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*Research Article*

# Constructing a descriptive sensory panel for tactile comfort evaluations: Effect of demographic variables and panel size

***Nazli Uren*** [a,*]

[a]*Department of Textile Engineering, Dokuz Eylul University, Izmir 35390, Turkey*

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ABSTRACT

Sensory tests are essential components of comfort studies, and constructing a sensory panel is a crucial step of this process. In the current study, Total Hand (TH) scores of 41 woven fabrics were determined by assessors having different demographic characteristics. Assessment accuracy and inter-rater reliability of panel members were investigated via correlation and concordance analyses. Effect of demographic variables (gender, age, and level of expertise), panel size and sampling method on sensory evaluation results were discussed based on statistical measures. Findings of the study certified that sensory evaluations carried out with female panel members represent overall TH scores more successfully than males and assessment of female participants are in a better agreement with each other. It was also observed that assessment accuracy and inter-rater agreement improved with increasing levels of expertise. Investigations revealed that small panel sizes were sufficient to accurately evaluate fabric hand. Therefore, it was concluded that increasing the number of participants may not necessarily provide further information on comfort preferences and perceptions of potential customers.

## 1. Introduction

Comfort is an important aspect which determines the commercial value of textile products. Many studies have been conducted in recent decades to establish a reliable test method which will accurately determine tactile comfort of textiles [1-2]. There are several measurement systems and devices designed for objective measurement of fabric hand [3-9]. In many cases, it is essential to apply both objective and subjective approaches to obtain verified results. In this respect, sensory tests are considered as the fundamentals of comfort studies. Even though a number of standards and procedures were proposed to introduce the methodology of different sensory analysis techniques such as paired comparisons, duo-trio tests and triangle tests, researchers might also prefer to follow a custom evaluation method which will correspond better with the time, labor, material and financial constraints [10-14]. In both cases, decisions regarding sampling method, panel size and demographics of panel members should be made on the grounds of scientific knowledge [15].

There are different sampling methods which can be used when constructing a sensory panel such as convenience sampling, random sampling, and purposive sampling. Convenience sampling is a non-probability sampling method where participants are selected for inclusion in the sensory panel because they are the easiest for the researcher to access. For instance, researchers who investigate tactile comfort of fabrics via sensory evaluations usually prefer to work with university students or work associates due to reasons such as geographical proximity, availability at a given time, or willingness to participate in the research. Even though commonly preferred by researchers, in non-probability sampling methods, the panel may not represent each member of the population. Therefore, these methods are considered to be less objective than probability (random) sampling techniques [16].

Tactile sensitivity of humans may vary depending on several variables such as physical condition, age, gender etc. The somatosensory system is a network of neural structures, and the conscious perception of touch is a cooperation of several body parts including the skin, spinal cord, and the brain. Consequently, in addition to tactile sensitivity, the transformation of sensory signals into a conscious perception may vary depending on factors

* Corresponding author. Tel.: +00-232-301-7719; Fax: +0-232-301-7452.
E-mail addresses: nazli.uren@deu.edu.tr (N. Uren)
ORCID: 0000-0003-4487-7800 (N. Uren)
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including knowledge of the research issue, product usage behavior, physical and personal characteristics, demographics, psychographics and observed behaviors [17,18].

Demographic segmentation includes characteristics such as gender, age, education, income, ethnicity and physical attributes. The possible differences among evaluations of assessors from different countries and nationalities were previously investigated by several researchers [19-22]. A good agreement among sensory evaluations of assessors from Japan, Australia, New Zealand, and India was recorded in the case of fabric hand being ranked on a simple scale according to assessors' own interpretation of fabric hand [19]. In another study, it was concluded that assessors from different cultures may interpret some terms differently if complicated expressions were used [20].

Besides the effect of ethnicity and culture, conditions such as temperature and humidity which are related to geographic location may also affect the tactile sensation. For instance, Speijers et al. [21] detected significant differences between discomfort sensations of Australian and Chinese wearers for trials carried out in hot environment during high levels of activity when wearing wool and cashmere products. However, Keefe et al. [22] stated that the difference between ethnic and cultural groups' pain behavior is often smaller than the effect of age and gender.

Marketing research advisors suggest that it is beneficial to include the opposite sex in the consumers' studies, even if the evaluated material is mostly used by one gender only [17]. A review of the previous literature indicated that researchers commonly prefer to work with female assessors during sensory evaluations [23-28]. In fact, in some studies, all panel members were females [21,29-32]. Effect of gender differences has been investigated in a variety of sensory tests [33-37], which mostly revealed that females have a greater tactile detection sensitivity than males. Roh et al. [38] stated that gender, age, and professionalism affect the perception of sensation and suggested the more females than males, the lower the age of assessors, and the more experts than nonexperts, the more sensitive their feeling would be in a subjective evaluation.

Researchers might prefer to work with untrained consumers and members of a local community as panel members, or they may prefer to work with expert assessors - university students, research assistants, lecturers, researchers, and workers of a company - to acquire a comprehensive and prudent data. In a study realized by Asad et al. [39], prickle sensation of fabrics was evaluated by trained university students. The inter-rater reliability reported for these assessors was at a moderate level. In another study realized by Harpa et al. [40], a minimum training was given to second year students of textile bachelor level who were regarded as untrained consumers. The level of agreement reported for these assessors was also quite low.

Researchers suggested categorization of assessors based on their electroneurophysiological responses to fabric-skin contact [41]. Hui et al. [26] worked with assessors selected based on their interest, availability, and successful completion of a tactile sensitivity screening test, and they reported a good test-retest reliability for the selected assessors. Similarly, Musa et al. [42] proposed a method to select assessors based on their level of finger sensitivity to minimize the disagreements among the panel members due to demographic criteria (age, gender, origin). Xue et al. [43] emphasized that simple sensory experiments such as sorting and rating tasks can be consistently performed by assessors without any specific expertise or training.

When constructing a panel for sensory evaluations, it is important to define a reasonable age range as well. If a research study does not specify a relevant gender, age, education, income, or ethnicity, it is suggested to construct a panel with assessors that covers as many demographic characteristics as possible [17]. The study of United Nations regarding world population prospects indicated that the global median age has increased from 21.5 to over 30 years, and the global population breakdown by age showed that half of the world population is between 25 and 65 [44]. The population reports also pointed that higher-income countries across North America, Europe and East Asia have a higher age median. In this respect, including older members in a sensory panel may be useful to gain a better understanding of the consumers' preferences. However, researchers who investigated fabric hand commonly preferred to work with university students or young adults [21,25-31,39,40,43,45-47], and participants with ages 40 and above were rarely included in sensory evaluations [24,42,48,49].

Considering the time and labor factors, it is important to determine the adequate panel size which would provide accurate, reliable, and reproducible sensory evaluation results. The number of panel members should be sufficient to produce reliable and representative sensory data. On the other hand, the involvement of a large number of assessors may cause an increase in time consumptions and cost [43]. Therefore, panel size should be limited to maintain efficient working conditions. Researchers who carried out sensory evaluations by trained or expert assessors may prefer to work with small panel sizes [23,24,48,50,51]. Xue et al. [43] stated that nonexpert assessors - when compared to trained or expert assessors - can be less capable of making a bias-free assessment in pure sorting tasks due to their limited knowledge on sensory evaluations. Therefore, it was suggested to work with a larger number of assessors with better representativeness for studies with the objective of acquiring comprehensive and prudent data. Stanton et al. [32] carried out wearer trials with 43 assessors and concluded that a reduction to 25 wearers was adequate for later trials with minimal loss in sensitivity.

A review of the previous literature indicated that researchers commonly preferred convenience sampling method for sensory evaluation of fabric hand. During construction of a descriptive sensory panel, if the members are selected from a closer circle but not from a large and more diverse population, decisions regarding demographic characteristics and panel size emerge as important factors. In the current study, the effects of gender, age, level of expertise and panel size on accuracy of sensory evaluations - in case of constructing the sensory panel according to convenience sampling method - were investigated. The effect of selecting a non-probability sampling method on the statistical findings was also discussed. As a secondary purpose, a sensory evaluation procedure which would be applicable regardless of assessors' ethnicity or cultural differences was proposed.

## 2. Materials and Methods

### *2.1 Material*

The study was carried out with 41 conventional woven fabrics made of cotton and its blends with various fibers such as polyester, viscose, angora, wool, silk, lyocell, elastane and linen. The studied fabrics have plain, 2/1 twill or 3/1 twill weave patterns and a mass per unit area between 150 and 275 g/m$^2$.

### *2.2 Sensory Panel*

Sensory tests were realized with participation of 200 assessors having different demographic characteristics. Panel members were chosen according to convenience sampling method. The panel members were students and academic staff of faculty of engineering (textile, mechanical, electrical-electronic, industrial and materials etc.), education, human sciences, social sciences, management, maritime and fine arts of the university at which the research took place.

In addition to these participants, students and academic staff of another local university, and workers (having different levels of education) of a textile manufacturer were also included in the panel. Any person over the age of 18 and willing to participate in the sensory evaluations was included in the study. No additional selection process was carried out.

The effect of age on sensory evaluation results was investigated for three sub-groups: youngsters, young adults, and adults (Table 1). Panel members were classified into three age clusters by a two-step cluster analysis. Segmentation for age clusters was based on age variable only, and the number of clusters was fixed to three.

The difference between total hand evaluations of assessors with different levels of expertise was investigated for four sub-groups. Expert assessors were researchers who have a bachelor's or higher degree in textile engineering. Qualified assessors were workers of textile related majors - technicians, laboratorians, or designers - with degrees other than textile engineering. Novice assessors were undergraduate students of the textile engineering faculty. Nonexpert assessors were workers and students from any major except textiles.

### *2.3 Sensory Evaluation Procedure*

Fabric hand assessments were made based on the total hand feel of fabrics. To increase the accuracy of sensory evaluations and prevent context, order and position effects, two specimens were prepared in warp and weft directions for each fabric type, and a mixed batch of specimens was presented to the assessor with a random positioning and order. To exclude bias caused by fabric appearance, assessments were carried out according to blind test requirements.

Correct lexicon usage is the ability of an assessor to understand and use attributes in a similar manner [18]. Differences in lexicon usage may lead to agreement issues when if one assessor understands the attribute to mean something different from the other panel members [19,22]. In this respect, it is important that each attribute being assessed has a precise definition which can be clearly understood by all assessors. To eliminate the bias caused by lexicon usage, a five-point hedonic scale with simple and universally understandable labels was used in the current study. The assessors were asked to arrange fabric samples into five groups, in the order of a five-point scale. The scale points were introduced as; 5 excellent, 4 good, 3 average, 2 fair, and 1 poor hand quality. At the end of the evaluation session, the numbers associated with the indicated groups were regarded as Total Hand (TH) scores and the score of each sample was recorded.

Assessors evaluated the fabric hand freely, according to their preferences and the attributes they prioritize the most. Sensory tests were performed as single trials. In order to not interfere with the original decisions of assessors, no training or preparation trial was carried out.

### *2.4 Assessment Accuracy and Inter-Rater Agreement*

Assessment accuracy of panel members was determined based on the assumption that the overall TH scores determined by participation of 200 assessors represent the opinion of the population on total hand of investigated fabrics. The closeness between the total hand values estimated by an individual participant and the overall TH scores (obtained from 200 participants) was statistically measured by Spearman's rank order correlation analysis and regarded as a measure of assessment accuracy.

Table 1. Demographic segmentation of sensory panel

| Demographics | Sub-group | Description | Panel size | | |
|---|---|---|---|---|---|
| | | | All | Female | Male |
| Gender | Female | Female | 100 | 100 | - |
| | Male | Male | 100 | - | 100 |
| Age | Youngster | Age between 19-26 | 114 | 64 | 50 |
| | Young adult | Age between 27-42 | 75 | 31 | 44 |
| | Adult | Age between 43-66 | 11 | 5 | 6 |
| Expertise | Nonexpert | Workers and students of non-textile related majors | 62 | 25 | 37 |
| | Novice | Undergraduate textile engineering students | 76 | 48 | 28 |
| | Qualified | Technicians, laboratorians, designers | 22 | 7 | 15 |
| | Expert | Textile engineers with bachelor's degree or higher | 40 | 20 | 20 |

Assessment accuracy of sub-groups was estimated using correlation coefficients calculated for panel members in that sub-group. The significance of the differences observed between accuracy of different sub-groups was evaluated at 90% and 95% confidence levels, using Mann-Whitney and Kruskal-Wallis Tests. To summarize the findings regarding assessment accuracy, panel members were classified into three clusters based on the correlation coefficient data, using statistical software.

Kendall's coefficient of concordance is often used to determine the agreement among members of a sensory panel, where a higher Kendall's W value indicates a better inter-rater agreement and it is a measure of how much homogeneity or consensus there is in the scores given by panel members [39,40]. In the current study, inter-rater agreement was discussed based on Kendall's W values.

The repeatability of a panel member is referred as intra-rater reliability, and it is a common indicator of assessment accuracy. In the current study, all assessors evaluated the investigated fabrics in a single trial where no second trial was carried out. In this respect, repeatability measures were not included in the study.

## 3. Result and Discussion

### *3.1 Effect of Demographic Variables on Assessment Accuracy*

Statistical findings certified that assessments of female participants were more correlated with overall TH scores than males (Table 2), and this difference was statistically significant (p=0.000). It was also observed that accuracy of panel members improves by expertise (p=0.003). Even though the correlation coefficients calculated for adult and young adult participants were considerably higher than youngsters, age was found out to be the least efficacious characteristic among the investigated demographic variables (p=0.091). When the effect of age and expertise on correlation coefficients was investigated separately for female and male participants, it was detected that correlation relations drastically improved by increasing the age and level of expertise of female assessors. On the other hand, for male assessors, only a slight improvement was observed in terms of expertise (Table 2).

To summarize the findings regarding assessment accuracy, panel members were classified into three clusters. As can be seen in Figure 1, 140 out of 200 panel members have very high accuracy, whereas assessments of 49 members were moderately accurate. When the number of assessors in accuracy clusters was investigated in terms of demographic variables, it was observed that 75% of female assessors have high accuracy, while this number was 65% for male assessors (Figure 2). Results of cluster analyses also indicated that expertise has a great effect on accuracy. In fact, 80% of expert assessors were in high accuracy cluster, while this number was between 66% and 68% for assessors with limited or no expertise.

Table 2. Assessment accuracy of panel members in different demographic sub-groups

| Demographics | Spearman's rho* | | |
|---|---|---|---|
| | ALL | Female | Male |
| Female | 0.793 ± 0.133 | 0.793 ± 0.133 | - |
| Male | 0.742 ± 0.140 | - | 0.742 ± 0.140 |
| Youngster | 0.755 ± 0.133 | 0.763 ± 0.149 | 0.744 ± 0.110 |
| Young adult | 0.785 ± 0.151 | 0.847 ± 0.079 | 0.740 ± 0.174 |
| Adult | 0.784 ± 0.093 | 0.841 ± 0.044 | 0.738 ± 0.100 |
| Nonexpert | 0.738 ± 0.160 | 0.752 ± 0.162 | 0.729 ± 0.160 |
| Novice | 0.762 ± 0.123 | 0.770 ± 0.131 | 0.748 ± 0.108 |
| Qualified | 0.762 ± 0.155 | 0.826 ± 0.069 | 0.732 ± 0.176 |
| Expert | 0.827 ± 0.108 | 0.888 ± 0.044 | 0.765 ± 0.118 |
| All | 0.767 ± 0.139 | 0.793 ± 0.133 | 0.742 ± 0.140 |

*Correlation coefficient was calculated between assessment of an individual panel member and overall Total Hand (TH) scores and presented as average ± standard deviation.

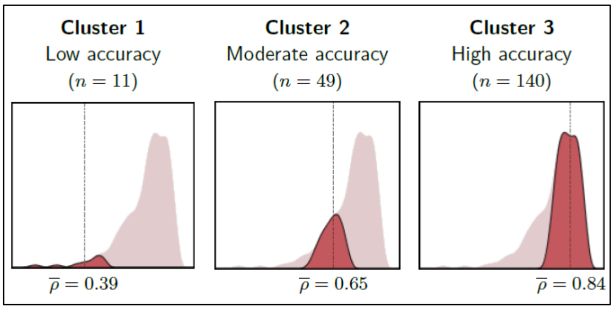


Figure 1. Assessment accuracy clusters of panel members constructed based on correlation coefficients (Spearman's rho, ρ) calculated between assessment of each individual panel member and overall Total Hand (TH) scores

Based on these findings it was concluded that most of the assessors have a moderate to good level of accuracy in general, regardless of demographics. However, sensory evaluations carried out with females, experts, young adults, and adults provided a better accuracy.

### *3.2 Effect of Demographic Variables on Scale Usage*

Using similar ratings across all samples may indicate a low sensory acuity [18]. Poorly discriminating assessors may prefer to use a "safe scale range" to cover their inability to discern the evaluated attribute. In Figure 3, the distribution of TH scores determined by assessors in different demographic sub-groups were presented in the form of box-plots. These plots indicated that females, adults, and experts used a larger portion of the 5-point scale when compared to the assessors in other demographic sub-groups.

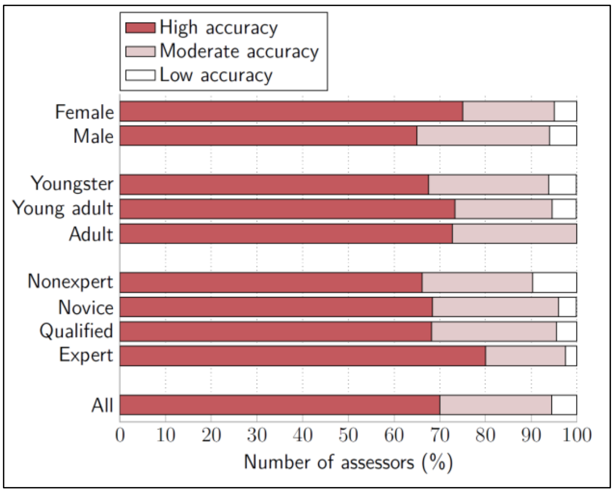


Figure 2. Number of assessors in accuracy clusters constructed based on correlation coefficients (Spearman's rho, ρ) calculated between assessment of each individual panel member and overall Total Hand (TH) scores

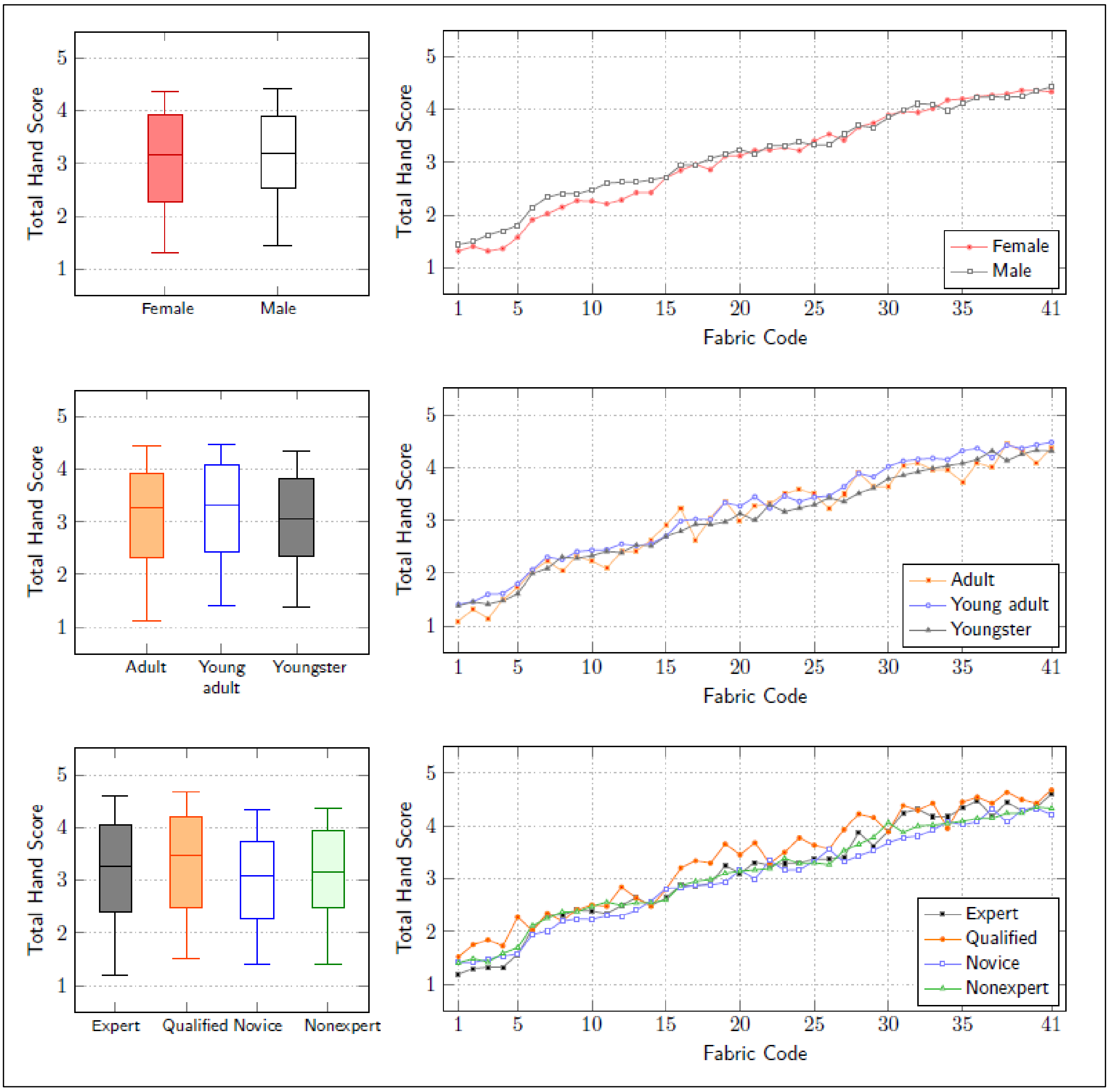


Figure 3. Total Hand scores of fabrics evaluated by assessors in different demographic sub-groups

TH score of each investigated fabric were given in Figure 3. TH scores were mostly within a similar range, regardless of demographics. In accordance with the differences recorded in scale usage behaviors, several differences in TH scores evaluated by participants in different demographic sub-groups were observed. For instance, fabrics with average or higher (≥3) hand qualities were rated with similar TH scores by female and male assessors. On the other hand, fabrics with fair or poor hand qualities (<3) were rated with lower TH scores by females and higher TH scores by males (Figure 3). The differences calculated between TH scores determined by female and male assessors were less than 0.40 points on a five-point scale.

The variations in distribution of TH scores attained by assessors in different age sub-groups were smaller than the variations recorded for expertise sub-groups, and larger than the variations recorded for gender sub-groups. It was recorded that young adults rated fabrics with relatively higher TH scores.

Noticeable differences were observed among assessments of participants in different expertise sub-groups as well. Qualified assessors rated most of the fabrics with higher TH scores. On the contrary, novice assessors rated the fabrics with considerably lower TH scores. In fact, the highest difference calculated among TH score assessments of different expertise sub-groups were recorded between novice and qualified assessors, which was 0.79 points. It was also found out that fabrics with better tactile comfort were rated with higher TH scores and fabrics with less desirable levels of tactile comfort were rated with lower TH scores, when evaluated by expert assessors.

### *3.3 Effect of Demographic Variables on Inter-Rater Agreement*

Kendall’s coefficient of concordance is a measure of agreement among panel members. Calculated concordance coefficients certified that female assessors were in a better agreement with each other than males (Table 3). Kendall’s W values indicated that the agreement among assessors improved by age and expertise, and this effect was stronger for females. These findings were also in accordance with the results of correlation analyses presented in section 3.1.

### *3.4 Effect of Panel Size and Sampling Method on Assessment Accuracy*

For panel size investigations, panels with different sizes were constituted regardless of their demographic characteristics. Panel members of the current study were selected according to convenience sampling method where the readily approachable panel members are selected for participation. To investigate the effect of sample size - in case of convenience sampling - the participants were grouped according to their order of participation, and the effect of panel size on accuracy was investigated in terms of correlation coefficients calculated between assessments of individual panel members and overall TH scores (Table 4). When the panels constructed with convenience sampling method were investigated, it was observed that the evaluation accuracy of the first 10 assessors of the study was the highest among all investigated panel sizes. As the number of participants increased from 10 to 100, the accuracy of the panel gradually decreased. Meanwhile the accuracy of panels with 100 or more assessors was almost the same (ρ=0.77).

Convenience sampling is a non-probability sampling method commonly preferred by researchers during participant selection for sensory evaluations. However, it is claimed that using a non-probability sampling method might have several possible effects on sensory evaluation results [16]. To investigate the effect of sampling method on accuracy of panels with different sizes, accuracy of panel members - in case of using probability (random) sampling method - was also investigated.

Table 3. Inter-rater agreement of demographic sub-groups

| **Demographics** | **Kendall's W*** | | |
|---|---|---|---|
| | **ALL** | **Female** | **Male** |
| Female | 0.638 | 0.638 | - |
| Male | 0.560 | - | 0.560 |
| Youngster | 0.578 | 0.592 | 0.571 |
| Young adult | 0.627 | 0.739 | 0.559 |
| Adult | 0.649 | 0.770 | 0.618 |
| Nonexpert | 0.557 | 0.587 | 0.544 |
| Novice | 0.592 | 0.608 | 0.584 |
| Qualified | 0.606 | 0.717 | 0.582 |
| Expert | 0.705 | 0.814 | 0.625 |
| All | 0.596 | 0.638 | 0.560 |

*Asymptotic significance is equal to 0.000 for all Kendall's W values.

Table 4. Assessment accuracy of panel members calculated for different panel sizes

| **Panel size** | **Spearman’s rho*** | |
|---|---|---|
| | **Convenience sampling** | **Random sampling** |
| 5 | 0.818 ± 0.078 | 0.851 ± 0.102 |
| 10 | 0.845 ± 0.067 | 0.757 ± 0.208 |
| 15 | 0.829 ± 0.074 | 0.776 ± 0.148 |
| 20 | 0.834 ± 0.079 | 0.769 ± 0.125 |
| 25 | 0.823 ± 0.086 | 0.761 ± 0.155 |
| 50 | 0.803 ± 0.104 | 0.787 ± 0.106 |
| 75 | 0.785 ± 0.122 | 0.761 ± 0.138 |
| 100 | 0.767 ± 0.148 | 0.784 ± 0.123 |
| 125 | 0.766 ± 0.141 | 0.762 ± 0.145 |
| 150 | 0.766 ± 0.140 | 0.780 ± 0.129 |
| 175 | 0.775 ± 0.135 | 0.768 ± 0.142 |
| 200 | 0.767 ± 0.139 | 0.767 ± 0.139 |

*Correlation coefficient was calculated between assessment of an individual panel member and overall Total Hand (TH) scores, and presented as average ± standard deviation.

To investigate the effect of panel size in case of using probability sampling method, random sampling conditions were generated with the help of statistical software and the desired number of panel members was selected among 200 participants according to random sampling principle. When the correlation coefficients calculated between assessments of randomly selected panel members and overall TH scores were investigated, it was observed that the panel members have the highest accuracy when the panel size was equal to five (Table 4). This finding indicated that each member of a panel with five assessors selected randomly among 200 participant candidates has a higher probability to represent the overall assessment of 200 assessors. Moreover, when the panel size increases, the possibility to include assessors with relatively lower accuracies increases as well. The accuracy of panels constructed with convenience sampling principle indicated a similar trend. Yet the decrease in accuracy caused by the increase in panel size was less drastic in case of using convenience sampling method.

### *3.5 Effect of Panel Size and Sampling Method on Inter-Rater Agreement*

Kendall's concordance coefficients were calculated for panels with different number of participants, and the level of agreement among panel members were investigated for panels with different sizes, constructed according to convenience sampling and random sampling methods. Larger panel sizes offer a wider diversity of assessors with possible differences regarding preferences on fabric hand. Accordingly, it is predictable to observe a lower level of agreement among assessors of larger panels. Concordance results of panels constructed with convenience sampling method indicated that the level of agreement among the first 10 assessors of the study was the highest (W=0.771). Similarly, the panel with five randomly selected assessors exhibited the highest Kendall's W value (W=0.758) (Figure 4).

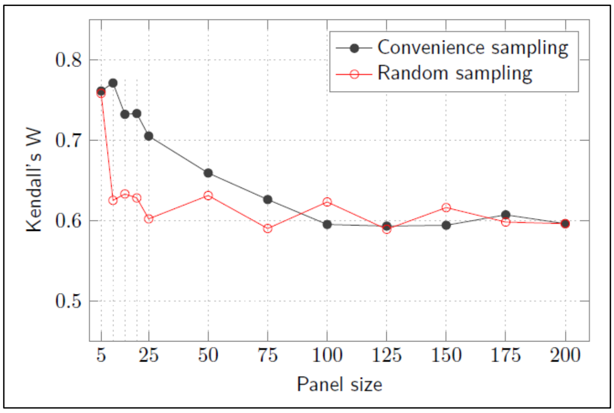

Figure 4. Kendall's coefficient of concordance (Kendall's W) values calculated for different panel sizes as a measure of inter-rater agreement

When the collection of new data does not provide any further information on the issue under investigation, it is usually concluded that the panel size has reached its saturation point [53,54]. For convenience sampling, when the panel size exceeded 100, the calculated Kendall's W values were almost constant (0.60 ± 0.01) (Figure 4). Based on these findings, it was concluded that a panel size of 100 is the saturation point for sensory evaluation of fabric hand. In the case of selecting assessors according to random sampling method, similar levels of agreement were recorded for panels with 10 or more assessors (0.61 ± 0.02), thus - in such case - the saturation point was reached with 10 assessors. This finding indicated that the panel size may reach the saturation point earlier, depending on the sampling method.

### *3.6 Discussion*

Tactile properties of textiles have a great effect on purchase decision of consumers and fabric hand is one of the important parameters that determine the market value of a textile product. Researchers have been investigating this phenomenon for several decades and numerous objective measurement methods were proposed for determining hand related properties of textiles. However, the significance of sensory evaluations was not altered by the developments in measurement technologies.

Most of the current standards proposing guidelines for sensory evaluations are compatible with majors other than textiles. Therefore, researchers may prefer to carry out a custom sensory evaluation technique instead of following a given standard. In such cases, decisions regarding selection of panel members, scale type and test protocol must be carefully considered, as these parameters may impact the accuracy of sensory evaluation results.

In the current study, hand of conventional woven fabrics was evaluated by 200 panel members and the assessment performance of participants with different demographic characteristics was investigated. The participants of the study were coming from the same geographic location, belonging to a similar culture and members of the same nationality. Therefore, effect of these parameters on sensory evaluation results was not discussed in this report. It was aimed to achieve scientific findings which may represent a larger and more diverse population. Therefore, in the current study, a basic five-point scale with simple and universally relatable labels was used.

It was observed that 94.5% of panel members have a moderate or good level of accuracy. Female participants exhibited a more desirable level of accuracy, and this accuracy was further improved by increasing age and expertise. Even though performance of female participants was significantly better than males, assessment accuracy of male participants was also at a desired level. Yet, it did not exhibit a noticeable change by age or expertise.

Another important factor regarding evaluation of fabric hand by a sensory panel is the number of panel members. Working with a large panel may provide a more precise representation of consumers' opinion on the total hand value. However, determining the optimum number of participants to minimize the required time and labor is a more reasonable approach. Even though it is a commonly preferred sampling method, selecting assessors according to convenience sampling may limit the ability of the sensory panel to represent the general population. For this reason, effect of panel size on accuracy of sensory evaluation results was investigated for both convenience and random sampling conditions. Results of the study pointed that it is possible to obtain accurate data even with 5 assessors with both sampling methods. In fact, increasing the panel size caused significant decreases in accuracy and inter-rater agreement. Based on these findings, it was concluded that working with small panel sizes may provide more reliable results.

## 4. Conclusion

Sensory tests are fundamentals of a comprehensive fabric hand evaluation. The aim of this study was to investigate the effect of panel size and demographic variables on sensory evaluation results and propose guidelines for future studies. The investigations were carried out with a panel of 200 assessors (100 females and 100 males), between ages 19 and 66, with different levels of expertise.

Correlation measures indicated that 140 of 200 assessors have high assessment accuracy, and the likelihood of selecting an assessor with low evaluation validity was only 5.5%. It was observed that working with a small number of assessors can provide sufficient data, regardless of demographic characteristics of the panel members or the sampling method (convenience or random).

Statistical investigations pointed that assessments of female panel members have a higher accuracy than males. It was also proved that the knowledge of textiles has a significant effect on accuracy, meanwhile the effect of age was less prominent. Highest correlation and concordance coefficients were recorded for adult females and expert females. Based on these findings, it was concluded that including female assessors with a higher level of expertise can significantly increase the accuracy of sensory evaluations.

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## Declaration

The author declared no potential conflicts of interest with respect to the research, authorship, and/or publication of this article. The author also declared that this article is original, was prepared in accordance with international publication and research ethics, and ethical committee permission or any special permission is not required.

## Author Contributions

N. Uren developed the methodology, performed the sensory evaluations and data analysis, and wrote the manuscript.

## References

1. Ciesielska-Wróbel I.L., and L. Van Langenhove, *The hand of textiles – definitions, achievements, perspectives – a review*, Textile Research Journal, 2012. **82**(14): p. 1457-1468.
2. Liao X., J. Hu, Y. Li, Q. Li, and X. Wu, *A review on fabric smoothness-roughness sensation studies*, Journal of Fiber Bioengineering & Informatics, 2011. **4**(2): p. 105-114.
3. Hu X., Z. Chen, and F. Sun, *Digitization of fabric comfort: a multidimensional evaluation strategy to human perceptions of sensorial, thermal and acoustic comfort in clothing*, International Journal of Clothing Science and Technology, 2023. **35**(1): p. 162-175.
4. Liu L., L. Wei, and F. Sun, *Simultaneous-integrated evaluation of mechanical–thermal sensory attributes of woven fabrics in considering practical wearing states*, Textile Research Journal, 2021. **91**(23-24): p. 2872-2881.
5. Liao X., Y. Li, J. Hu, X. Wu, and Q. Li, *A simultaneous measurement method to characterize touch properties of textile materials*, Fibers and Polymers, 2014. **15**(7): p. 1548-1559.
6. Wang H., T.J. Mahar, and R. Hall, *Prediction of the handle characteristics of lightweight next-to-skin knitted fabrics using a fabric extraction technique*, Journal of the Textile Institute, 2012. **103**(7): p. 691-697.
7. Strazdiene E., and M. Gutauskas, *New method for the objective evaluation of textile hand*, Fibres and Textiles in Eastern Europe, 2005. **2**(50): p. 35-38.
8. Kim J.O., and B.L. Slaten, *Objective evaluation of fabric hand: Part I: Relationships of fabric hand by the extraction method and related physical and surface properties*, Textile Research Journal, 1999. **69**(1): p. 59-67.
9. Kawabata S., and M. Niwa, *Clothing engineering based on objective measurement technology*, International Journal of Clothing Science and Technology, 1998. **10**(3/4): p. 263-272.
10. ISO 6658, *Sensory analysis - Methodology - General guidance*, International Organization for Standardization, 2017.
11. ISO 5495, *Sensory analysis - Methodology - Paired comparison test*, International Organization for Standardization, 2005.
12. ISO 10399, *Sensory analysis - Methodology - Duo-trio test*, International Organization for Standardization, 2017.
13. ISO 4120, *Sensory analysis - Methodology - Triangle test*, International Organization for Standardization, 2021.

14. AATCC EP5, *Evaluation procedure for fabric hand value*, American Association of Textile Chemists and Colorists Committee, 2020.
15. ISO 8586, *Sensory analysis - Selection and training of sensory assessors*, International Organization for Standardization, 2023.
16. Stratton SJ. *Population Research: Convenience Sampling Strategies.* Prehospital and Disaster Medicine, 2021. **36**(4): p. 373-374.
17. Kolb B., *Choosing participants for qualitative research. In: Marketing research*, London: SAGE Publications Ltd., 2008.
18. ASTM E3000-18, *Standard guide for measuring and tracking performance of assessors on a descriptive sensory panel*, American Society for Testing and Materials, 2018.
19. Dhingra R.C., T.J. Mahar, R. Postle, V.B. Gupta, S. Kawabata, M. Niwa, and G.A. Carnaby, *The objective specification of the handle of men’s suiting materials: A comparison of fabric handle assessments in India, Australia, Japan and New Zealand*, Indian Journal of Textile Research, 1983. **8**: p. 9-15.
20. Kim H., and G. Winakor, *Fabric hand as perceived by U.S. and Korean males and females*. Clothing and Textile Research Journal, 1996. **14**(2): p. 133-144.
21. Speijers J., J. H. Stanton, G.R. Naylor, P. Ramankutty, and D. Tester, *Skin comfort of base layer wool garments. Part 3: The effect of ethnicity on perceptions of comfort using Chinese and Australian wearers*, Textile Research Journal, 2015. **85**(11): p. 1167-1180.
22. Keefe F.J., M.A. Lumley, A.L. Buffington, J.W. Carson, J.L. Studts, C.L. Edwards, D.J. Macklem, A.K. Aspnes, L. Fox, and D. Steffey, *Changing face of pain: Evolution of pain research in psychosomatic medicine*, Psychosomatic Medicine. 2002. **64**(6): p. 921-938.
23. Bacci L., F. Camilli, S. Drago, M. Magli, E. Vagnoni, A. Mauro, and S. Predieri, *Sensory evaluation and instrumental measurements to determine tactile properties of wool fabrics*, Textile Research Journal, 2012. **82**(14): p. 1430-1441.
24. Xue Z., X. Zeng, L. Koehl, and Y. Chen, *Extracting fabric hand information from visual representations of flared skirts*, Textile Research Journal, 2014. **84**(3): p. 246-266.
25. Suzuki Y., and S. Sukigara, *Mechanical and tactile properties of plain knitted fabrics produced from rayon Vortex yarns*, Textile Research Journal, 2013. **83**(7): p. 740-751.
26. Hui C.L., T.W. Lau, S.F. Ng, and K.C.C. Chan. *Neural network prediction of human psychological perceptions of fabric hand*, Textile Research Journal, 2004. **74**(5): p. 375-383.
27. Temel M., A.A. Johnson, and A.B. Lloyd, *Evaluating the repeatability of friction coefficient measurements and tactile perceptions in skin–textile interactions across body regions*, Tribology Letters, 2022. **2022**(70): 23.
28. Jiao J., X. Hu, Y. Huang, J. Hu, C. Hsing, Z. Lai, C. Wong, and J.H. Xin, *Neuro-perceptive discrimination on fabric tactile stimulation by Electroencephalographic (EEG) spectra*, PLoS One, 2020. **15**(10): e0241378.
29. McGregor B.A., M. Naebe, H. Wang, D. Tester, and J. Rowe, *Relationships between wearer assessment and the instrumental measurement of the handle and prickle of knitted wool fabrics*, Textile Research Journal, 2015. **85**(11): p. 1140-1152.
30. Ryu H.S., and E. Kyung, *Preference and subjective evaluation of washed fabric hand using conjoint analysis*, Textile Research Journal, 2010. **80**(20): p. 2167-2175.
31. Yokura H., and M. Niwa, *Objective hand measurement of nonwoven fabrics used for the top sheets of disposable diapers*, Textile Research Journal, 2003. **73**(8): p. 705-712.
32. Stanton J.H., J. Speijers, G.R.S. Naylor, S. Pieruzzini, J. Beilby, E. Barsden, and A. Clarke, *Skin comfort of base layer knitted garments. Part 1: Description and evaluation of wearer test protocol*, Textile Research Journal, 2014. **84**(13): p. 1385-1399.
33. Wilfling J., G. Havenith, M. Raccuglia, and S. Hodder, *Can you see the feel? The absence of tactile cues in clothing e-commerce impairs consumer decision making*, International Journal of Fashion Design, Technology and Education, 2023. **16**(2): p. 224-233.
34. Boles D.B., and S.M. Givens, *Laterality and sex differences in tactile detection and two-point thresholds modified by body surface area and body fat ratio*, Somatosensory and Motor Research, 2011. **28**(3-4): p. 102–109.
35. Chen C.C., G.K. Essick, D.G. Kelly, M.G. Young, J.M. Nestor, and B. Masse, *Gender-, side-, and site-dependent variations in human perioral spatial resolution*, Archives of Oral Biology, 1995. **40**(6): p. 539-548.
36. Komiyama O., M. Kawara, and A. De Laat, *Ethnic differences regarding tactile and pain thresholds in the trigeminal region*, The Journal of Pain, 2007. **8**(4): p. 363-369.
37. Wohlert A.B., *Tactile perception of spatial stimuli on the lip surface by young and older adults*, Journal of Speech, Language and Hearing Research, 1996. **39**(6): p. 1191-1198.
38. Roh E.K., K.W. Oh, and S.H. Kim, *Effect of raising cycles on mechanical, comfort, and hand properties of artificial suede*, Textile Research Journal, 2014. **84**(18): p. 1995-2005.
39. Asad R.A., W. Yu, Q. Siddiqui, M. Vincent, and Q. Wang, *Subjective evaluations of fabric-evoked prickle using the unidimensional rating scale from different body areas*, Textile Research Journal, 2016. **86**(4): p. 350-364.
40. Harpa R., C. Piroi, I. Cristian, E. Visileanu, and M. Blaga, *Sensory analysis of textiles: case study of an assortment of stretch denim fabrics*, Industria Textila, 2019. **70**(4): p. 358-365.
41. Ye T., L. Cui, C. Zhang, and Y. Qiu, *Electroneurophysiological responses to fabric-skin dynamic contact with different fabrics among different types of people*, Textile Research Journal, 2023. **93**(17-18): p. 4140-4152.
42. Musa A.B.H., B. Malengier, S. Vasile, and L. Van Langenhove, *A comprehensive approach for human hand evaluation of split or large set of fabrics*, Textile Research Journal, 2019. **89**(19-20): p. 4239-4252.
43. Xue Z., X. Zeng, L. Koehl, and L. Shen, *Consistency and reliability of untrained consumers’ perceptions of fabric hand of men’s suiting*, Textile Research Journal, 2016. **86**(13): p. 1425-1442.
44. Ritchie H., and M. Roser, [cited 2023 23 October] Available from: https://ourworldindata.org/age-structure
45. Hanada M., *Tactile dimensions of fabrics expressed by Japanese onomatopoeic words and phonemic features related to fabric luxuriousness and pleasantness*, Frontiers in Language Sciences, 2023. **2**: 1075055.
46. Wang Q., Y. Tao, Z. Zhang, J. Yuan, Z. Ding, Z. Jiang, Z.

Jia, and J. Wang, *Representations of fabric hand attributes in the cerebral cortices based on the Automated Anatomical Labeling atlas*, Textile Research Journal, 2019. **89**(18): p. 3768-3778.

47. Tang W., S. Zhang, C. Yu, H. Zhu, S. Chen, and Y. Peng, *Tactile perception of textile fabrics based on friction and brain activation*, Friction, 2023. **11**(7): p. 1320-1333.
48. Vasile S., B. Malengier, A. De Raeve, and F. Deruyck, *Influence of selected production parameters on the hand of mattress knitted fabrics assessed by the Fabric Touch Tester*. Textile Research Journal, 2019. **89**(1): p. 98-112.
49. Uren N., and A. Okur, *Analysis and improvement of tactile comfort and low-stress mechanical properties of denim fabrics*, Textile Research Journal, 2019. **89**(23-24): p. 4842-4857.
50. Shao Y., Y. Sun, D. Zheng, G. Liu, Z. Du, J. Liu, and M. Wang, *Tactile comfort characterization of knitted fabrics based on the ring-shaped style tester*, Textile Research Journal, 2021. **91**(7-8): p. 766-777.
51. Sun F., Z. Du, and M. Naebe, *Determination of model parameters for predicting handle characteristics of wool-rich suiting woven fabrics based on the Wool HandleMeter* and KES-F. Journal of the Textile Institute, 2018. **109**(2): p. 147-159.
52. Sun F., Z. Du, D. Zheng, X. Hu, Y. Sun, and W. Gao, *In-situ characterization of handle characteristics of suiting woven fabrics by a simultaneous measurement method*, Textile Research Journal, 2019. **89**(13): p. 2522-2531.
53. Mason M., *Sample size and saturation in PhD studies using qualitative interviews*, Forum Qualitative Sozialforschung / Forum: Qualitative Social Research, 2010. **11**(3): 4902282.
54. Nascimento L.C.N., T.V. Souza, I.C.S. Oliveira, J.R.M.M. Moraes, R.C.B. Aguiar, and L.F. Silva, *Theoretical saturation in qualitative research: An experience report in interview with schoolchildren*. Revista Brasileira de Enfermagem, 2018. **71**(1): p. 228-23.