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Early onset of tactile sensory deterioration begins in the thirties

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1. Introduction

Life expectancy is increasing [1] in many parts of the world and should be regarded as one of the most important human achievements in recent history. Unfortunately, aging populations can also bring societal challenges, and strategies for meeting these challenges must be considered and implemented [2]. Regarding skin, it is known that age-related deficiencies in skin function can lead to skin cancers and potentially fatal skin tears and pressure ulcers [3]. There are several age-related changes in skin properties reported that include increases in macroscopic stiffness [4], decreases in skin hydration and elasticity [5-7], as well as decreases in the density of mechanoreceptors in the skin [8-11]. In short, aging can affect both the mechanical and physical properties of the skin, as well as neurophysiological capabilities for the detection, transmission or interpretation of cutaneous signals when acting both as an emitter or receiver of a stimuli [12].

In glabrous skin such as that found on the soles of the feet and the palms of the hands, four main cutaneous mechanoreceptors and their associated specialized nerve endings are involved in tactile perception [13, 14]. The four mechanoreceptor types are Meissner corpuscles, Merkel disks, Ruffini corpuscles, and Pacinian corpuscles, and these are specialized for specific perceptual purposes [15]. Meissner corpuscles and Merkel disks are localized in the dermal papilla between the epidermis and the dermis, have small receptive fields and are relevant for gentle touch and appreciation of texture. These mechanoreceptors are mainly connected to the myelinated Aβ nerve fibers that allow quick transmission of the information to the central nervous system. Meissner corpuscles are associated with fast-adapting nerve endings that are sensitive to on- and offset of tactile stimulation, while Merkel disks are associated with slow-adapting nerve endings that provide a continuous response given sustained tactile stimulation. Ruffini's (slow-adapting nerve endings) and Pacinian (fast-adapting nerve endings) corpuscles are localized in the dermis and hypodermis respectively, and are sensitive to pressure and stretching and both have large receptive fields.

The fast-adapting Meissner and Pacinian corpuscles are both sensitive to vibration information, such that the vibratory signals induced through active exploration of surfaces are detected at low frequency (10-50 Hz) by Meissner Corpuscles and at low frequency (30-150 Hz) Pacinian corpuscles [15]. In fact, for surfaces with a spatial period below ~200 μm the vibrotaction signals that engages the Pacinian corpuscles have been suggested to be highly important, since people's ability to detect these fine textures was significantly diminished in the absence of movement that induces vibrotaction [16].

The sense of touch is relevant not only for discrimination and perception, but also serves as a means for sharing feelings and communication [17, 18] and plays a role in emotional regulation [19]. This implies that deterioration of tactile acuity with age could impact an individual's quality of life. Given this, understanding which changes in skin properties contribute to the degradation of tactile acuity throughout life and when these may begin to emerge is imperative. This could lead to a development of methods for reducing the impact of aging on skin properties relevant for retaining good tactile sensitivity.

The development and implementation of a psychophysical method for quantifying diminished tactile acuity among the elderly for active touch was investigated by Skedung et al. [10]. The developed method for tactile ability during dynamic touch showed that fine texture (μm scale) discrimination acuity was reduced among elderly relative to young participants. Interestingly, the elderly participants could be sub-categorized into those who could successfully (high performers) or unsuccessfully (low performers) discriminate between surfaces of 100 μm and 20 μm wavelength on 80% of trials. There were no differences in skin hydration or elasticity between these subcategories, implying other parameters explaining the differences between the two groups. However, the authors also found that among the low performers, use of a skin humectant improved performance in the low performing elderly participants. This is consistent with the results of Lévêque et al. [6] who showed that application of a moisturizer improved two-point discrimination for passive touch, as well as with the results of Aimonetti et al. [20] who found that long-term use of a topical humectant improved tactile discrimination among the elderly. Dione et al. [21] also examined touch on the finger in younger (20–28 years) and older (65–75 years) females and found that glabrous (non-hairy) finger skin becomes drier and touch performance declines with age but did not observe not significantly change touch perception when hydration levels increased after applying skin moisturizers. Previous work has mainly focused on investigation of tactile discrimination in elderly [6, 20] or young and elderly [10, 21], but less is known about the ages in between and when the onset of tactile sensory deterioration begins.

In this study, the same method as described in Skedung et al. [10] was used to measure the fine texture discrimination ability of groups of participants either aged 26-45 or 46-65 years. The purpose was to expand on those results by including these two additional age groups, so that the nature of the effects of age on tactile perception and skin characteristics could be better understood. Additionally, more extensive assessment of skin characteristics has been conducted, in order to more comprehensively assess the relationships between the condition of the skin and tactile perception, and how these may be influenced by aging. The work aims to contribute to the understanding of age-related tactile deterioration and how age-related changes in key skin properties can be offset so as to preserve tactile acuity longer as we age.

2. Materials and Methods

2.1.Ethics

The experiment was conducted in accordance with the Declaration of Helsinki (1964) and its later amendments. All participants gave written informed consent before taking part and the collected personal data were processed in accordance with the General Data Protection Regulation (EU) 2016/679 (GDPR). No invasive methods were used, and no sensitive personal information was collected.

2.2. Participants

Two groups of female participants were recruited, who were either aged 26-45 years (N = 30; Mage = 36 years, SDage = 6 years) or 46-65 years (N = 32; Mage = 55 years, SDage = 6 years). The data from the 18-25 years (N = 30; Mage = 22 years, SDage = 2 years) and 66+ years (N = 30; Mage = 73 years, SDage = 5 years) groups from Skedung et al. [10] were also included in the analysis.

2.3. Stimuli and tactile discrimination test

Six textured surfaces varying systematically in wavelength were produced and used in the study. These wrinkled surfaces have been used in different studies [10, 22-24], where the fabrication method was first described by Skedung et al. [22]. Figure 1 shows area images (1x1 cm obtained from 250 line scans) and line scans (1.1 mm) obtained with a stylus profilometer (DektakXT Profiler, Nano GmbH, Germany) obtained of the six stimuli used in the tactile discrimination test. The nominal wavelengths of the test surfaces, obtained from the average peak spacing parameter PSm, were 20 µm, 40 µm, 60 µm, 80 µm, and 100 µm (denoted S20, S40, S60, S80, and Ref100, respectively). In addition, a smooth, non-textured surface (S0) was included in the study.

The tactile discrimination test developed by Skedung et al. [10] was used in this study to complement the understanding of tactile sensory deterioration with two additional age groups. The participants completed the tactile perception test where they judged whether a presented surface was perceived as the same or different to the Ref100 surface on each trial. They completed 12 repeats of each possible pair, including Ref100 versus itself, giving 72 trials in total per participant.

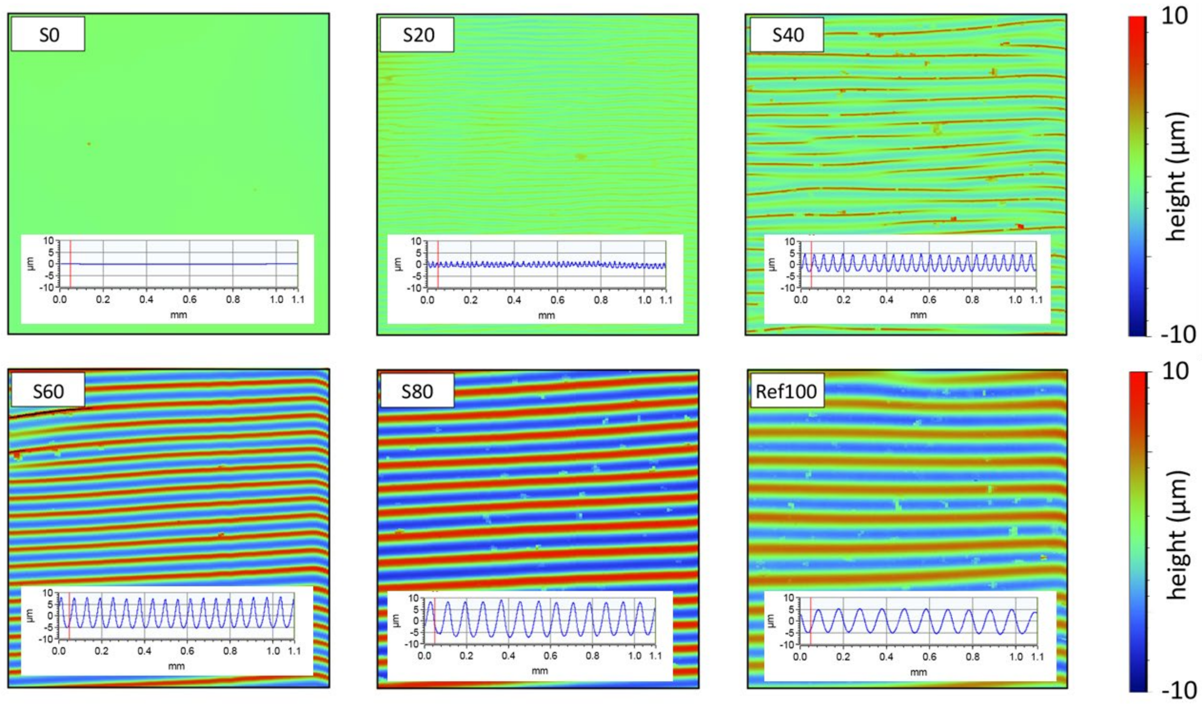

Figure 1. Stylus profilometry area images and line scans of the six stimuli used in the tactile discrimination test.

2.4. Cutaneous properties

Additionally, participants' skin hydration and elasticity of the index finger and cheek were measured in arbitrary units (A.U.) using a Corneometer CM 825 probe and Cutometer MPA 580 probe from Courage & Khazaka Electronic GmbH (Cologne, Germany). Each elasticity measurement consisted of three suction cycles of 2 s using a constant negative pressure of 450 mbar, followed by a 2 s period when the pressure was switched off (relaxation phase) allowing the skin to return to its original shape. The net elasticity parameter, R5 (the linear elastic relaxation response as a ratio of the linear elastic deformation response) was used to represent finger elasticity here because it has been identified as a suitable parameter for comparing difference between young and aged skin [7]. Net elasticity is a dimensionless ratio that represents the skin's ability to return to its original state after deformation. The closer the value is to 1, the more elastic the skin is.

3. Results

3.1. Tactile discrimination

The sensitivity measure d' was calculated from the hit rates [proportion of times ("Responded Different" | Surfaces Different)] and false alarms [proportion of times ("Responded Different" | Surfaces Same)] for each pair of surfaces for each participant. The data from the participants in the young and elderly groups were recalculated as d' instead of % correct as was analysed there [10]. Figure 2 shows the mean d' for each age group for each pair of surfaces. A higher d' indicate that the surfaces were perceptually more easily distinguished. As expeced S0 was easily distinguished from Ref100 in all age groups and the smaller the wavlength, the more challenging they were to perceptually distinguish. The results also show that the elderly group as well as the two middle-aged groups had a lower d' than the young group when perceptually comparing S20 with Ref100.

A mixed ANOVA with pair and age group as factors revealed significant differences in d' both across the pairs, $F(4, 472) = 249.204$, $p < .001$, $\eta p2 = 0.679$, and between age groups, $F(3, 118) = 8.151$, $p < .001$, $\eta p2 = 0.172$. A pair × age group interaction, $F(12, 472) = 5.869$, $p < .001$, $\eta p2 = 0.130$ was also identified. Bonferroni corrected post-hoc analysis showed that the 18-25 year olds performed significantly better than the other age groups when Ref100 was compared to S20 [Δ λ = 80 μm; mean difference compared to 26-45 = 1.41; 45-65 = 1.30; 66+ = 1.73, all $p < .001$] and S40 [Δ λ = 60 μm; mean difference compared to 26-45 = 1.37; 45-65 = 1.37; 66+ = 1.96, all $p < .001$]. The 66+ group performed significantly worse than the 18-25 group when Ref100 was compared to S60 [Δ λ = 40 μm; mean difference = -1.07, $p = .004$]. Performance was equally good across age groups when Ref100 was compared to S0 [Δ λ = 100 μm] and equally poor when compared to S80 [Δ λ = 20 μm].

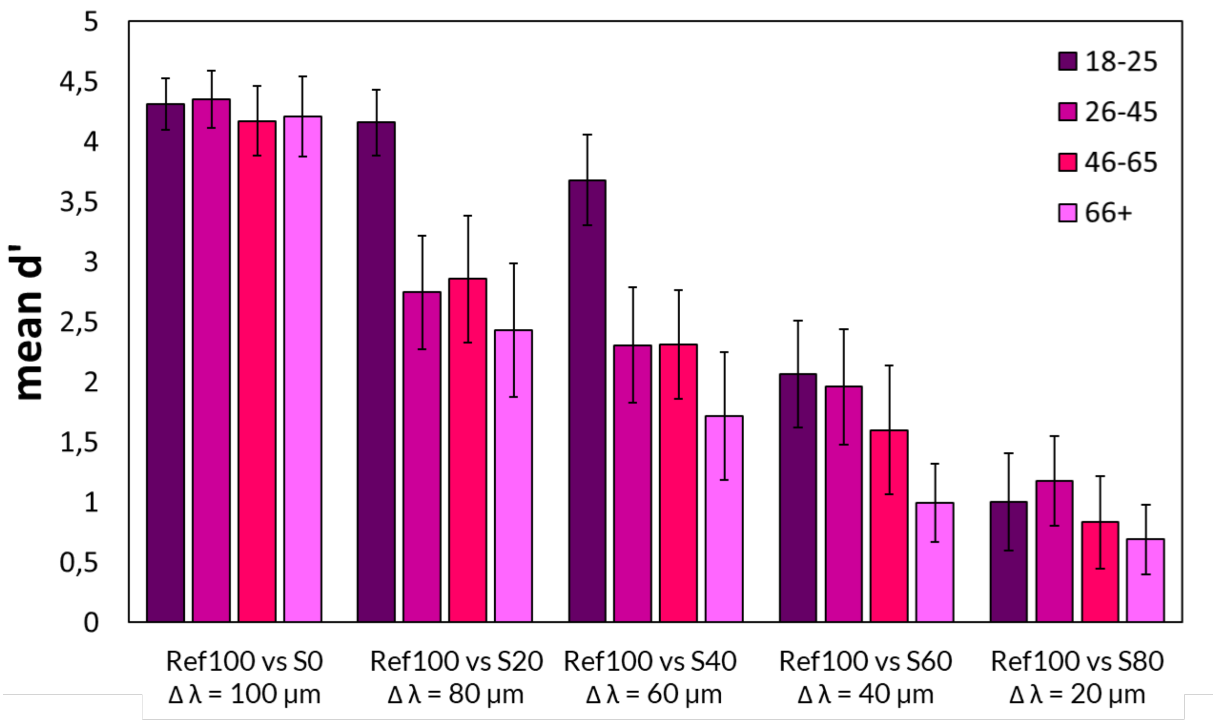

Figure 2. Mean d' (sensitivity measure) for each age group for each pair type, shown as wavelength difference (Δ λ) from Ref100. Error bars show 95% confidence intervals.

Posterior distributions were estimated using the Bayesian inference method with standard normal priors (mean = 1, SD = 0) to contrast performance (d') across different age groups, see Figure 3.

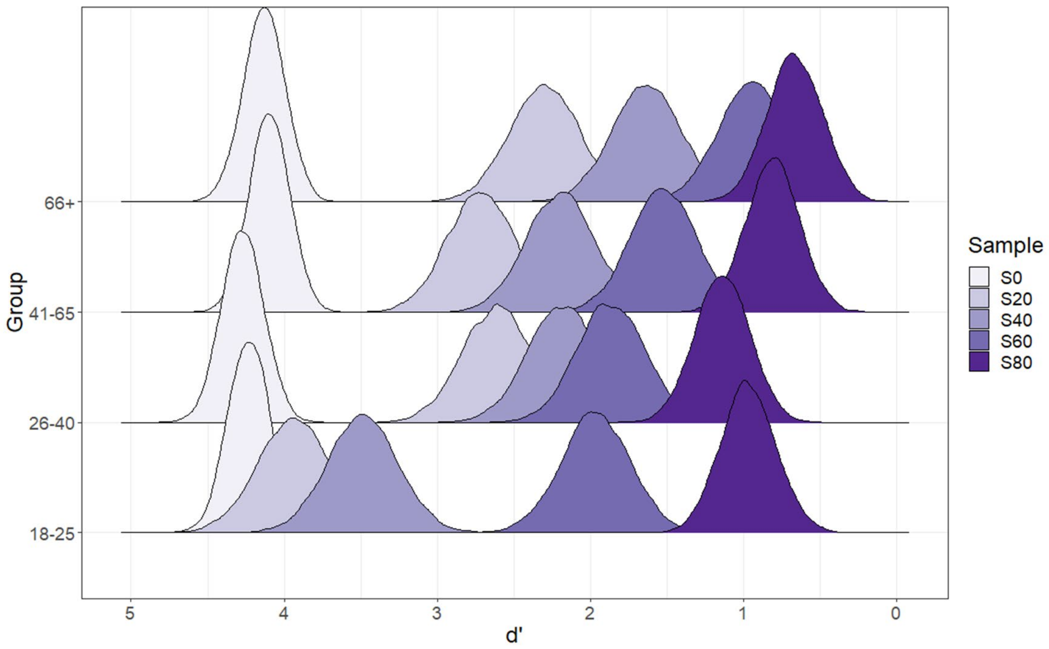

Figure 3. Posterior distributions of the sensitivity measure d' across age groups and sample pairs.

3.1. *Cutaneous propoerties and tactile discrimination ability*

Skin hydration and the net alsticity for the the different age groups are presented in Figure 4. Both skin hydration ($r = -0.457$, $p < .001$) and net elasticity ($r = 0.531$, $p < .001$) in the finger declined with age. To examine the effects of skin hydration and net elasticity on tactile acuity, these were included in multiple linear regression analyses alongside age in years for each pair type. The results are shown in Table 1. Age was negatively associated with d' for all pair types even when controlling for skin hydration and skin elasticity, apart from when Ref100 was compared to S80. Net elasticity was negatively associated with tactile acuity when Ref100 was compared so S0, indicating that higher skin elasticity was related to worse discrimination ability for this pair, although note that the variation in responses for this pair was very small. Intyerestingly there are age differenecs in net elasticity on the cheek but no differences in cheek hydration.

Table 1. Standardized regression coefficients (β) and t-values for age, skin hydration and net elasticity on d' for each pair type.

	Ref100 vs S0		**Ref100 vs S20**		**Ref100 vs S40**		**Ref100 vs S60**		**Ref100 vs S80**	
	β	**t**	**β**	**t**	**β**	**t**	**β**	**t**	**β**	**t**
Age (years)	0.30**	-2.69	0.41***	-3.81	0.43***	-4.10	0.30**	-2.69	-0.10	0.36
Skin hydration (A.U.)	0.08	0.65	0.12	0.94	0.13	1.06	0.08	0.65	-0.08	0.54
Net elasticity (A.U.)	0.37*	-2.73	-0.18	-1.41	-0.12	-0.97	-0.02	-0.18	0.06	0.66

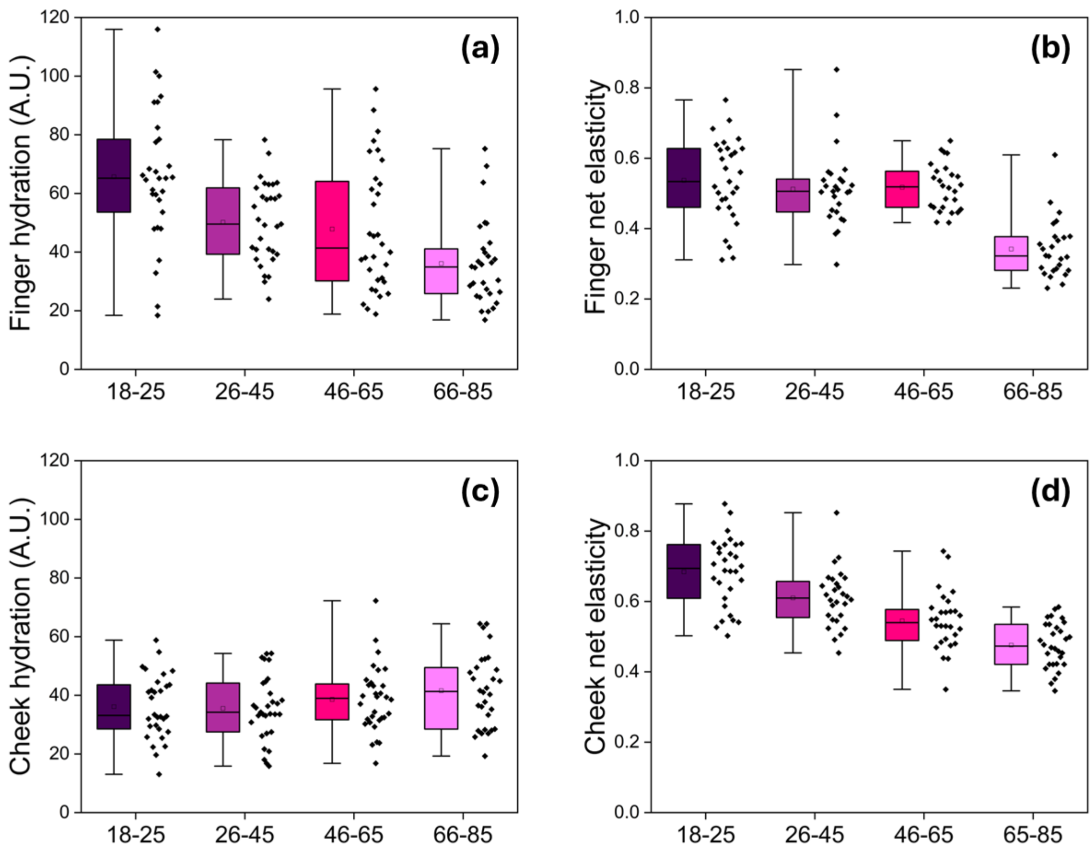

Figure 4. Box plots showing the distribution of data for skin hydration (a & c) and net elasticity (b & d) for the four age groups, with the box representing the interquartile range (25th to 75th percentile). The horizontal line within the box indicates the median, while the dot represents the average value. The whiskers extend to the minimum and maximum values of the datasets. Net elasticity is a dimensionless ratio that represents the skin's ability to return to its original state after deformation. The closer the value is to 1, the more elastic the skin is.

4. Discussion

The aim of the present work was to further investigate age-related tactile acuity decline by including two additional age groups (26-44 and 45-64 years old) together with a previous study on young (18-25) and elderly (>66 years old) [10]. The results demonstrate a clear deterioration in tactile acuity with age, with an early onset already in the thirties. These findings are consistent with previous research which also reported a decline in tactile acuity with aging [6, 8, 20, 21, 25-28]. However, our study extends this knowledge by pinpointing the onset of deterioration to the early thirties.

Different parts of the skin may respond differently to ageing, where Samain-Aupic et al. [28] found that tactile sensitivity declines significantly with age on the finger pad, while sensitivity on the forearm and cheek remains relatively preserved. While most studies have investigated age-related decline in tactile ability using static touch or millimeter-scale textures, we have developed a novel method to quantify tactile acuity during active exploration (dynamic touch) using a set of systematically varying micrometer-textured surfaces. With fine-textures and dynamic touch, this method targets involvement of the fast-adapting Meissner and Pacinian corpuscles sensitive to vibration information [15]. Five different surfaces varying in texture wavelength were compared to Ref100 (reference surface with 100 µm wavelength). When comparing Ref100 with S0, the high friction induced by sliding the finger across the smooth, blank surface likely acted as a strong cue that this surface was different to Ref100 [10, 22]. Alternative strategies for each pair type may differ depending on the relative differences in both friction coefficient, detectability of the surface topography and induces vibrations during active exploration. A follow-up study by Fischer et al. [24] on young participants performing parts of the discrimination task showed that brain activations varied with the difficulty of the tactile discrimination task. As task difficulty increases, the brain adapts by engaging additional neural resources to meet higher cognitive demands.

Many countries around the world now have aging populations, and life expectancy continues to increase. Since this trend may bring with it a series of challenges regarding age-related skin function concerns [3], increased understanding of the mechanisms underlying age-related skin deterioration is of increasing importance. These efforts could lead to the development of methods or treatments for improvement or even retention of tactile ability with age. Moreover, understanding the mechanisms of sensory deterioration among the elderly is not only important for developing methods to retain tactile sensitivity longer into life, but could be relevant for detecting other age-related health concerns [29].

Although the results show that finger skin hydration and elasticity decrease with age, these cutaneous properties did not significantly explain the decline in tactile acuity observed in this study. It is important to note that substantial individual variations in skin properties and tactile acuity may obscure significant findings. Also skin thickness and morphological affect the stimulation of the mechanoreceptors [30]. Skedung et al. [10] proposed a age-related decline in neural properties as the primary explanation for the reduction in active touch acuity where a reduced density of receptors was shown when comparing the poor and high performing elderly groups. Unfortunately, Meissner corpuscle density was not measured on the participants in this study but is something that should be included together with skin mechanical properties on the same participants in future studies. Recently Infante et al. [31] studied the role of different skin factors comprising hydration and density of Meissner corpuscles in tactile perception. They confirmed the known effect of both factors but indicating that well hydrated skin will eventually reduce the dependence of tactile sensitivity on the density of Meissner corpuscles.

An improvement in the biomechanical properties of the skin through rehydration was observed by Skedung et al. [10] indicate that the loss in discrimination in the one dimension, can be significantly ameliorated by an improvement in tactile discrimination ability in the other, friction based, dimension. Leveque et al. [6] also found that the skin's discriminative function was partially restored after hydration with a moisturizer. Another recent example showed an increase of tactile acuity by applying cosmetic oil with added aromatic compounds [28]. In contrast, Dione et al. [21] found that glabrous (hairless) skin on the fingers became drier and touch performance declined with age, while these aspects were preserved in hairy skin. Moisturization immediately increased hydration levels but did not significantly change touch perception. A study by Aimonetti et al. [20] demonstrated that the tactile discrimination threshold decreased after one month of cosmetic application with an active ingredient. While hydration seems to positively affect tactile ability in the fingertips, extensive, dexterous manual work can delay, the effects of aging on tactile perception [32].

5. Conclusion

The study demonstrates a clear decline in tactile acuity with age, beginning as early as in the thirties. This decline is evident across various surface comparisons, with younger participants outperforming older groups. Significant differences in tactile sensitivity were obtained both across different surface pairs and age groups, with notable interactions between these factors. Despite the observed decrease in skin hydration and elasticity with age, these cutaneous properties did not significantly explain the decline in tactile acuity. Instead, the findings suggest that age-related neural changes, such as reduced receptor density, may be the primary contributors to diminished tactile sensitivity. The study highlights the importance of understanding the mechanisms underlying age-related sensory deterioration, which could inform the development of methods or treatments to retain tactile ability longer into life. Future research should include measurements of Meissner corpuscle density alongside skin mechanical properties to further elucidate the relationship between skin morphology and tactile perception.

6. References

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