Specifying Relevant Textural Properties for Unobtrusive Feedback on Sports Performance

Hayati Havlucu
Koç University – Arçelik Research Center for Creative Industries
Istanbul, Turkey
hhavlucu16@ku.edu.tr

Aykut Coşkun
Koç University – Arçelik Research Center for Creative Industries
Istanbul, Turkey
acoskun@ku.edu.tr

Oğuzhan Özcan
Koç University – Arçelik Research Center for Creative Industries
Istanbul, Turkey
oozcan@ku.edu.tr

Permission to make digital or hard copies of part or all of this work for personal or classroom use is granted without fee provided that copies are not made or distributed for profit or commercial advantage and that copies bear this notice and the full citation on the first page. Copyrights for third-party components of this work must be honored. For all other uses, contact the Owner/Author.
TEI '19, March 17–20, 2019, Tempe, AZ, USA
© 2019 Copyright is held by the owner/author(s).
ACM ISBN 978-1-4503-6196-5/19/03.
https://doi.org/10.1145/3294109.3300974

Abstract
Textural changes can be promising to give feedback on sportspeople's performance who needs less attention demanding modalities. However, previous research does not address which textural property's change would be more appropriate to give information in specific contexts, i.e. sports performance feedback. We focus on sport towels as a case to understand how to give feedback on sports performance through changes in textural properties. We address the gap by conducting experiments with 32 sportspeople to investigate (1) the textural properties (i.e. roughness) that can be perceived by sportspeople through a towel and (2) that can convey information on sportspeople's performance (i.e. smooth texture - good performance). The results indicate that *hardness* and *bendability* are appropriate to convey information about sportspeople's performance. To the best of our knowledge, this result is the first to explore that a change in the state of a textural property is able to give a specific feedback.

Author Keywords
Textural properties; sports performance; feedback; psychophysical; material properties; shape change.

CSS Concepts
• Human-centered computing~Empirical studies in HCI
• Human-centered computing~Laboratory experiments



Figure 1: The sample towels from the experiments.

Introduction

Sportspeople want to receive performance feedback and commonly rely on activity trackers to get it [7]. With current activity trackers, utilizing information in real-time is considered difficult and distracting [10,11]. However, sportspeople need to concentrate on the activity and sustain attention throughout. Thus, they need less attention demanding and less distracting modalities to get feedback on their performance [8].

In this respect, Texture Displays [6] might be used to design such feedback, because it provides a less attention demanding modality. A texture display device presents different textural states, i.e. relaxed and stretched states, to give information. This way, instead of alerting the user, the device waits passively for user to take action and explore the information. Harrison and Hudson proposed applications to everyday objects in attention demanding contexts such as meeting or driving, which may also be applicable to sports.

The sports towel is an everyday object that is tangibly used by people from various sports during, between or right after the sports activities. We believe that towel holds a potential to give sports performance feedback by utilizing the texture display modality. Therefore, we focus on sport towels as a case to understand how we can give sports performance feedback through changes in the textural properties. We believe this case addresses the two gaps we identified in the literature: (1) Previous research presents various textural properties (i.e. roughness, hardness) [15]. Although there are studies on the textural properties of different materials [4] and how different textural properties are perceived [5], none has explored which properties can be perceived through specific materials by specific users. We propose that the perception would be context dependent and for specific materials, the towel, and specific users, sportspeople, some of the properties would be perceived easier and prioritized over the others. (2) Research suggests that changes in the textural properties could be used to give information, but it only focuses on the perception of the changes [6]. We propose that some of these textural properties would be associated to previous experiences. Thus, they would be more appropriate to give specific types of information, sports performance feedback.

We aim to fill these gaps by investigating the textural properties (1) that can be perceived by sportspeople through a towel, and (2) that can convey information on sportspeople's performance. For this purpose, we conducted experiments with 32 regular sportspeople. The results could be adopted by researchers and designers in the fields of smart textiles and materials, wearables, fashion, tangible interaction and sports.

Background & Related Work

Texture is a material property that affects our perception of an artefact and its interactive qualities [15]. Researchers have been trying to understand textural properties in three layers: physical, sensory and affective [1]. We can draw out an example through friction, roughness and pleasantness [2]. Friction is a physical property of a material that we can scientifically measure with unit of friction coefficient. However, when we touch a material, we cannot sense friction, but we sense roughness, which is the sensory property. Thus, if the friction coefficient is high, we perceive materials as rough. Last, when we perceive a material as rough, we start to associate this property with properties of the affective layer. To illustrate, we perceive rough materials as unpleasant or smooth as pleasant.

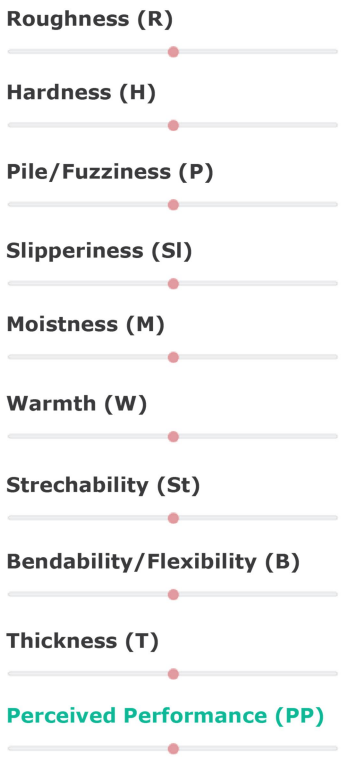


Figure 2: Example of the survey items used in the experiment with all of the textural properties and *perceived performance*.

Researchers conduct psychophysical experiments to learn about these three layers. In these experiments, participants either actively or passively (i.e. via robotic arm) [3-5] touch materials with different physical properties (i.e. compliance) [1], on different body sites (i.e. hairy or glabrous) [4]. Then they rate the sensory (i.e. warm) and affective properties (i.e. sensual) [3-5,9] of these materials. These experiments helped to understand the sensory properties of different fabrics (i.e. silk, cotton) [4,9], and how they make the users feel (i.e. pile feels comfortable) [5,9]. However, none presented a specific use case or context. Presenting a fabric as a towel during sports performance might change the perception and affection of the participants.

Most of these experiments focus on the perception of the materials through the sensory layer. For example, [6] showed that at least two states of stretch can be perceived through elastic fabrics to give information. However, they do not investigate the information these textural states can convey. In fact, to the best of our knowledge, there is no study that can describe the relationship between the textural properties and the type of information they can convey other than the affective properties. We believe that some sensory texture properties would be more relevant and more competent to give a specific type of information, because of the qualities they elicit in the affective layer.

Addressing these gaps, this study aims to investigate the textural properties of towels that can be perceived by specific users, and that can convey a specific type of information in the context of sports performance.

Experiment

Participants. 32 regular sportspeople participated in the experiment (18 males). They were all college students aged between 19-27 (M=21.5, SD=1.68). In average, they exercised 2.94 days a week (SD=1.62) for 4.72 years (SD=3.41). They were from 19 different sports fields including ice skating and rugby. 23 participated in a sports tournament. 20 monitor their performance regularly and 8 of them occasionally. 29 participants stated they would want to get performance feedback.

Samples & Textural Properties. Towel is a piece of cloth used for drying someone or something that is wet [14]. We procured 15 different types of towel including sports towel and kitchen cloth, which have different contents, because we thought a wide range of samples would present a wide range of textural properties. We left out the samples that had different textures on different sides (double sided). We cut each sample to a 25x25 centimeter squares and stitched the edges to prevent loose fibers (Figure 1). We procured 9 textural properties from the literature: *Roughness (R), hardness (H), pile/fuzziness (P), slipperiness (Sl), moistness (M)* and *warmth (W)* were recurring in multiple [1,3,5,12]. We also added *strechability (St), bendability/flexibility (B)* and *thickness (T)* because they are proposed properties for soft materials such as the towel [13].

Method & Procedure. We used a method similar to the psychophysical experiments in the literature, based on [4]. We formed a survey that presented each textural property and its definition on a continuous scale from -50 to +50 that presented each state (i.e. roughness, -50=smooth, +50=rough). The last item of the survey was *perceived performance (PP)* on a similar scale, from poor to good (Figure 2). The participants did not see the scores they gave on the scale. Texture perception is also affected by the visuals [15]. Instead of blind folding the participants, we built a 30x40x50 cm box with a 20 cm diameter hole on the front side, covered by a piece of



Figure 3: The blind box.

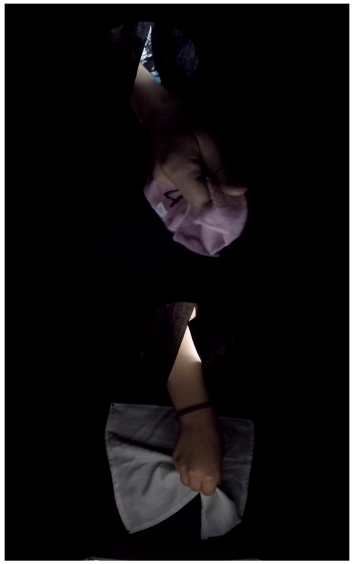


Figure 4: Screenshots from the video recordings. (The link for the video recordings will be provided)

cloth (Figure 3). Participants touched the samples inside the box through this hole.

Prior to the experiment we interviewed each participant on their sports field, frequency and duration of training, tournament history, and their preference in getting feedback. First, they had a tutorial study with an example sample to make sure they understand each item and the process. We asked them to put their dominant hand inside the box and touch the sample for 30 seconds. Unlike other experiments, we did not specify the way they touch, because there are multiple ways and areas to touch the towel. After touching the sample, they rated their perceptions of the textural properties. At the performance item, we asked them to visualize a sports performance that corresponds to their tactile feeling and rate accordingly. Once we were sure they understood the process, we continued with our 15 samples. We randomized the order of these samples for each participant and the order of the survey items for each sample, except the performance item. In the process, we encouraged participants to think aloud. We video recorded the experiment from a camera inside the box (Figure 4). After the experiment, we asked participants if there was a textural property they could not perceive, and if they believed they can get sports performance feedback from the textures of the towel.

Results

Content Analysis

In this section, we grouped the textural states according to the frequency they were mentioned.

Hardness, thickness, roughness and pile. For 26 of 28 participants hard textures, for 16 of 27 participants thick textures and for 17 of 24 participants rough textures were associated with poor performance. Out of 21 participants who referred to pile, 8 associated it with great and 8 associated it with poor performance. The remaining 5 continuedly changed their thoughts.

Bendability and slipperiness. 14 of 15 participants perceived bendable towels and 10 of 12 perceived slippery towels as an indication for great performance.

Warmth, moistness and strechability. 7 of 8 participants associated warmth with poor performance. 3 of 5 participants thought moist textures are related good performance. Only 1 participant mentioned stretched textures felt like he performed poorly.

Quantitative Analysis

We conducted a nine-stage hierarchical multiple regression by entering the textural states as predictor variables at each stage with *perceived performance* as the dependent variable. We tested the statistical assumptions with all variables, including the gender of the participants. *Gender (G)* did not show a significant effect on the model. The Pearson correlation results show that there was no multicollinearity between the variables, and *hardness* (r=-0.65, p=0.00) and *bendability* (r=-0.55, p=0.01) were significantly correlated with the perceived performance (Table 1).

The first-stage results revealed that *hardness* significantly predicted 65% of the variance (R^2=.40, $F(1,30)$=22.00, p<.00) (Table 2). Including *bendability* at the second-stage, explained 72% of the total variance with a significant change in R^2 and F values (p<0.05) (R^2=.49, $F(2,29)$=15.79, p<.00). Including rest of the predictor variables at the following stages did not improve the model significantly. All nine textural predictors were accounted for 76% of the total variance in perceived performance. Thus, our second-stage

	Rougness		Hardness		Pile		Slipperiness		Moistness		Warmth		Strechability		Bendability		Thickness		Performance		Gender			
	Correla-tion	Sig.	Correla-tion	Sig.	Correla-tion	Sig.	Correla-tion	Sig.	Correla-tion	Sig.	Correla-tion	Sig.	Correla-tion	Sig.	Correla-tion	Sig.	Correla-tion	Sig.	Correla-tion	Sig.	Correla-tion	Sig.		
R	1		.260	.151	.227	.212	-.251	.166	-.023	.902	-.033	.857	.100	.584	-.379*	.032	.105	.567	-.238	.189	-.130	.479		
H	.260	.151	1		-.075	.685	-.024	.896	.214	.239	.037	.841	.310	.084	-.402*	.023	.185	.311	**-.650****	**.000**	.072	.697		
P	.227	.212	-.075	.685	1		.278	.124	.310	.084	.307	.087	.098	.592	.196	.281	**.618****	**.000**	.214	.240	.012	.950		
SI	-.251	.166	-.024	.896	.278	.124	1		**.630****	**.000**	-.151	.410	-.027	.885	.175	.338	.083	.652	.284	.115	.113	.539		
M	-.023	.902	.214	.239	.310	.084	**.630****	**.000**	1		.256	.158	.097	.599	.078	.671	.406*	.021	.026	.889	-.060	.744		
W	-.033	.857	.037	.841	.307	.087	-.151	.410	.256	.158	1		**.454****	**.009**	-.013	.944	.431*	.014	-.051	.783	-.143	.435		
St	.100	.584	.310	.084	.098	.592	-.027	.885	.097	.599	**.454****	**.009**	1		**-.545****	**.001**	.151	.410	-.272	.133	.155	.389		
B	-.379*	.032	-.402*	.023	.196	.281	.175	.338	.078	.671	-.013	.944	**-.545****	**.001**	1		-.017	.926	**.548****	**.001**	.145	.427		
T	.105	.567	.185	.311	**.618****	**.000**	.284	.115	.026	.889	-.051	.783	-.272	.133	**.548****	**.001**	-.072	.696	-.072	.696	-.090	.625		
PP	-.238	.189	**-.650****	**.000**	.214	.240	.284	.115	.026	.889	-.051	.783	-.272	.133	.145	.427	-.090	.625	1		.128	.484		
G	-.130	.479	.072	.697	.012	.950	.113	.539	-.060	.744	-.143	.435	.155	.389	.145	.427	-.090	.625	.128	.484	1			

*Note. **p<0.01, *p<0.05*

Table 1: Pearson Correlation results of textural properties, performance and gender.

model, the final model, indicated that *hardness* (β=-.51, p<.01) and *bendability* (β=.34, p<.05) significantly predicted the perceived performance.

Predictors	**β**	**p**	**F**	**pΔF**	**R**	**R^2**	**ΔR^2**
Stage 1			21.997	.000***	.650	.423	.423
Hardness	-.650	.000***					
Stage 2			15.785	.021*	.722	.521	.098
Hardness	-.513	.001***					
Bendability	.342	.021*					
Stage 9			3.429	.844	.764	.584	.063
Hardness	-.537	.004**					
Bendability	.396	.073					
Slipperiness	.266	.281					
Warmth	-.032	.876					
Moistness	-.070	.766					
Pile	.005	.982					
Roughness	.100	.600					
Strechability	.125	.553					
Thickness	.022	.920					

*Note. β, unstandardised beta; p, significance level; F, F statistic; pΔF, significance level of F change; R, ΔR^2, change in variance; R^2, variance;*p<.05, **p<.01, ***p<.001; N=32*

Table 2: The hierarchical regression results showing the effect of the textural properties on perceived performance.

Discussion

Hardness, thickness, roughness, pile, bendability and slipperiness can be perceived by sportspeople through a towel. These were the most mentioned properties, because they were easier to perceive compared to the rest. Also, participants explicitly mentioned that they could not perceive *warmth* and *moistness*, and *strecthability* was only mentioned by one. According to Pearson correlation results (Table 1), *moistness* is highly correlated with *slipperiness*, *strechability* with *bendability* and *warmth* with *strechability* (p<0.01). Because *slipperiness* and *bendability* are perceived easier, participants might have prioritized these properties over *warmth*, *moistness* and *strechability*. In this respect, some textural properties presented in the literature may be more dominantly perceived by specific users through specific materials. Designers that work with interactive textiles and materials can benefit from focusing on the prioritized properties.

Hardness and bendability can convey information on sports performance. Although participants perceived most of the textural properties, some of them did not give any direction to their *perceived performance*. For example, participants were split to three even groups when they rated *pile*. On the other hand, both content and quantitative analysis demonstrated that *hardness* and *bendability* showed a single direction predicting *perceived performance*. According to the results, softer and more bendable textures were associated with greater performance. This study is first to describe the relationship between a textural property and a specific information. We recommend interaction designers to adopt this approach to convey information through texture or shape changes. We should also note that *hardness* affected *perceived performance* 1.5 times more than *bendability*. Thus, there is a hierarchy between these properties in terms of sports performance, and designers should consider this hierarchy while choosing the properties. Participants explained this relationship by stating if a texture is too soft, it means that it is bendable. They added, softer textures feel better than bendable textures and being soft might compensate if the texture is unbendable.

Perception is context dependent and can change among different sports. Overall results show that softer and

more bendable textures are associated with greater performance. However, this perception changed for people from different sports. For example, participants thought softer and more bendable textures are more suitable for ice skating and dancing because they feel more relaxed. They felt uneased with rough textures. Contrarily, 2 participants thought harder and rougher textures are more suitable for basketball to convey greater performance information, because they felt more powerful. They thought soft and fuzzy textures felt too relaxed and drowsy. While rating the properties participants also considered their previous experiences. They assumed cooler textures are better for football, because that is how the field feels like, and thicker textures are better for snowboard, because of the thick garments. Additionally, they associated the slippery textures to the slippery feeling of professional sport clothing and moist textures to the feeling of taking a shower after the exercise. These examples demonstrate that participants associate the textural properties to good or poor performance according to their own experiences. Thus, in different contexts the perception of these properties could change. We recommend interaction designers to consider the diversity between the contexts and previous experiences.

Conclusion

We conducted experiments with 32 sportspeople to investigate the textural properties (1) that can be perceived by sportspeople through a towel and (2) that can convey information on sports performance. We found two findings that may contribute to the field:

(1) The content and quantitative analysis suggests that *hardness, thickness, roughness, pile, bendability* and *slipperiness* can be perceived through a towel. However, the perception of these properties is context dependent. In the context of soft materials for sports, textile designers could prioritize these properties.
(2) The regression results indicate that in hierarchical order *hardness* and *bendability* are associated to the perception of good or bad sports performance and able to convey this information about sports performance. Designers can manipulate these properties to convey information on sports performance. Additionally, this result is the first to describe that a change in the state of a textural property is able to give a specific information. We recommend tangible interaction designers to consider this approach in their studies.

Limitations & Future Work

Our study only focused on perceived performance and the participants were from a variety of sports. To fully test these results, we plan to conduct experiments involving an actual sports performance and focus only on a single sport, because the results were context dependent. We also believe a Wizard of Oz experiment, in which sportspeople perform and get feedback via using different towels with varying softness, can present insights on the usability and the feasibility of a towel to give feedback on sports performance.

Acknowledgements

We thank Ceren Yüksel and Demet Özer for their help in data collection and analysis phases of this research.

References

[1] X. Chen, C. J. Barnes, T. H. C. Childs, B. Henson, and F. Shao. 2009). Materials' tactile testing and characterisation for consumer products' affective packaging design. *Materials & Design*, *30*(10), 4299-4310.

[2] Mathew A. Darden and Christian J. Schwartz. 2009. Investigation of skin tribology and its effects on the tactile attributes of polymer fabrics. *Wear*, *267*(5-8), 1289-1294.

[3] Greg K. Essick, Francis McGlone, Chris Dancer, David Fabricant, Yancy Ragin, Nicola Phillips, Therese Jones, and Steve Guest. 2010. Quantitative assessment of pleasant touch. *Neuroscience & Biobehavioral Reviews*, *34*(2), 192-203.

[4] Roberta Etzi, Charles Spence, and Alberto Gallace, A. 2014. Textures that we like to touch: An experimental study of aesthetic preferences for tactile stimuli. *Consciousness and cognition*, 29, 178-188.

[5] Steve Guest, Jean Marc Dessirier, Anahit Mehrabyan, Francis McGlone,
Greg Essick, George Gescheider, Anne Fontana, Rui Xiong, Rochelle Ackerley, and Kevin Blot. 2011. The development and validation of sensory and emotional scales of touch perception. *Attention, Perception, & Psychophysics*, 73(2), 531-550.

[6] Chris Harrison and Scott E. Hudson. 2009. Texture displays: a passive approach to tactile presentation. *In Proceedings of the SIGCHI Conference on Human Factors in Computing Systems (CHI '09)*. ACM, New York, NY, USA, 2261-2264. DOI: https://doi.org/10.1145/1518701.1519047

[7] Hayati Havlucu, İdil Bostan, Aykut Coşkun, and Oğuzhan Özcan. 2017. Understanding the Lonesome Tennis Players: Insights for Future Wearables. *In Proceedings of the 2017 CHI Conference Extended Abstracts on Human Factors in Computing Systems (CHI EA '17)*. ACM, New York, NY, USA, 1678-1685. DOI: https://doi.org/10.1145/3027063.3053102

[8] Hayati Havlucu, Terry Eskenazi, Barış Akgün, Mehmet Cengiz Onbaşlı, Aykut Coşkun, and Oğuzhan Özcan. 2018. Flow State Feedback Through Sports Wearables: A Case Study on Tennis. *In Proceedings of the 2018 Designing Interactive Systems Conference (DIS '18)*. ACM, New York, NY, USA, 1025-1039. DOI: https://doi.org/10.1145/3196709.3196807

[9] Anthony David Hope, Mark Jones, and Hengfeng Zuo, H. 2013. Sensory perception in materials selection for industrial/product design. *The International Journal of Designed Objects*, *6*(3), 17-31.

[10] Mads Møller Jensen and Florian 'Floyd' Mueller. 2014. Running with technology: where are we heading?. *In Proceedings of the 26th Australian Computer-Human Interaction Conference on Designing Futures: the Future of Design (OzCHI '14).* ACM, New York, NY, USA, 527-530. DOI=http://dx.doi.org/10.1145/2686612.2686696

[11] Roland Sigrist, Georg Rauter, Robert Riener, and Peter Wolf. 2013. Augmented visual, auditory, haptic, and multimodal feedback in motor learning: a review. *Psychonomic bulletin & review*, 20(1), 21-53.

[12] Minghui Sun, Xiangshi Ren, Shumin Zhai, and Toshiharu Mukai. 2012. An investigation of the relationship between texture and human performance in steering tasks. In *Proceedings of the 10th asia pacific conference on Computer human interaction* (pp. 1-6). ACM.

[13] Katrin Wolf and Timm Bäder. 2015. Illusion of Surface Changes Induced by Tactile and Visual Touch Feedback. *In Proceedings of the 33rd Annual ACM Conference Extended Abstracts on Human Factors in Computing Systems (CHI EA '15).* ACM, New York, NY, USA, 1355-1360. DOI: https://doi.org/10.1145/2702613.2732703

[14] Towel. n.d. Retriewed November 8, 2018 from https://dictionary.cambridge.org/dictionary/english/towel

[15] Hengfeng Zuo, T. Hope, P. Castle, and M. Jones. 2001. An investigation into the sensory properties of materials. *Psychology*.