standard values on the x-axis and TSA values on the y-axis (**Fig. 6**). A linear regression curve was fitted to each participant's data and scaled standard values were calculated from the slope and intercept.

The analytical hierarchy process also allows us to track participant performance. Some basic assumptions are made about stimuli, such as:

- Each stimulus is presented without variation to each participant.
- Handfeel value of a product can be expressed by a single real number.
- Participant accurately reports their preference and selection.

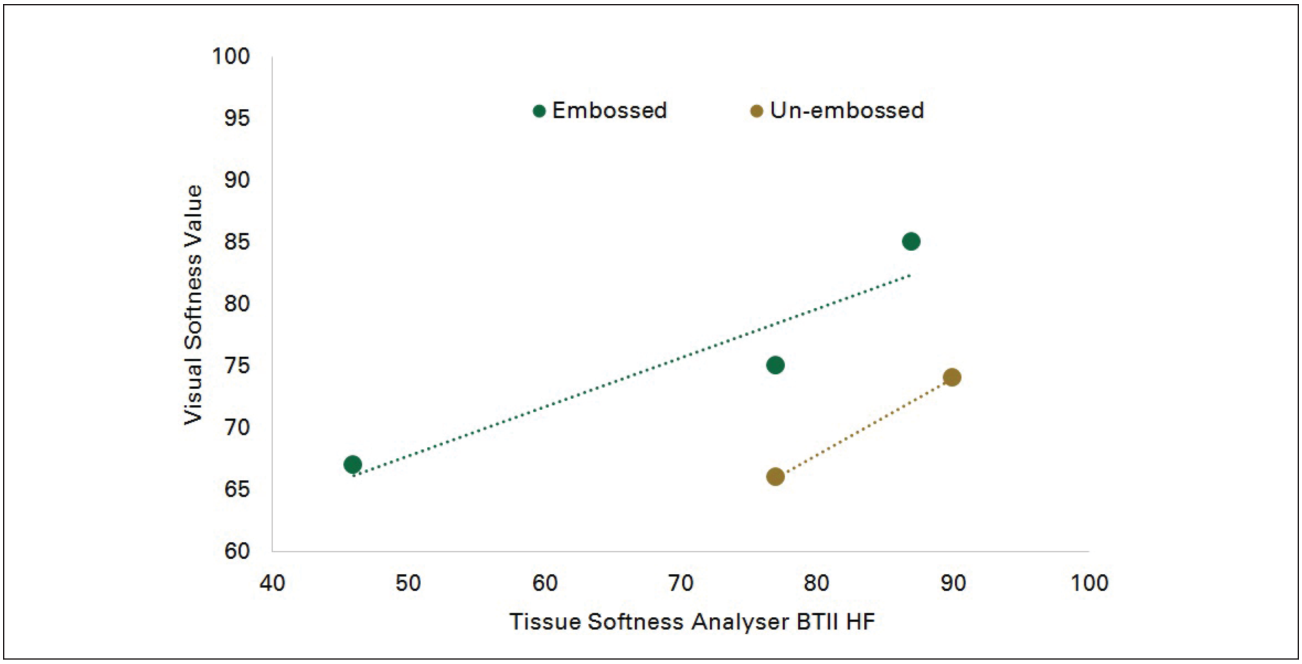
A perfectly consistent comparison matrix would have an eigenvalue equal to the number of stimuli. All panel-type tests have some level of inconsistency because of the subjectivity of the test. Thus, the largest real eigenvalue of the comparison matrix is proportionate to the inconsistency of the participant, while the minimum eigenvalue (λ) is equivalent to the number of stimuli [24]. One participant with an inconsistency significantly higher than the group was removed from calculations. In our case, the first participant had $\lambda = 15$ and the average was 14.5, with a standard deviation of 0.3; thus, participant 1 was excluded from all further analysis.

Participants were also evaluated on discordance or how well they agreed with the group. Discordance is the relative distance between a person's responses and the group's average. It is expressed as the sum of squares of the difference between a value, x, and the average, $\bar{x}$, divided by the number of stimuli, n, in Eq. (3):

$$discordance = \frac{\sum (x - \bar{x})^2}{n}$$

RESULTS AND DISCUSSION

Our first and second hypotheses were confirmed with the comparison data of the unaltered embossed stimuli. Participants rated the three unaltered embossed stimuli in the correct order and with a relative magnitude similar to the TSA softness (**Fig. 7**; **Table III**). With only three points, the fit-



7. Unaltered embossed stimuli were ranked with a similar magnitude as the tissue softness analyzer (TSA) handfeel (HF) value; the regression coefficient is 82%. The un-embossed stimuli were perceived as less soft than the embossed samples for equivalent TSA HF values.

Softness	Visual Characteristic	Tissue Softness Analyzer "TPII" Handfeel Value	Visual Softness Value	Standard Deviation	Significance
High	Bluish		90	9	
	Unaltered	87	85	5	A
	Yellowish		88	10	B
	Low resolution		88	9	AB
	Un-embossed	90	74	10	
Medium	Bluish		74	5	C
	Unaltered	77	75	4	
	Yellowish		72	3	
	Low resolution		74	4	C
	Un-embossed	77	66	3	
Low	Bluish		68	7	DE
	Unaltered	46	67	6	D
	Yellowish		66	8	E
	Low resolution		68	7	DE

III. Softness comparison results. Results with a significant difference in response populations are represented with the connected letter method. Stimuli not connected by the same letter are significantly different per the non-parametric Wilcoxon two-tailed test with a confidence level of 0.1. For example, the high softness unaltered and low-resolution visual softnesses were not significantly different, with results of 85 and 88, respectively.

ness of the linear regression is artificially high, with a regression coefficient of 88%. The reported visual softness of three embossed samples were significant, with p-values between high (H) and medium (M) = 0.0005, high and low = 0.0004, and medium and low = 0.01, with n = 16.

Opacity might play an important role in visual perception of softness. The low softness samples, both embossed and unembossed, were noticeably less opaque than the medium and high softness samples. Basis weight has an indirect effect on softness and can be inferred from the opacity of the sheet. For equivalent bulks, a high basis weight sheet will have a higher caliper and therefore deform more under stress, resulting in a higher handfeel value. We concluded that the participants associated thin, low basis weight as not soft. Most low basis weight, away-from-home, one-ply bath tissues are indeed much less soft than any two-ply retail brand.

Our third hypothesis was inconclusive. The decision time for stimuli pairs was not proportionate to the perceived difference in softness. We hypothesized that a smaller difference in softness would result in a longer decision time. The only significant difference was for pairs with a large difference in softness (**Table IV**). It took participants more than 1 s longer (p = 0.004) to decide for large difference pairs than for medium difference pairs.

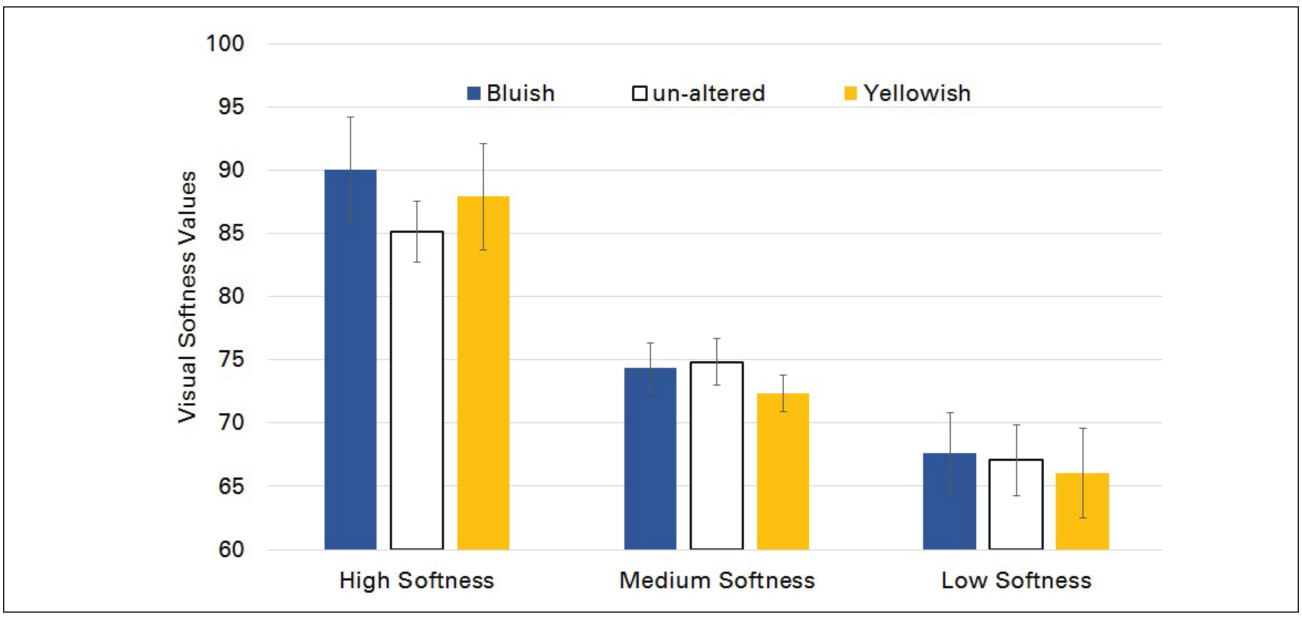
Participants perceived the yellowish stimuli as less soft than the bluish stimuli, supporting the fourth hypothesis (i.e., a consumer interprets images of hygiene tissue that are yellowish as less soft than images with a pure white or bluish tone). The yellowish images were perceived as 2 points less soft than the bluish images (Table II; **Fig. 8**). Only the results for the high and medium samples were significant, with p-values of 0.003 and 0.01, respectively. Color, having no physical effect on fiber or sheet structure, does not directly affect softness. The results of the color comparison seem to show that the participants have a positive color bias toward blue. Premium and ultra-premium hygiene tissue is bleached, and some even contain optical brightening agents to shift the emitted spectrum toward blue. Consumers have been habituated to associate this color with quality and softness and the contrary for yellow-toned tissues. Psychologically, yellow induces negative feelings associated with unpleasant feelings of sickness [25,26].

Some of this calibration is culturally acquired through the availability of materials. In North America, document paper

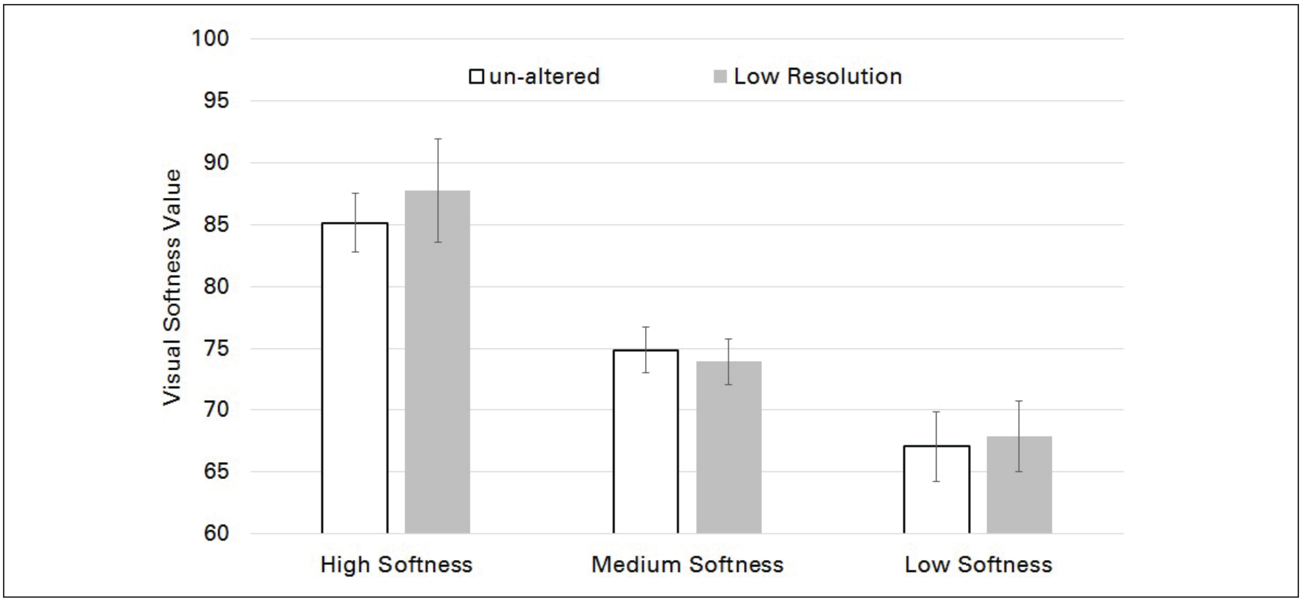
Difference in Perceived Softness of Stimuli Pairs	Determination Time, ms	Standard Deviation	No.	Significance*
Small	4243	1154	582	A
Medium	4316	1220	544	A
Large	5251	1630	295	

*Stimuli not connected by the same letter are significantly different per the non-parametric Wilcoxon two-tailed test with a confidence level of 0.1.

IV. Stimuli pairs with a large difference in perceived softness had a longer decision time than medium or small difference softness pairs. The difference was insignificant between small differences and medium differences.



8. Yellowish was perceived as less soft than bluish stimuli; however, the unaltered image was in one case perceived as softer than blue, and less soft in two other cases.



9. The effect of resolution was small, between one and three handfeel points.

	Determination Time, ms	Standard Deviation	No.
Low NFT (≤4)	3389	705	6
High NFT (<4)	3858	1125	10
Mann–Whitney U test	p-value	0.5	

V. A high or low "need for touch" (NFT) did not influence the participants' decision time.

and some hygiene papers are treated with optical brightening agent to shift the reflected light spectrum toward blue, which is viewed as true white or bright white. In Asia, yellow tones are preferred. Other sensorial associations may be made with tissue products because the materials used have an inherent softness component. Chemically bleached virgin fibers are preferred for soft tissue because of their low coarseness compared with recycled fibers, high yield pulp, agricultural fibers, or unbleached chemical fibers. Deinked pulp has specks of unremoved ink and the color is greyer than bleached pulps and high yield pulps, and agricultural fibers are often more yellow than bleached kraft. After repeated exposures, consumers might associate yellow or grey as less soft than pure white.

The fifth hypothesis can be altered to read that decreasing the resolution of an image of hygiene paper to 10% its original size does not negatively influence visual softness perception. The lower resolution stimuli were perceived as soft or softer than the full resolution images (**Fig. 9**). The loss in detail blurs any angular structures and smooths out the noise and apparent roughness.

Participants were divided into two groups of high and low NFT average scores. We might assume that a person who has a high NFT might take longer in making decisions about tactile quantities than someone who does not put much importance on such factors. However, contrary to our sixth hypothesis (i.e., the consumer's need for touch will influence their decision time to visually discriminate softness), results showed no correlation between decision time and NFT ($p = 0.5$) (**Table V**).

CONCLUSIONS

Our sense of softness, although dominated by haptic feedback, is also influenced by the other senses. Through repeated exposure to tissue products of varying softness, humans have been trained to associate certain aspects of the material (e.g., color, embossing, transparency, fuzziness) with softness. In this way, we can correctly identify the softness of a narrow set of stimuli by visual inspection only. Manufacturers and retailers can use this information to better present and market their products to reflect the desired attributes. The participants of this study perceived yellow-hued images of hygiene paper as less soft than blue-hued images. A reduction in resolution quality to 10% of the original size did not negatively affect softness perception.

The techniques used in this study can be applied to reveal the relationship between different sensorial stimuli and determine the criteria by which humans judge materials. Toyota, for example, used similar techniques to help develop leather for luxury automobile interiors that looks soft [27]. To further confirm these findings, the effects of dirt count, greyness, broader ranges of softness, more embossing patterns, and the difference between structured and conventional sheets should be examined, along with handfeel panel data and consumer preference panel data. **TJ**

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ABOUT THE AUTHORS

Our senses work in synergy to help us perceive the world around us. We undertook this study because we wanted to understand how our vision changes the perception of a dominantly tactile quality to help the industry design products so that the quality of softness is apparent before physical interaction.

Much of previous work on understanding the perception of softness has concentrated wholly on the tactile aspect. The rise in popularity of virtual reality and increasingly sophisticated haptic technology may beacon a new era in which we consider stimuli from all senses to describe an object.

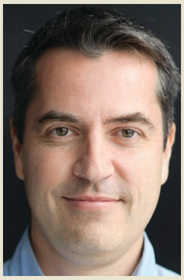
The most difficult aspect of our study was ensuring that the participants were judging the variables presented to them and no other environmental factors. We therefore designed the study around digital images.

I was personally very surprised by the speed of determination. Participants took less than 5 s to look at a pair of images and decide which was the softest. The oculometry data also showed that participants looked at a very narrow area of the sample and scanned back and forth repeatedly in that short time span.

We hypothesized that the effect of the blue/yellow color change would have a much larger effect on softness perception. Having worked with optical brightening agents in the past on fine paper, we assumed that the participants would rate the yellowish samples as much less soft.

Carette

Léger



Sénécal

The key take-home message for mills and manufacturers is that first impressions count. Customers are making very rapid judgements of your product's quality based on appearance alone. Embossing, color, and presentation are drivers for first-time purchasers.

For future studies, we would like to extend the list of variables to cover other common tissue characteristics and add a tactile component to see if changing the visual appearance influences the tactile perception of softness.

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