

Article

Investigation on Decorative Materials for Wardrobe Surfaces with Visual and Tactile Emotional Experience

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Abstract: This work investigates the relationship between the material properties of wardrobe furniture and visual and tactile emotional responses, with a focus on age-related differences in emotional experiences. This research measured material surface properties (roughness, gloss, and Lab color) and utilized the PAD (pleasure, arousal, dominance) emotion model to assess emotional responses among elderly and younger participants. (1) In the context of tactile emotional experiences, a systematic correlation was observed between surface roughness and the reported levels of pleasure, arousal, and dominance in both elderly and younger participants. Moreover, pleasure demonstrated a systematic correlation with gloss. Rough surfaces were perceived as unpleasant. The elderly participants showed greater emotional dominance when exposed to rough surfaces. (2) In terms of visual–tactile emotional experiences, a responsive relationship was found between pleasure, dominance, and the a^* parameter (representing the red and green color channels) in both age groups. However, no systematic correlations were observed between luminance (L^*), glossiness, and PAD emotional experiences in either group. A responsive correlation was found between pleasure, dominance, and the b^* parameter (representing the yellow and blue color channels) in elderly individuals. Notably, a significant correlation was observed between arousal and roughness in younger individuals. These findings suggest a partial difference in emotional responses across the PAD dimensions between elderly and younger participants.



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1. Introduction

Population aging is a global phenomenon in societal evolution and is poised to be a significant feature of China's national context in the long run. According to the National Bureau of Statistics, China's population aged 60 years and above surpasses 296 million [1]. Aging is a multidimensional and dynamic process. Before reaching old age, individuals experience childhood, adolescence, and adulthood, demonstrating their holistic and dynamic features. The psychological perceptions of older adults are influenced by alterations in physiological states and their active engagement in social activities [2]. Sensory characteristics, including vision and touch, experience varying degrees of decline with age. As a result, there are significant differences in the physiological functions of older adults compared to their younger counterparts [3]. However, the existing research on home living spaces and products focuses on children and younger individuals. Consequently, it is essential to investigate the perceptual experiences associated with age-friendly materials. Such

research will provide valuable implications for how to enhance the sensory experiences of material surfaces, contributing to an improved quality of life for older adults.

Wooden furniture is eco-friendly, natural, and durable [4]. Due to the increasing scarcity of timber resources and advancements in wood furniture production technology, wood-based panels have become the primary materials for furniture manufacturing, owing to their exceptional stability, cost-effectiveness, and practical utility [5]. The wardrobe is an essential piece of furniture in the home, serving the purpose of storing family members' clothing and enhancing the decoration of the space. Solid wood and wood-based panels, such as particleboard, fiberboard, and plywood, are used as base materials. Surface decoration materials, including decorative paper, polyvinyl chloride (PVC) film, polypropylene (PP) film, and coatings, are applied to wardrobe surfaces and create texture effects that resemble wood, leather, and fabric [6]. Surface decoration techniques protect wardrobe surfaces, enhance the wear resistance of materials, and improve the tactile properties of wardrobe surfaces. In addition, these techniques provide consumers with a wider range of decorative options.

1.1. Visual and Tactile Sensory Experience of Materials

Materials have inherent surface physical properties, including geometric and physico-chemical characteristics [7]. Human sensory organs and perceptual systems interact with material surfaces, generating systematic and comprehensive emotional experiences. Cognition and emotion are linked to the physical properties of material surfaces [8]. Bhatta et al. [9] investigated the tactile perception and emotional evaluation of pine and oak materials subjected to varying surface treatments, finding a significant correlation between the effects of wood surface qualities and emotional responses; smooth and natural surfaces were shown to evoke more positive emotional experiences. Chen et al. [10] investigated the relationship between the tactile physical properties of packaging material surfaces and sensory and emotional responses, establishing a hierarchical framework. Guest et al. [11] investigated the sensory and emotional dimensions of material touch, revealing the semantic and perceptual structure of materials. Lindberg et al. [12] utilized analytical techniques, indicating that materials can be distinguished through tactile perception. Furthermore, the tactile perception of wood-based materials exhibits significant differences compared to solid wood.

The perceptual and emotional dimensions are derived from the properties of the materials. Picard et al. [13] examined the tactile perceptions and experiences associated with seat cover materials, revealing that roughness and softness are the primary perceptual dimensions of fabrics, both associated with pleasantness. Secondary dimensions included thinness and thickness, relief, and hardness. In a related study, Guest et al. [11] further classified the tactile sensory dimensions of materials into four distinct factors: roughness, slipperiness, pile, and hardness. Emotional attributes were divided into two dimensions: comfort and arousal. Ackerley et al. [14] utilized the tactile perception task (TPT) method combined with factor analysis, identifying five sensory factors: texture, pile, moisture, heat/sharpness, and cold/slipperiness. Additionally, the research revealed three emotional dimensions: positive, arousal, and negative. Drewing et al. [15] utilized principal component analysis (PCA) to delineate six sensory dimensions associated with material touch, fluidity, roughness, deformability, fibrousness, heaviness, and granularity, along with VAD emotional dimensions. Building upon these findings, Drewing [16] subsequently found partial disparities in emotional experiences elicited by materials between older and younger individuals.

Emotional experiences arise from a combination of multiple factors. Guest et al. [11] developed the tactile perception task (TPT) to explore tactile perceptual experiences, finding

that, across different body regions or via varying stimulation methods, various emotional responses were produced. Ackerley et al. [14] employed this tactile perception task (TPT) method to further investigate differences in tactile emotion across various parts of the body. Their findings revealed a distinction in emotional experiences between hairy and glabrous skin. HU et al. [17] utilized PAD emotion models and measured electrical skin responses to assess tactile perception differences on beech wood surfaces with varying roughness and shapes, revealing that rough surfaces elicited feelings of anxiety. Klocker et al. [18] demonstrated that pleasure is influenced by both the roughness and mean friction of the surface. Greg et al. [19] discovered that pleasure ratings varied depending on texture, the specific body area stimulated, the speed of touch, and the intensity of the stimulus. In a systematic evaluation and meta-analysis, Taneja et al. [20] demonstrated that, in addition to the texture of the material itself and the velocity and force of the touch, the duration of continuous stroking also influences tactile pleasure. Differences in the emotional experience of touch can also be shaped by an individual's past experiences and cultural backgrounds [13–15]. Thus, the stimulation provided by the material is not solely physical; it also involves an individual's recall of memories and experiences stored in the brain [13].

In exploring the relationship between emotional tendencies and the properties of material surfaces, Etzi et al. [21] utilized subjective questionnaires and objective skin response experiments to investigate pleasure and physiological arousal elicited by different material textures. Their findings indicated that tactile stimuli elicited stronger skin responses compared to visual stimuli, with smooth surfaces being more pleasurable than rough ones. Ramanantoandro et al. [22] conducted quantitative measurements of wood density, surface color, and texture to explore consumer preferences. Their findings indicate that consumers in Antananarivo favor yellow hues with slightly darker wood tones and directional textures, and they observed that these preferences are influenced by socioeconomic factors. Huang et al. [23] investigated the visual perception of color and texture in reconstituted decorative veneer, uncovering a significant correlation between subjective preferences and color attributes. Rapuano et al. [24] explored the impacts of various indoor features on individuals' positive and negative emotions, finding that older adults may evaluate environments emotionally based on the features and colors of covering materials.

Shiraku et al. [25] investigated the relationship between the visual and tactile perceptions of wood by measuring surface properties and conducting subjective self-assessments, showing that the perceptions of wood were related to surface roughness and brightness. The study established a mapping between objective physical properties and visual–tactile perception. Jin et al. [26] measured the physical properties of cabinet surfaces and conducted self-assessment experiments using regression analysis to establish a response relationship between material properties and individual emotional experiences. Wastiels et al. [27] investigated the perception of warmth in building materials through both visual and tactile senses, revealing that warmth perception correlates with certain technical material parameters. In a subsequent experiment, Wastiels et al. [28] further explored the relationship between multisensory warmth experiences and the material surface properties, concluding that color exerts a greater impact on warmth perception than surface roughness. Briand et al. [29] examined the cross-modal relationship among packaging glossiness, tactile perception, and consumer responses, finding that glossiness significantly influences tactile perception, consumers' internal consumer responses, and behavioral intentions. Furthermore, a cross-modal correspondence was identified between visual stimuli and tactile perception. Separately, Fenko et al. [30] investigated the dominance of visual and tactile sensory modalities in relation to warmth and pleasantness with color, determin-

ing that color and materials contribute equally to the warmth experience of scarves and breakfast trays.

1.2. The Present Study

Previous research on the visual and tactile emotional experiences elicited by materials has revealed a correlation between the physical properties of material surfaces and emotional perception. However, few studies have utilized validated emotional theoretical models to explore material-related emotional experiences or to establish the relationships between the physical properties of material surfaces and emotional experiences. In addition, previous research has primarily focused on younger individuals, with much less attention given to older adults. To address this gap, the present experiment utilizes the PAD (pleasure, arousal, dominance) emotion model to investigate consumers’ visual and visual–tactile emotional experiences, with wardrobes as a case study. This study aims to explore the relationships between emotional responses and the physical properties of material surfaces. Furthermore, it examines whether differences exist in emotional experiences between elderly and younger individuals.

2. Materials and Methods

2.1. Materials and Measurement

Through field investigations at furniture factories, interviews with industry professionals, and online research on home furnishing brands, we analyzed and summarized the materials used in wardrobes. The 12 representative samples of wardrobe materials are illustrated in Table 1: M1 blister board, M2 density board, M3 Osson board, M4 multi-layer plywood, M5 solid wood multi-layer board (gray stone pattern), M6 solid wood ecological board, M7 OSB board, M8 solid wood, M9 solid wood particle board (oak grain), M10 solid wood particle board (chrome metal silver gray), M11 fireproof board (leather grain), and M12 fireproof board (cloth grain).

Table 1. Experimental sample materials.

M1 blister board PVC surface finish	M2 density board beechwood grain	M3 Osson board PVC surface finish	M4 multi-layer plywood UV paint
			

Table 1. Cont.

M5 multi-layer board gray stone pattern	M6 ecological board melamine surface finish	M7 OSB board melamine surface finish black wood grain	M8 solid wood white oak
			
M9 particle board melamine surface finish oak grain	M10 particle board melamine surface finish chrome metal silver gray	M11 fireproof board leather grain	M12 fireproof board cloth grain
			

2.1.1. Measurement of Surface Roughness

As shown in Figure 1, surface roughness was evaluated using the JB-4C type roughness measuring instrument (JB-4C, Tarmin Co., Ltd., Shanghai, China), employing a stylus-based contact measurement method. The measurement direction adhered to the GB/T1031-2009 [31] standard for surface roughness assessment and was conducted along the sample’s surface. The sampling length (lr) of 2.5 mm was established. The arithmetic mean deviation (Ra) was utilized as the criterion for roughness evaluation. Each sample underwent five measurements, with the average of these readings being adopted as the definitive result.

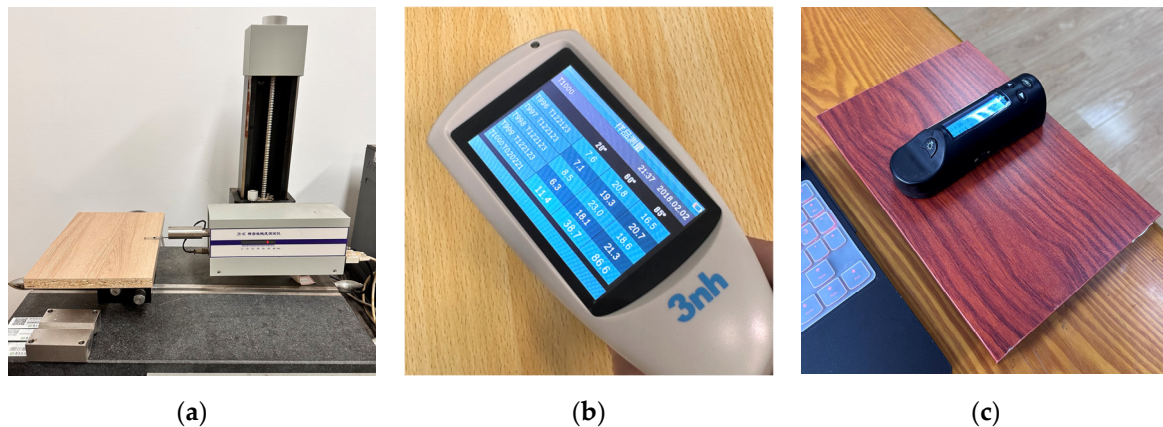


Figure 1. Measurement of physical properties of material surfaces: (a) Surface roughness; (b) Surface gloss; (c) Surface color.

2.1.2. Measurement of Surface Gloss

As shown in Figure 1, surface gloss was measured by a gloss meter (3NH-NHG 268, 3NH Intelligent Technology Co., Ltd., Guangdong, China) in a closed room with a cold light source (LED). The geometrical optical condition for the measurements was 60 degrees of specular reflection.

2.1.3. Measurement of Surface Color

The Lab color model consists of one luminance (L^*) and two color channels. L^* represents the luminance from 0 (pure black) to 100 (pure white), a^* represents the red and green color channels, and b^* represents the yellow and blue color channels [22]. The CIE $L^* a^* b^*$ color space is used to measure the color of the surface of a material [22,25–28]. As shown in Figure 1, an SEGT-J colorimeter measured the surface color Lab values of the specimens in a closed room.

2.2. Participants

The study participants included younger and elderly individuals from China. The elderly group comprised 30 participants aged 60 years and above ($M = 67.633$, $SD = 5.474$), with 15 females and 15 males. The younger group consisted of 30 participants aged 18 to 30 years ($M = 23.167$, $SD = 1.84$), who were undergraduate or graduate students from Nanjing Forestry University, including 15 females and 15 males. All participants were healthy and completed both tactile and visual–tactile experiments.

2.2.1. Self-Evaluation Experiment

This study used the PAD emotion model to investigate the participants' emotional responses to wardrobe materials. Developed by Russell and Mehrabian [32], the PAD emotion model comprises three dimensions: pleasure (P), arousal (A), and dominance (D). Each dimension consists of four pairs of opposing adjectives, with a total of 12 questionnaire items. To facilitate the participants' understanding of the PAD dimensions, the study used the Self-Assessment Manikin (SAM) visual graphic assessment scale, which visually represents the PAD emotion model of Russell and Mehrabian [33]. The SAM graphical scale describes each level of the PAD emotion dimension through images, simplifying the questionnaire and improving experimental efficiency. As shown in Figure 2, the SAM graphical questionnaire comprises three sets of 15 images, each corresponding to the three dimensions of pleasure, arousal, and dominance. Pleasure reflects the emotional spectrum ranging from pleasant to unpleasant. Arousal reflects the continuum from a relaxed state to heightened excitement. Dominance reflects the range of emotions from being externally

influenced and passively experiencing feelings to exercising self-control and actively generating emotional responses [34]. The experiment employed a 7-point questionnaire scale to assess the participants' emotional states in response to the experimental materials.

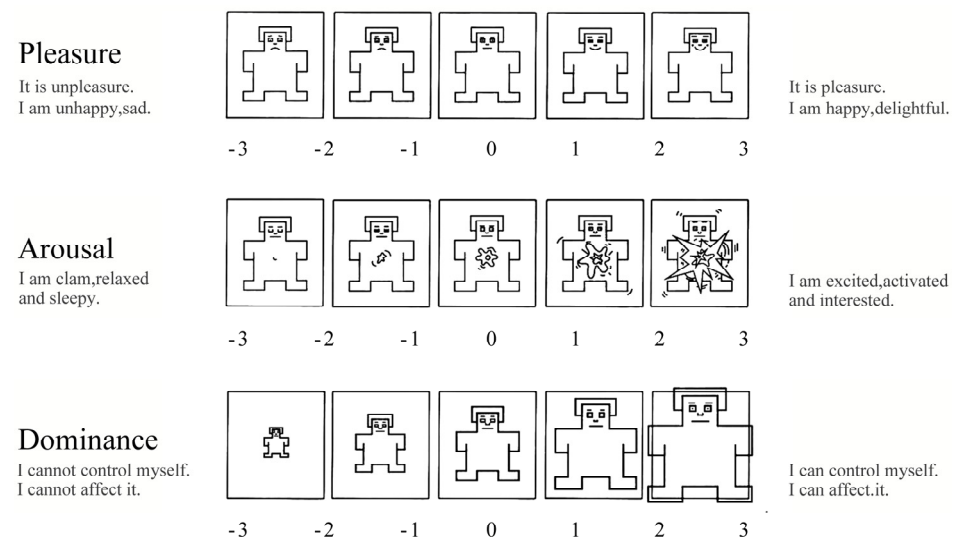


Figure 2. Self-Assessment Manikin (SAM) scale.

2.2.2. Procedure

Before the experiment, the experimenters provided the participants with a comprehensive explanation of the experimental procedure and the questionnaire instructions. The experimental stimulus materials were displayed on a table. The participants were seated comfortably in a chair to complete the subjective tactile and visual–tactile experiments in a quiet environment.

As shown in Figure 3, in the tactile experiment, the participants were instructed to wear blindfolds while using their dominant hands to touch 12 experimental samples. After touching the randomly presented materials, the participants provided verbal responses to rate their emotional feedback on a 7-point SAM scale, which the experimenters recorded.

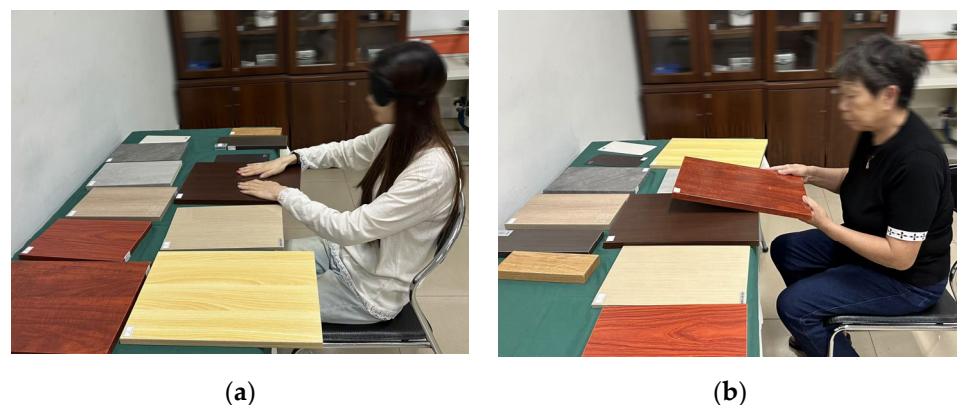


Figure 3. Self-assessment experiment: (a) Tactile experiment; (b) Visual–tactile experiment.

After completing the tactile experiment, the participants rested for five minutes before proceeding to the visual–tactile experiment. As shown in Figure 3, during the visual–tactile experiment, the participants evaluated 12 experimental samples by both their visual and tactile senses. They viewed and touched the materials, which were presented in a random order, and completed the 7-point SAM scale for emotional ratings. Each participant engaged in both the tactile and visual–tactile experiments for all 12 materials.

3. Results and Discussion

3.1. Measurement of Material Technical Parameters

Table 2 presents the technical parameters of the experimental material samples. Sample M9 (13.7404 μm) has the highest value of surface roughness, followed by M5 (12.9102 μm), M12 (10.8372 μm), M11 (7.7952 μm), M10 (5.4462 μm), M6 (5.0448 μm), M8 (4.8582 μm), M7 (3.0722 μm), M1 (1.5888 μm), M3 (0.7976 μm), M2 (0.5148 μm), and M4 (0.2296 μm).

Table 2. Surface technical parameters of experimental sample materials.

Sample Number	Physical Properties of Material Surfaces				
	Roughness (μm)	Gloss (60°) (GU)	Color		
			L*	a*	b*
M1	1.5888	15.5	25.9	12.2	12.0
M2	0.5148	38.7	74.3	14.6	38.0
M3	0.7976	37.6	31.8	29.5	22.3
M4	0.2296	136.6	59.4	11.2	13.6
M5	12.9102	4.6	52.8	1.6	3.0
M6	5.0448	16.3	36.3	35.2	24.8
M7	3.0722	6.1	33.7	4.1	7.1
M8	4.8582	11.8	58.8	17.4	32.4
M9	13.7404	5.2	63.4	7.8	15.6
M10	5.4462	7.8	68.1	3.4	4.2
M11	7.7952	3.1	32.5	2.7	4.5
M12	10.8372	8.9	80.4	4.3	8.7

In the glossiness test, M4 (136.6GU) has the highest value of glossiness, followed by M2 (38.7GU), M3 (37.6GU), M6 (16.3GU), M1 (15.5GU), M8 (11.8GU), M12 (8.9GU), M10 (7.8GU), M7 (6.1GU), M9 (5.2GU), M5 (4.6GU), and M11(3.1GU).

In the laboratory measurement of material colors, M12 has the highest luminance (L*) of 80.4, while M1 has the lowest at 25.9. Regarding the a* values, M6 has the highest a* value of 35.2, whereas M5 has the lowest value of 1.6. For the b* value, M2 has the highest b* value of 38.0, while M5 has the lowest value of 3.0.

3.2. Tactile Experimental Results and Analysis

This study utilized SPSS (IBM SPSS Statistics 27) for data analysis. The reliability of the subjective self-assessment data for the tactile PAD dimensions was assessed using Cronbach's alpha coefficients. For the elderly group, the Cronbach's alpha values were 0.832 for pleasure (P), 0.844 for arousal (A), and 0.846 for dominance (D). In the younger group, the corresponding values were 0.824 for pleasure (P), 0.824 for arousal (A), and 0.827 for dominance (D). The results showed strong internal consistency, meeting reliability standards and confirming the suitability of the data for further analysis. A descriptive statistical analysis was conducted to calculate the mean values of pleasure (P), arousal (A), and dominance (D) across the 12 samples, with corresponding bar charts plotted. Additionally, independent t-tests were conducted to compare the PAD emotional experiences of the 16 materials between the older and younger groups. The aim was to explore differences in tactile emotional experiences, as shown in Figure 4.

Tactile Pleasure: Both the elderly and younger groups showed the highest pleasure with M4. The elderly group reported the lowest tactile pleasure with M9, while the younger group indicated the lowest with M6. Significant differences in pleasure between the elderly and younger groups were observed for five materials: M1 ($t = 2.068$, $p = 0.016$), M5 ($t = 2.151$, $p = 0.036$), M9 ($t = 2.614$, $p = 0.011$), M11 ($t = 2.089$, $p = 0.042$), and M12 ($t = 2.085$, $p = 0.042$).

With these five materials, the younger group had higher mean pleasure ratings than the elderly group.

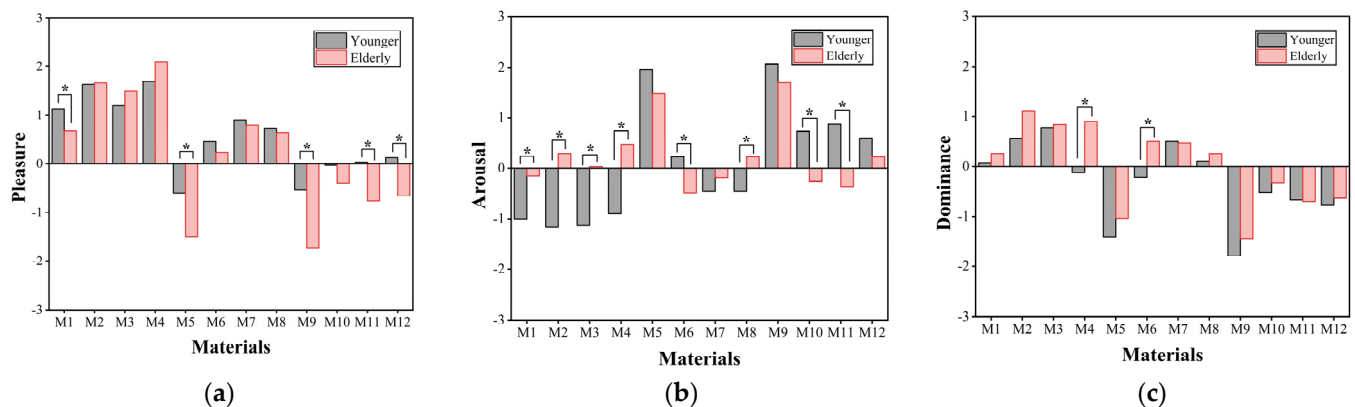


Figure 4. Means of tactile PAD assessment in elderly group vs. younger group; t-test significance is marked on bar; * $p < 0.05$. (a) Pleasure; (b) Arousal; (c) Dominance.

Tactile Arousal: The elderly group showed the highest arousal with M9, indicating that this tactile sensory stimulus was the most effective, eliciting emotions of excitement, vitality, and interest, along with the greatest variation in arousal levels. Conversely, the elderly group demonstrated the lowest arousal with M6, suggesting that a minimal tactile sensory stimulus induced feelings of calmness and relaxation, accompanied by the least fluctuation in arousal. The younger group showed the highest tactile arousal with M9 and the lowest tactile arousal with M2. Significant differences in arousal between the elderly and younger groups were observed for M1, M2, M3, M4, M6, M8, M10, and M11. Specifically, the elderly group demonstrated higher arousal than the younger group for M1 ($t = 2.481$, $p = 0.016$), M2 ($t = 3.847$, $p < 0.001$), M3 ($t = 3.166$, $p = 0.002$), M4 ($t = 3.166$, $p = 0.002$), and M8 ($t = 2.017$, $p = 0.048$). In contrast, the elderly group displayed lower arousal than the younger group for M6 ($t = 2.245$, $p = 0.029$), M10 ($t = 3.223$, $p = 0.002$), and M11 ($t = 3.442$, $p = 0.001$).

Tactile Dominance: Among the elderly group, the highest dominance value was observed for M2, indicating minimal influence from the material surfaces. Conversely, the lowest dominance value was recorded for M9, implying a pronounced impact from the material surfaces on the elderly group. The younger group showed the highest dominance with M3 and the lowest with M9. Significant differences in dominance between the elderly and younger participants were observed for M4 and M6. Specifically, the elderly group exhibited higher mean degrees of dominance compared to the younger group on both M4 ($t = 2.323$, $p = 0.024$) and M6 ($t = 2.073$, $p = 0.043$).

3.2.1. Correlation Analysis of Tactile Experiment

This study investigated the impact of material surface roughness and gloss on tactile PAD emotional responses through correlation analysis. As shown in Table 3, both elderly and young participants exhibited significant correlations between tactile pleasure, arousal, dominance, and surface roughness ($p < 0.05$). Specifically, tactile pleasure and dominance in both groups were significantly negatively correlated with surface roughness. In contrast, tactile pleasure showed a significantly positive correlation with surface gloss. However, neither arousal nor dominance in either group demonstrated a significant correlation with surface gloss.

Table 3. Correlation analysis of tactile experiment.

		Pleasure		Arousal		Dominance	
		Younger	Elderly	Younger	Elderly	Younger	Elderly
Roughness	Pearson's correlation	−0.937 *	−0.954 *	0.951 *	0.608 *	−0.914 *	−0.948 *
	Sig. (two-tailed)	<0.001	<0.001	<0.001	0.036	<0.001	<0.001
Glossiness	Pearson's correlation	0.657 *	0.678 *	−0.486	0.037	0.284	0.555
	Sig. (two-tailed)	0.02	0.015	0.109	0.910	0.371	0.061

* $p < 0.05$.

3.2.2. Regression Analysis of Tactile Experiment

This research further employed regression analysis to explore the responding relationship between the physical properties of material surfaces and tactile PAD emotional experiences, as shown in Figure 5. In regression analysis, the coefficient of determination, R-squared (R^2), measures the goodness of fit of the regression model, with values ranging from 0 to 1. An R^2 value closer to 1 indicates a superior fit and demonstrates a stronger explanatory power of the independent variable with respect to the dependent variable.

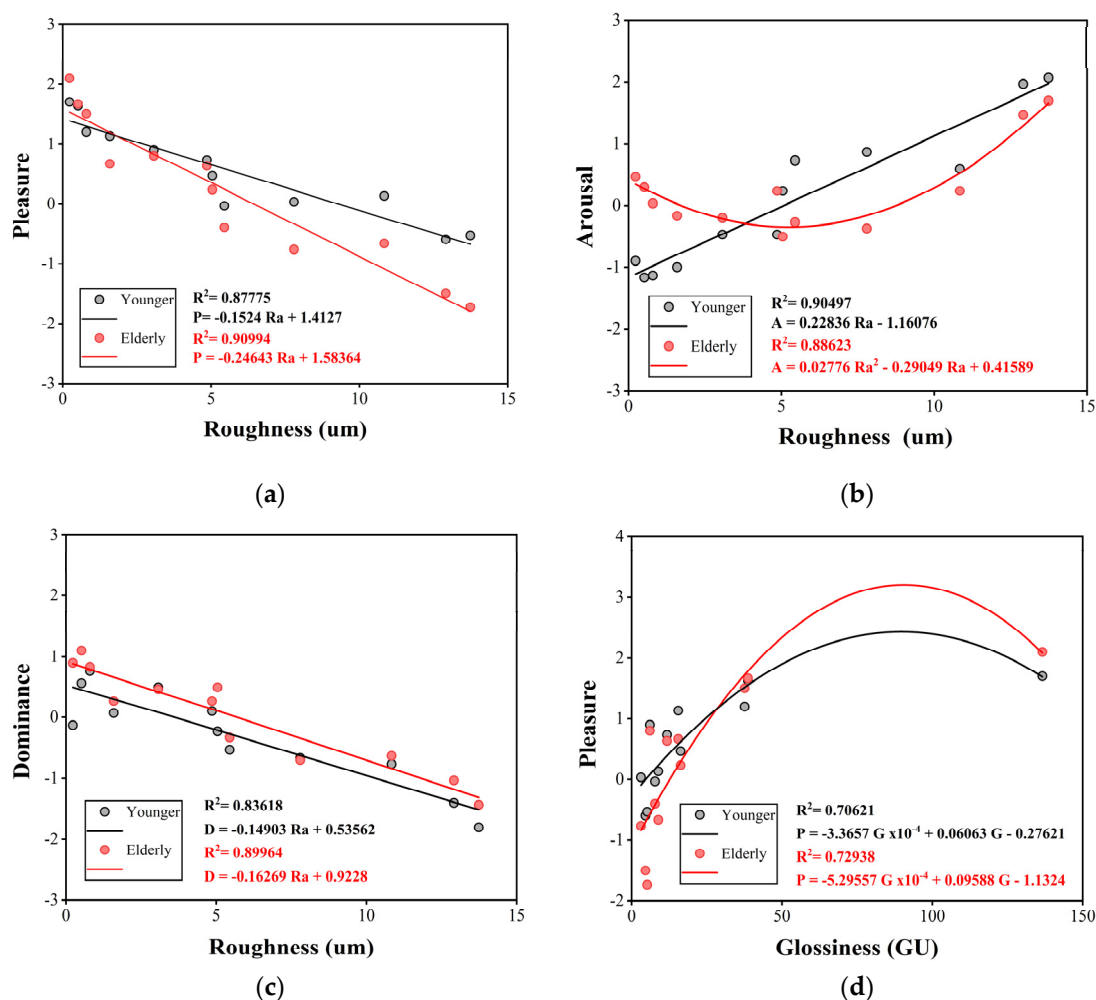


Figure 5. Tactile PAD emotion model fitted with regression analysis of material surface parameters of technology: (a) Pleasure–Roughness; (b) Arousal–Roughness; (c) Dominance–Roughness; (d) Pleasure–Glossiness. P is pleasure; A is arousal; D is dominance; Ra is roughness in μm ; G is gloss in GU.

Tactile Pleasure and Roughness: In the elderly group, regression analysis of the relationship between tactile pleasure and surface roughness produced an R^2 value of 0.90994 for Equation (1). Lower surface roughness was associated with greater tactile pleasure among the elderly participants. Specifically, tactile pleasure in the elderly group significantly decreased as surface roughness increased. For the younger group, regression analysis yielded an R^2 value of 0.87775 for Equation (2). Consistent with the findings in the elderly group, pleasure in the younger participants also declined with greater surface roughness. Previous research has revealed that rough surfaces are generally perceived as unpleasant [10,18,19], whereas smooth materials are regarded as pleasurable [18,19]. This experiment further verifies the negative correlation between roughness and tactile pleasure. Notably, the regression slope for the elderly group was steeper than that for the younger group, indicating that the older adults are more sensitive to variations in roughness. In contrast, younger individuals tend to decorate their wardrobes with a marginally rougher materials and exhibit greater tolerance for rough textures compared to the elderly group.

$$P = -0.24643 Ra + 1.58364 \quad (1)$$

$$P = -0.1524 Ra + 1.4127 \quad (2)$$

Tactile Arousal and Roughness: The relationship between tactile arousal and surface roughness in the elderly group was modeled using nonlinear regression, resulting in an R^2 value of 0.88623 for Equation (3). Among the elderly participants, tactile arousal initially decreased with increasing roughness, reaching a minimum at a roughness of 5.2322 μm . Beyond this threshold, arousal began to increase as roughness continued to rise. This U-shaped functional relationship indicates that the elderly still experience heightened states of arousal when exposed to excessively smooth materials. For the young group, a linear regression analysis was performed to model the relationship between tactile arousal and roughness, yielding an R^2 value of 0.90479 for Equation (4). Tactile arousal in younger people increased linearly with the rise in surface roughness. Tactile arousal can rapidly activate the user's neural state, inducing excitement. However, prolonged exposure to high levels of arousal may lead to fatigue. Therefore, in the design of age-friendly wardrobes, it is advisable to avoid materials that are excessively rough or smooth to help users maintain a more relaxed and comfortable state.

$$A = 0.02776 Ra^2 - 0.29049 Ra + 0.41589 \quad (3)$$

$$A = 0.22836 Ra - 1.16076 \quad (4)$$

Tactile Dominance and Roughness: The relationship between tactile dominance and surface roughness in the elderly group was modeled using linear regression, resulting in an R^2 value of 0.89964 for Equation (5). Tactile dominance among the elderly participants significantly decreased as surface roughness increased. For the young group, regression analysis of tactile dominance in relation to surface roughness produced an R^2 value of 0.83618 for Equation (6), indicating a similar decline in tactile dominance with increasing surface roughness. The regression analysis prediction model further demonstrated that, under the same surface roughness conditions, the elderly group exhibited higher tactile dominance than the younger group. This suggests that older adults may show more proactive emotional responses and greater control compared to their younger counterparts.

$$D = -0.16269 Ra + 0.9228 \quad (5)$$

$$D = -0.14903 Ra + 0.53562 \quad (6)$$

In the present study, glossiness exhibited a poor fit with tactile pleasure in both groups and showed no systematic associations with arousal and dominance. Possible explanations for this phenomenon include the following. On one hand, uneven gloss distribution in the materials may have caused data discontinuities. On the other hand, tactile perception is a multidimensional process, and roughness may be perceived as a more prominent dimension than glossiness when participants interact with the material surface. Research by Picard et al. [13] indicated that the primary dimensions of tactile perceptions in fabric materials are roughness and softness, which are linked to pleasure. Studies by Guest et al. and Drewing et al. further demonstrated that roughness, rather than glossiness, is the primary tactile sensory attribute of material [11,15]. Therefore, establishing systematic associations between gloss and individual emotional responses may require stricter control over experimental material parameters to facilitate more accurate research on gloss.

3.3. Visual–Tactile Experimental Results and Analysis

The reliability of the subjective self-assessment data for the visual–tactile PAD dimensions was assessed using Cronbach’s alpha coefficients. In the elderly group, the Cronbach’s alpha values were 0.849 for pleasure (P), 0.829 for arousal (A), and 0.832 for dominance (D). In the young group, the corresponding values were 0.829 for pleasure (P), 0.846 for arousal (A), and 0.827 for dominance (D). Additionally, we further examined the differences in material visual–tactile PAD emotional experiences between the elderly and young groups, as shown in Figure 6.

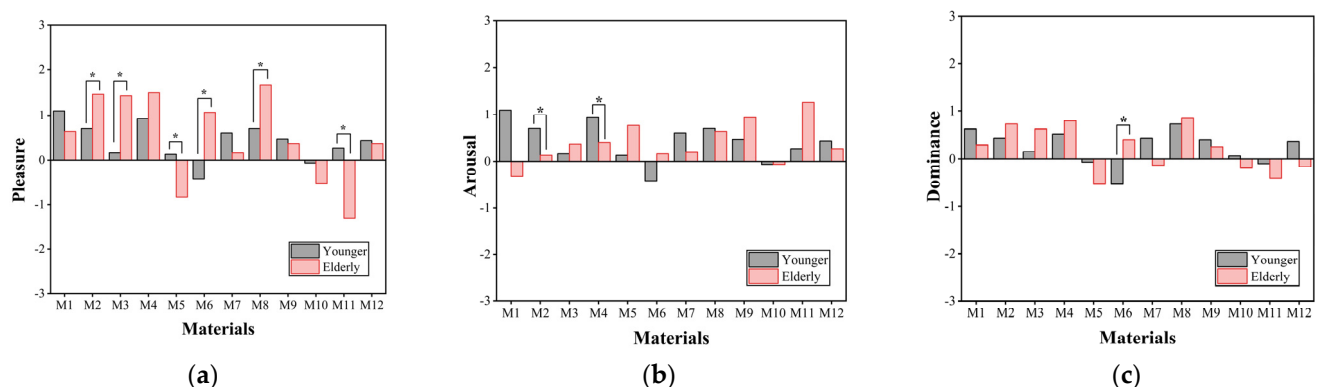


Figure 6. Means of visual–tactile PAD assessment in elderly group vs. younger group; t-test significance is marked on bar; * $p < 0.05$. (a) Pleasure; (b) Arousal; (c) Dominance.

Visual–Tactile Pleasure: The elderly group reported the highest visual–tactile pleasure with M8 and the lowest with M11. In contrast, the younger group identified M1 as the highest visual–tactile pleasure and M6 as the lowest. Significant differences in pleasure ratings between the elderly and younger groups were observed for M2 ($t = 2.501$, $p = 0.015$), M3 ($t = 3.140$, $p = 0.003$), M5 ($t = 2.052$, $p = 0.045$), M6 ($t = 3.892$, $p < 0.001$), M8 ($t = 2.926$, $p = 0.005$), and M11 ($t = 4.287$, $p < 0.001$). For M2, M3, M6, and M8, the elderly group exhibited higher mean pleasure ratings compared to the younger group, perceiving these four materials as pleasant by the elderly group. For M5 and M11, the younger group reported higher mean pleasure ratings than the older group, perceiving these two materials as pleasurable, while the elderly group perceived M5 and M11 as unpleasant.

Visual–Tactile Arousal: The elderly group reported the highest visual–tactile arousal with M11, while the younger group reported the highest arousal with M5. Both groups demonstrated the lowest arousal with M1. Significant differences in visual–tactile arousal ratings in both groups were observed for M2 ($t = 2.113$, $p = 0.037$) and M4 ($t = 2.121$,

$p = 0.038$). Although both groups perceived M2 and M4 as arousing, the younger group had higher mean arousal ratings than the elderly group.

Visual–Tactile Dominance: Both groups showed the highest visual–tactile dominance with M8. The elderly group demonstrated the lowest visual–tactile dominance with M5, while the younger group reported the lowest dominance with M6. Significant differences in dominance between the elderly and younger groups were observed for M6 ($t = 2.258$, $p = 0.028$). In this context, the younger group expressed feelings of being influenced and dominated, whereas the elderly group reported feelings of control and dominance. The elderly participants had a higher mean self-assessment of dominance with M6 compared to the young participants.

3.3.1. Correlation Analysis of Visual–Tactile Experiment

Table 4 presents the results of the correlation analysis between visual–tactile objective parameters and the PAD emotional experiences. A significant negative correlation ($p < 0.05$) was found between roughness and both pleasure and dominance in the elderly group. In contrast, a significant positive correlation ($p < 0.05$) was observed between roughness and arousal in the younger group. Neither group showed significant correlations between a^* , b^* , and arousal. No significant correlations were found between gloss, luminance (L^*), and the emotional dimensions.

Table 4. Correlation analysis of visual–tactile experiment.

		Pleasure		Arousal		Dominance	
		Younger	Elderly	Younger	Elderly	Younger	Elderly
Roughness	Pearson’s correlation	−0.342	−0.594 *	0.886 *	0.565	−0.272	−0.626 *
	Sig. (two-tailed)	0.277	0.042	<0.001	0.056	0.392	0.029
Glossiness	Pearson’s correlation	0.384	0.519	−0.542	−0.117	0.262	0.568
	Sig. (two-tailed)	0.217	0.084	0.069	0.718	0.412	0.054
L^*	Pearson’s correlation	0.059	0.117	0.024	0.01	0.252	0.075
	Sig. (two-tailed)	0.856	0.716	0.941	0.975	0.429	0.816
a^*	Pearson’s correlation	−0.299	0.690 *	−0.250	−0.247	0.662 *	−0.268
	Sig. (two-tailed)	0.345	0.013	0.434	0.439	0.019	0.4
b^*	Pearson’s correlation	0.131	0.818 *	−0.372	−0.144	0.221	0.841 *
	Sig. (two-tailed)	0.684	0.001	0.234	0.656	0.491	<0.001

* $p < 0.05$.

3.3.2. Regression Analysis of Visual–Tactile Experiment

Regression analysis was conducted to fit the relationship between visual–tactile PAD emotional experiences and material surface parameters, as shown in Figure 7. After incorporating the visual sense and considering color factors, a responsive relationship between visual–tactile arousal and surface roughness was still found in young individuals, with an R^2 value of 0.80837. However, the increasing trend of the curve was relatively slower compared to tactile arousal. The influence of roughness on individual pleasure is not limited to the tactile sensory modality; it may also have cross-modal effects.

The visual–tactile pleasure in both groups was related to a^* . For the elderly group, regression analysis of visual–tactile pleasure in relation to a^* yielded an R^2 value of 0.85099. Pleasure among the elderly group increased with rising a^* , but when the a^* value reached its maximum, the pleasure rating exhibited a rebound effect. In the young group, regression analysis of the relationship between visual–tactile pleasure and a^* yielded an R^2 value of 0.81643. Pleasure in the young group also increased with the a^* value in the initial stage but at a slower rate compared to the elderly group. The a^* value at which the elderly group reached peak pleasure was higher than that of the younger group. When the young group’s

pleasure reached its maximum, the elderly group continued to rise with increasing a^* value. Before the intersection point, the younger group exhibited a higher pleasure rating than the elderly group. After the intersection, the elderly group demonstrated greater pleasure compared to the younger group.

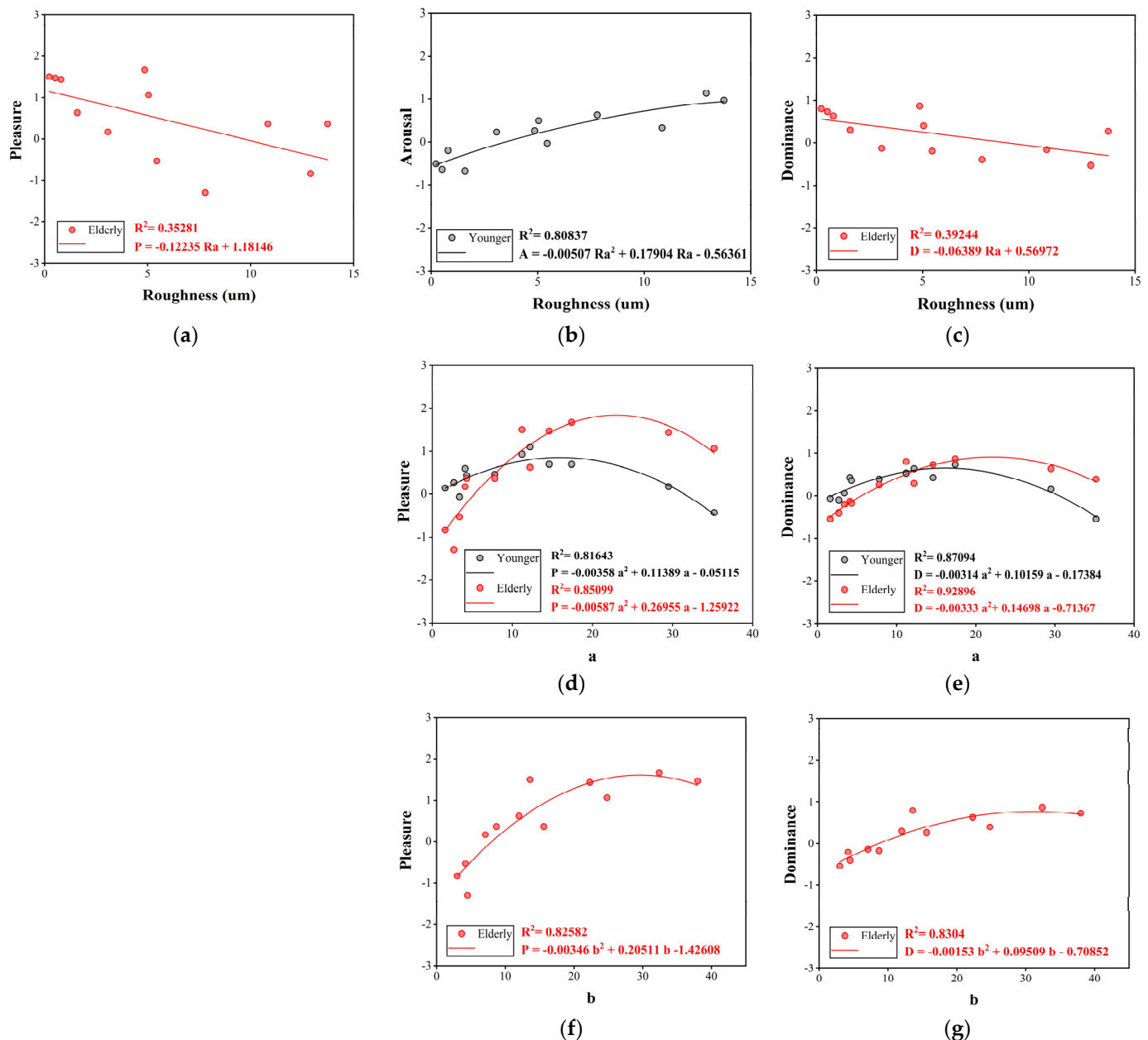


Figure 7. Visual–tactile PAD emotion model fitted with regression analysis of material surface parameters of technology: (a) Pleasure–Roughness (elder group); (b) Arousal–Roughness (younger group); (c) Dominance–Roughness (elder group); (d) Pleasure– a^* value (both the elder and younger groups); (e) Dominance– a^* value (both the elder and younger groups); (f) Pleasure– b^* value (elder group); (g) Dominance– b^* value (elder group). P is Pleasure; A is Arousal; D is Dominance; Ra is roughness in μm; G is gloss in GU; a is the color parameter a^* ; b is the color parameter b^* .

Both the elderly and younger groups showed nonlinear regression analyses of the relationship between visual–tactile dominance and the a^* value, yielding R^2 values of 0.92896 and 0.87094, respectively. According to the predictive model, dominance in both groups increased with the a^* value, reached a peak, and then gradually decreased. The elderly group exhibited a more pronounced increasing trend compared to the younger

group. The findings indicate that the elderly group demonstrated a greater acceptance and tolerance of red-colored wardrobe materials compared to the younger group.

In the elderly group, significant relationships were observed between visual–tactile pleasure, dominance, and the b^* value, yielding R^2 values of 0.82582 and 0.8304, respectively. Visual–tactile pleasure experienced by the elderly group increased rapidly with the b^* value, reaching a peak before stabilizing. Visual–tactile dominance in the elderly group ranged from -1 to 1 , gradually increasing alongside the b^* value. Therefore, in designing age-friendly wardrobe materials, appropriately enhancing the a^* and b^* values of color can effectively improve the pleasure of the elderly.

However, in this work, no correlation was found between luminance (L^*) and the PAD emotion dimensions. This may be attributed to the material surfaces presenting multiple stimulus elements in the dual visual–tactile modality, which diverted the participants' attention from concentrating on a single task. These findings further underscore the significance of the chromaticity parameters a^* and b^* in influencing individual emotional experiences.

4. Conclusions

In summary, this investigation used the PAD emotion model to reveal the association and variability between the physical properties of decorative wardrobe surfaces and age-related individual emotional experiences. The material parameter factors that were selected and their corresponding emotional dimensions are broadly applicable and universal.

The experimental results show that the PAD emotional responses in the elderly group are partially different from those of the younger one, though there are similarities in some dimensions. Regression analysis indicated that tactile pleasure decreased as roughness increased, with the decline being more pronounced in the elderly group (slope = -0.24643) compared to the younger group (slope = -0.1524). Tactile arousal increased linearly with roughness in the younger participants, whereas the elderly group displayed a U-shaped relationship. Notably, tactile arousal in the elderly group reached its minimum at a roughness of $5.2322\ \mu\text{m}$. In both groups, tactile dominance decreased with increasing roughness.

The visual–tactile experiment revealed that, in the elderly group, both pleasure and dominance were significantly correlated with the a^* and b^* values, whereas in the younger group, only the a^* value demonstrated an association. Additionally, visual–tactile arousal in the younger group exhibited a significant regression relationship with roughness. These results offer valuable insights for the intelligent and age-friendly design of wardrobe surface decorations, providing both theoretical and practical support for the emotional design of multimodal visual–tactile materials.

Research on the emotional experiences elicited by age-friendly materials spans multiple disciplines, including materials science, psychology, and statistics. Future research could introduce additional potential influencing variables to comprehensively understand the relationship between material properties and emotional preferences. Additionally, in the era of intelligence and population aging, future research could combine artificial intelligence technology with age-related material sensory experiences to dynamically explore emotional experiences across the full life cycle, thereby effectively addressing the emotional needs at different age life stages.

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