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Enhancement of Handshake Attraction through Tactile, Visual, and Auditory Multimodal Stimulation

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Abstract: "Handshaking parties", where pop idols shake hands with fans, can be exciting. The multimodal stimulation of tactile, visual, and auditory sensations can be captivating. In this study, we presented subjects with stimuli eliciting three sensory responses: tactile, visual, and auditory sensations. We found that the attraction scores of subjects increased because they felt the smoothness and obtained a human-like sensory experience grasping a grip handle covered with artificial skin, faux fur, and abrasive cloth with their dominant hand as they looked at a picture of a pop idol or listened to a song. When no pictures or songs were presented, a simple feeling of slight warmth was correlated with the attraction score. Results suggest that multimodal stimuli alter tactile sensations and the feelings evoked. This finding may be useful for designing materials that activate the human mind through tactile sensation and for developing humanoid robots and virtual reality systems.

Keywords: artificial hair; human hair; synthetic resin; morphology; friction

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1. Introduction

Shaking hands with the pop idol of your dreams—what a wonderful moment! Pop stars in Japan hold "handshaking parties", where they shake hands with fans who have purchased their music and talk with them briefly; fans form long lines, and hit songs of their idols are played while they wait. According to a mathematical model of the relationship between pop idols and their fans, handshaking parties are important for direct communication between them [1].

Handshakes can bring a variety of feelings. People who shake hands feel more familiar compared with those who just meet and exchange a few words [2]. Burgoon et al. measured the emotional responses of subjects to seven types of physical contact, including shaking hands, grabbing hands, and touching forearms, and found that trust, affection, and composure scores were the highest with handshakes [3]. Chaplin et al. found that a firm handshake is related positively to extraversion and emotional expressiveness and negatively to shyness and neuroticism [4]. Handshakes enhance feelings of satisfaction, extraversion, and affirmation and induce economic risk-taking [5–8].

We believe that tactile stimulation is one of the most important factors in emotional activation that is triggered by shaking hands with a pop idol. Shipps et al. reported that many subjects felt strong arousal during handshakes, and this feeling correlated positively with tactile sensations such as warmth and dryness [9]. Warmth evokes positive impressions: two groups of participants who evaluated the same person rated the person holding a hot coffee as kinder and more generous [10]. The Japanese word *nukumori* signifies "slight warmth" and is defined as "a beautified feeling of soft, faint warmth on contact with the skin" [11]. This tactile sensation is attractive to many Japanese people. Recently, we triggered this tactile sensation by having subjects touch fur or cowhide and found that it was related to softness and warmth [12]. The desirability of handshakes is related to the softness, smoothness, and warmth of the human skin [13].

The tactile sensation of the human skin is influenced by factors such as friction, wettability, elasticity, and surface topography. Egawa et al. evaluated the friction and tactile sensation of human forearms and found that the friction coefficient increased as the amount of water in the stratum corneum increased; in addition, these changes correlated highly with tactile sensations such as dryness, freshness, and moistness [14]. Researchers showed that the texture of the human skin is characterized by smoothness, moistness, and softness and that these tactile sensations are related to physical properties such as surface shape, friction, wettability, and elastic modulus [15]; they also showed that the tactile sensations of fur and wood are highly attractive because of their large surface roughness and low friction force [16].

As noted above, handshaking parties bring fans close to their idols, close enough to chat, with the artists' hit songs being played in the background. At these parties, the mind is activated not only by the tactile sensation but also by the visual and auditory stimuli. In particular, the perception of humanity correlates strongly with attraction. In random presentations of images of people, animals, and objects, attraction correlated with anthropomorphism: the attraction score was higher when the presented images were more human-like [17].

Separately, auditory stimulation activates the human mind, and attractive stimuli can also change people's physiological phenomena and behaviors. Garlin et al. studied the effects of background music (BGM) on human feelings and found that it gave people pleasure and that its tempo significantly aroused people's feelings [18], and subjects asked to choose between two images tended to gaze more toward the attractive image [19]. Slower BGM also slowed the pace of grocery shopping; shoppers stayed longer when the BGM was slow [20].

When incoming stimuli activate multiple senses, it is necessary to consider possible cross-modal effects in which one sense interferes with how the others receive the information. In general, cross-modal phenomena occur in near-body spaces because multisensory neuronal activity is strong in these areas [21]. Multisensory neurons encode the locations of sensory stimuli around the body to generate appropriate motor responses [22]; the strength of the neuronal activity is inversely proportional to the distance between the presenting stimulus and the body part and is stronger when the stimulus is near the body [23]. One of the most famous cross-modal effects of tactile and visual stimuli in the near-body space is the "rubber hand illusion" [24]: when your hand and a rubber hand are stimulated in sync in an environment where you cannot see your hand, you feel the rubber hand as if it were your own. Researchers have also reported cross-modal phenomena between tactile and auditory stimuli: when sound was played from speakers located either near or distant from a subject while the subject received electrical stimulation to a hand, the subject responded to the current more quickly when the sound came from the inner speaker [25].

A handshaking party induces strong feelings of attraction toward pop idols and grants pleasure through tactile stimuli. Other sensory information, such as visual and auditory senses, can also reinforce such psychological phenomena. We performed the following investigations to test this hypothesis: We evaluated the sensations and feelings of people meeting a pop idol at a handshaking party and clarified the multisensory effects of tactile, visual, and auditory stimuli and the relationship between feelings and behavior. For the experiment, we tested the subjects under four conditions: T: only a tactile stimulus was applied during the handshake; TV (tactile/visual): participants shook hands while viewing a picture; TA (tactile/auditory): participants shook hands while listening to a song; and TVA (tactile/visual/auditory): participants shook hands while looking at a picture and listening to a song (Figure 1). We chose songs as the auditory stimulus in this study because hit songs by pop idols were almost always played as background music, which influences the psychology of the people at handshaking parties. Figure 2 shows a device we used to evaluate the physical parameters, in particular grip force and grip time while grasping, to show the effects of applying tactile stimuli to the palm. We covered an instrumented grip handle with elastic artificial skin, soft faux fur, or uneven abrasive cloth. We then showed a picture of a pop idol and played music to confirm the multisensory effects. The findings of this study will enhance our comprehension of factors that influence tactile sensations and evoke strong feelings under multimodal conditions. The results will also aid the development of robotics and entertainment technologies to regulate feelings.

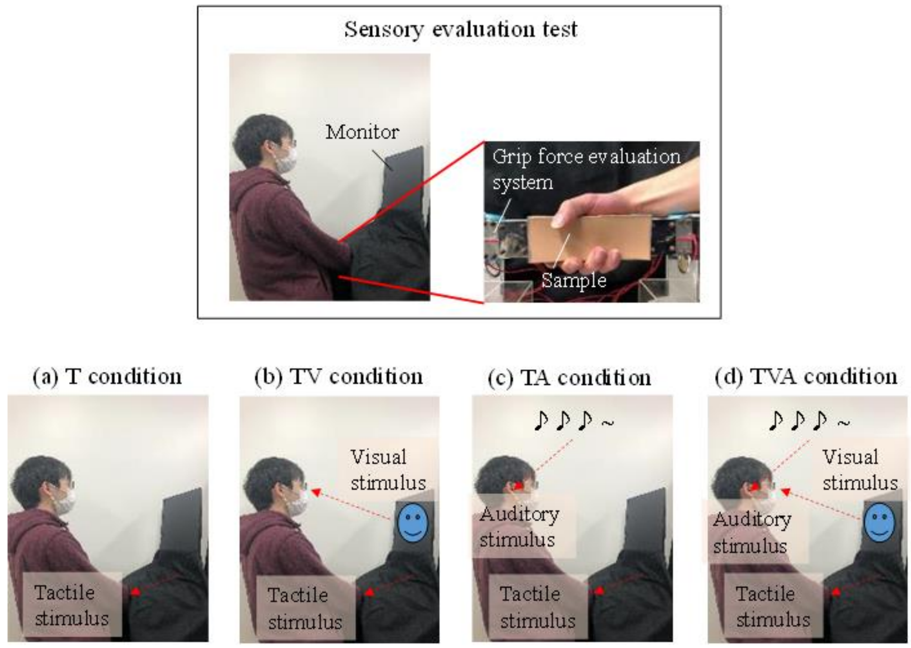

Figure 1. Evaluating sensations and feelings induced by handshaking under various conditions: (**a**) T—tactile stimulus; (**b**) TV—tactile/visual stimuli; (**c**) TA—tactile/auditory stimuli; and (**d**) TVA—tactile/visual/auditory stimuli.

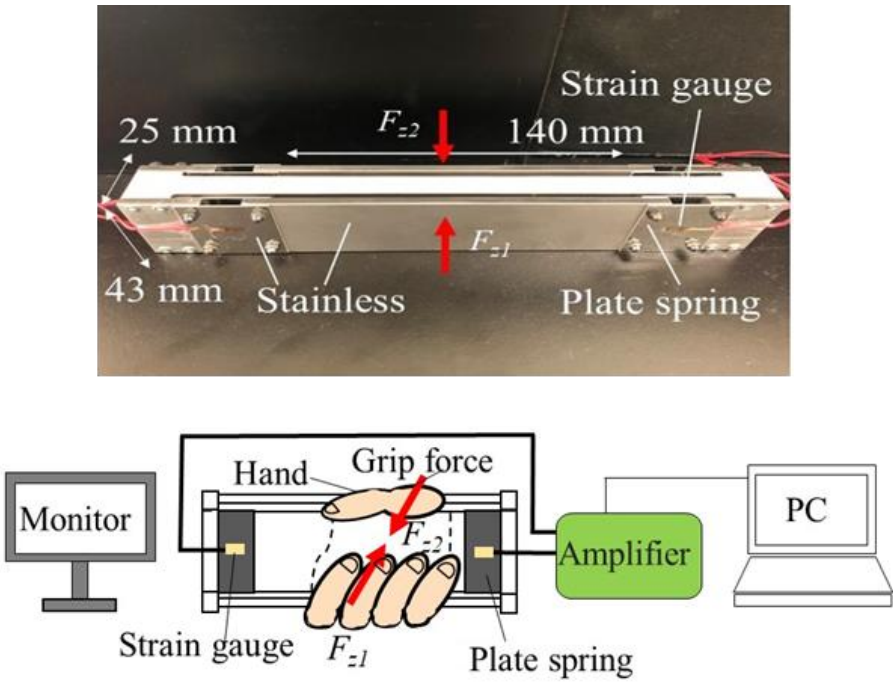

Figure 2. Grip force evaluation device. Overall view and a conceptual diagram.

2. Materials and Methods

2.1. Materials

To show the influence of tactile sensation on the attraction of a handshake, the surface of the grip handle was coated with three materials: artificial skin S (BIOSKIN PLATE #30, Burex Corporation, Saitama, Japan), faux fur F (faux fur, 100% polyester, Fujiku Co., 100%, Fujihisa Co., Ltd., Aichi, Japan), or abrasive cloth A (particle size 40, Noritake Coated Abrasive Co., Ltd., Aichi, Japan).

2.2. Grip Force Evaluation Device

We developed a device to measure the force in the process of shaking hands, as shown in Figure 2. In this apparatus, gripping forces (F_{z1} and F_{z2}) were measured using strain gauges (KFGS-5-120-C1-16L1M2R, Kyowa Dengyo Co., Ltd., Tokyo, Japan) attached to two plate springs (SUS304) installed at the top and bottom of the apparatus when the subject grasped the grip handle. These gauges were connected to a PC (VW2000, Keyence, Tokyo, Japan) via a data logger unit (NR-500 and NR-ST04, Keyence, Tokyo, Japan). The sampling rate was 2 m s^{-1}. To remove noise, the obtained grasp force data were processed by a low-pass filter with a cut-off frequency of 49 Hz (ORIGIN8.6, OriginLab Corp., Northampton, MA, USA).

2.3. Sensory Evaluation

We conducted the sensory evaluation with 15 men and 15 women in a quiet room at 25 ± 1 °C and 50 ± 5% humidity (see Figure 1 for the experimental setup). All subjects were students at Yamagata University and were 20–24 years old. For the TV, TA, and TVA conditions of the experiment, we showed participants a picture of Miku Kanamura (aged 18 years in 2020) of the idol group *HINATA-ZAKA 46* (Sony Music Solutions Inc., Tokyo, Japan) on the monitor and/or played the group's hit song "*KYUN*" (SRCL-11127, Sony Music Labels Inc., Tokyo, Japan). We selected *HINATA-ZAKA 46* because this group was most representative of Japan's pop idols in 2020. Many Japanese young people knew their songs and admired them. In addition, we chose Miku Kanamura, the most popular and renowned of the group's nine members. As of 2020, the girls have released four compact discs, each of which sold more than 400,000 copies in the week of its release. Their official YouTube channel has aggregated 131.4 million views of their videos.

Meanwhile, under the T condition, we presented neither pictures nor music. Under TV, respondents gripped the device while they looked at the picture, and under TA, they listened to the song at the same time. To eliminate the effect of the order, we randomized the order of the 12 different assessments using a random number table.

Before the experiments, subjects washed both hands with commercial hand soap and waited in the evaluation room for 20 min to acclimatize their fingertips. Subjects grasped the evaluation device, which was covered with artificial skin, faux fur, or abrasive cloth, with their dominant hand under T, TV, TA, or TVA conditions and answered six questions about sensation and feeling. Q1: "When you shook the hand, did you feel any kind of attraction?" Q2: "Why did you feel that way?" Q3: "When you shook the hand, did you feel the same as when you shake hands with a human?" Q4: "When you shook the hand, did you feel slight warmth (*nukumori*)?" Q5: "What kind of tactile sensation (warm, cold, soft, hard, dry, moist, slippery, sticky, rough, or smooth) did you feel when you shook the hand?" Q6: "Please write down everything else you felt when you shook the hand."

The sensation was evaluated based on the visual analog scale (VAS) method. The VAS method is an evaluation method in which a subject is marked on a horizontal straight line, indicating the degree of a certain sensation. Subjects were marked in the most appropriate place on a 10 cm line with "feel strong" or "not at all" written at the ends. The degree of sensation is quantified by the length between the mark and the end of "not at all".

The Ethical Review Committee of Yamagata University confirmed that the sensory evaluation was safe for the subjects and that the psychological stress was low and gave prior approval on 28 August 2020. All methods were carried out according to guidelines and regulations that were determined by the Ethical Review Committee. All experimental protocols were approved by the committee, and informed consent was obtained from all subjects. All subjects were aged between 20 and 24 years. In addition, because the manuscript contains images that may lead to the identification of study participants, informed consent was obtained for the publication of the images in an online open-access publication.

2.4. Physical Evaluation

We measured the surface roughness, Young's modulus, and the maximum initial heat flux (q-max), which is an index of how easily heat is lost when the material is touched, of artificial skin, faux fur, and abrasive cloth; we took all measurements three times at a room temperature of 25 ± 1 °C and a humidity of $50 \pm 5\%$. We took the thermal conductivity and surface energy values from the literature, substituting polyurethane, polyester, and Al_2O_3 for the physical properties of artificial skin, faux fur, and abrasive cloth, respectively [26–30]. The physical measurements of surface roughness (arithmetic mean roughness S_a, maximum height S_z), Young's modulus, and q-max were accomplished using a laser microscope LEXT OLS4000 (Olympus, Osaka, Japan), a YAWASA MSES-0512-1-SL (Tech Giken Co., Ltd., Kyoto, Japan), and a KES-F7 THERMOLAB (Kato Tech Co., Ltd., Kyoto, Japan), respectively.

2.5. Statistical Analysis

Most of the data obtained by this study on sensory and grip force evaluations did not evince normality in the Kolmogorov–Smirnov test. Therefore, multiple comparisons of the sensory data and the mechanical data (grip force F_z and grip time t) were performed using a nonparametric method called the Friedman test adjusted by the Bonferroni method. We also conducted Spearman's rank correlation analysis and the Friedman test to confirm the relationships between sensory data and other factors. The null hypothesis was rejected at $p < 0.05$. The SPSS 25.0 BASE SYSTEM (IBM, New York, NY, USA) was employed for the stated analyses.

3. Results

3.1. Sensory Evaluation

Table S1, which is included as supplementary information, and Figure 3 exhibit the attraction scores registered by the participants ($S^{attraction}$) under each condition as they held a grip covered with diverse types of surfaces. The figure shows that $S^{attraction}$ was the highest (mean ± standard deviation: 7.7 ± 1.5) under $\underline{S}^{TVA}$, where the subjects grasped the artificial skin while they looked at the idol's picture and listened to her music. In contrast, the lowest $S^{attraction}$ was observed in the $\underline{A}^{T}$ condition at 0.5 ± 0.7 when the subjects grasped the abrasive cloth without looking at the picture or listening to the music. In TV, TA, and TVA, $S^{attraction}$ was the highest for artificial skin and the lowest for abrasive cloth; in contrast, in T, $S^{attraction}$ was the highest for faux fur and the lowest for abrasive cloth. These results show significant differences in attraction scores under all conditions between grasping the artificial skin, the faux fur, and the abrasive cloth. Table S2 shows p values for all statistics, for instance, showing $p < 0.001$ for the differences in $S^{attraction}$ between $\underline{S}^{TVA}$ who grasped the artificial skin and $\underline{A}^{TVA}$ who grasped the abrasive cloth and between $\underline{F}^{TVA}$ who grasped the faux fur and $\underline{A}^{TVA}$ who grasped the abrasive cloth. We also found significant differences in $S^{attraction}$ for artificial skin $\underline{S}^{TVA}$ and faux fur $\underline{F}^{T}$ and $\underline{F}^{TA}$ ($p < 0.001$ and $p = 0.002$). Complementing the above results, we also found significant differences in attraction scores depending on the stimulus even when the subject grasped the evaluation device coated with the same material, for example, between $\underline{S}^{TVA}$ and $\underline{S}^{T}$ ($p < 0.001$).

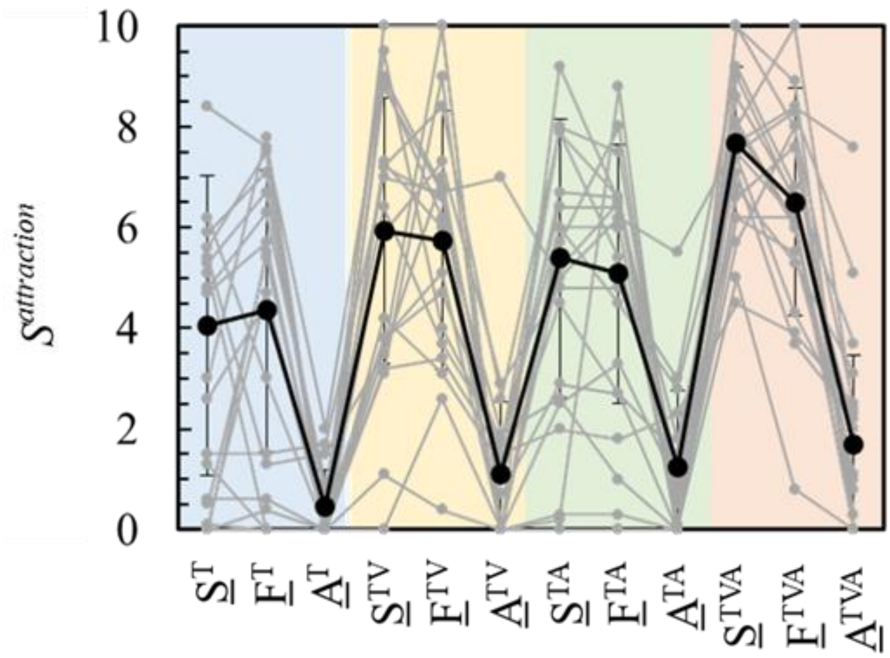

Figure 3. Attraction scores $S^{attraction}$. Materials: S—artificial skin; F—faux fur; and A—abrasive cloth. Conditions: T—blue; TV—yellow; TA—green; and TVA—pink. Small and large circles represent, respectively, the scores for all subjects and their arithmetic means.

We analyzed the tactile responses of the subjects to the artificial skin, faux fur, and abrasive cloth under each condition based on the five psychophysical dimensions proposed by Okamoto et al.: rough–smooth, hard–soft, cold–warm, moist–dry, and sticky–slippery [31]. Figure 4 and Table S1 show the tactile dimension scores for artificial skin, faux fur, and abrasive cloth under T, TV, TA, and TVA conditions, respectively. We set 6.0 as the sensory evaluation score for salient characteristics and found the following for each material: The characteristic dimensions were soft, smooth, moist, and sticky for the artificial skin; soft and warm for faux fur; and hard, rough, and dry for the abrasive cloth, independent of the combination of sensory stimuli.

3.2. Grip Force

Figure 5 shows a typical temporal grip force profile according to the following physical parameters:

Maximum grip force (F_z^{max}): maximum force generated during gripping (sum of F_{z1} + F_{z2} in Figure 2).

Average grip force (F_z^{ave}): average grip force from the beginning of the gripping until the force becomes zero (the average of F_{z1} and F_{z2} in Figure 2).

Grip time (t): time from the start to the end of gripping. The measurement begins at the temporal base moment, t = 0.

The grip force F_z increased from 5 s when the grasping began to a F_z^{max} value of 4 N at 7 s, while F_z^{ave} and t were 1 N and 3.2 s, respectively. We also observed interesting trends in the mechanical parameters (Table 1): F_z^{max} was 16 ± 15 N and 15 ± 11 N for the artificial skin under TA and TVA, respectively, and it was 12 ± 7 N and 12 ± 8 N for faux fur and abrasive cloth under TVA, respectively. Similarly, F_z^{max} was the highest for artificial skin and the lowest for faux fur under all conditions.

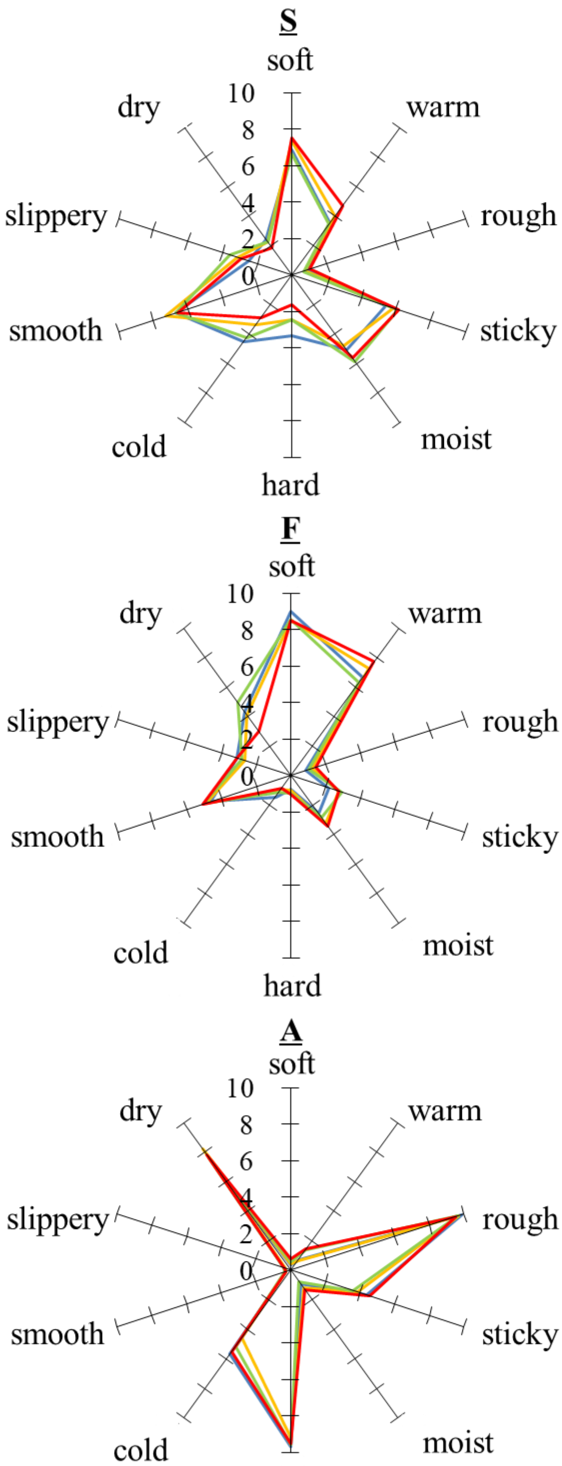

Figure 4. Scores of tactile dimensions for the different materials. Artificial skin (S), faux fur (F), and abrasive cloth (A). Patterns: T condition (blue), TV condition (yellow), TA condition (green), and TVA condition (red).

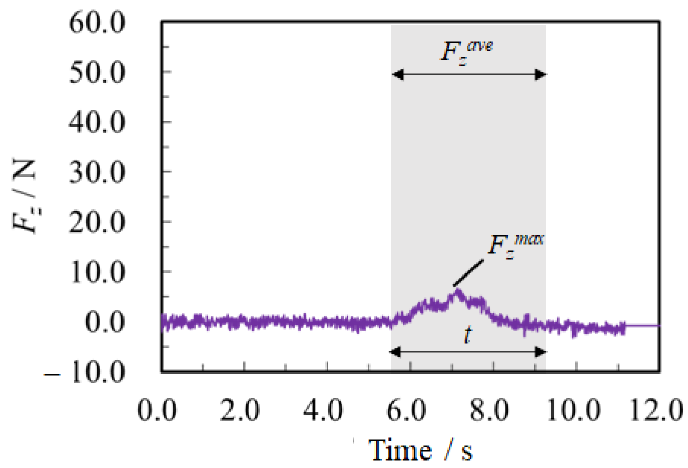

Figure 5. Typical temporal profile of grip force. $F_z{}^{max}$, $F_z{}^{ave}$, and t represent maximum grip force, average grip force, and grip duration, respectively.

3.3. Physical Evaluation

Table 1 provides the physical properties of each material: surface roughness S_a and S_z, Young's modulus, q-max, thermal conductivity, and surface energy. The artificial skin had the smallest S_a and the largest q-max. Faux fur had the largest surface roughness and the smallest Young's modulus and q-max. The abrasive cloth had the largest Young's modulus.

3.4. Dominant Factors of Attraction in Handshaking with Pop Idols under TVA Condition

Under TVA, subjects shook hands while looking at a picture and listening to music. The humanity score had the strongest correlation with the attraction score. Figure 6 shows the relationship between $S^{attraction}$ and $S^{humanity}$: $S^{attraction}$ increased with the surge in $S^{humanity}$. The Spearman's rank correlation coefficient R was 0.87. This association was found to be significant in the uncorrelated test (Table S3, $p < 0.001$). Figure 6 shows the distributions of the data for the three materials and indicates a significant role of humanity in attraction: the artificial skin had the highest $S^{attraction}$, 4.5–10.0, and $S^{humanity}$, 1.8–10, while the abrasive cloth had the lowest at $S^{attraction}$ = 0–7.5 and $S^{humanity}$ = 0–7.9. In contrast, both $S^{attraction}$ and $S^{humanity}$ for faux fur were widely distributed in the range of 0–10.

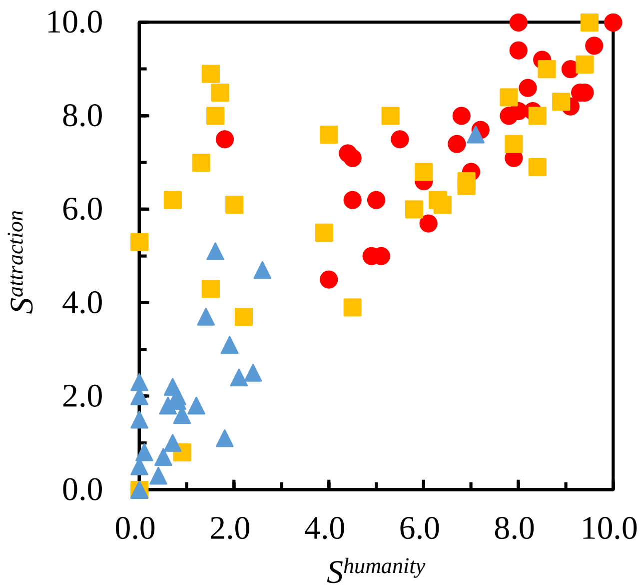

Figure 6. Correlations between humanity and attraction scores under TVA. Material representation: artificial skin (●), faux fur (■), and abrasive cloth (▲).

Table 1. Mechanical properties of grip and physical properties of the materials.

Sample	F_z^{max}/N	F_z^{ave}/N	t/s	S_a/µm	S_z/µm	Young's Modulus/kPa	Thermal Conductivity/ W mK^{-1}	q-max/W cm^{-2}	Surface Tension /mN m^{-1}
$\underline{S}^{T}$	14 ± 11	3 ± 3	3.8 ± 1.8	13.51 ± 0.94	221.92 ± 26.40	228.5 ± 81.6	0.16~0.17	0.229 ± 0.004	36.3~39
$\underline{F}^{T}$	10 ± 6	3 ± 2	3.4 ± 2.1	203.47 ± 32.96	2419.42 ± 461.83	2.5 ± 0.5	0.08~0.17	0.034 ± 0.001	44.6
$\underline{A}^{T}$	10 ± 8	2 ± 2	3.4 ± 1.8	83.10 ± 16.54	936.87 ± 70.83	7603.2 ± 554.3	36.0	0.135 ± 0.004	606
$\underline{S}^{TV}$	14 ± 11	3 ± 3	4.3 ± 2.5	13.51 ± 0.94	221.92 ± 26.40	228.5 ± 81.6	0.16~0.17	0.229 ± 0.004	36.3~39
$\underline{F}^{TV}$	10 ± 6	2 ± 2	3.8 ± 2.3	203.47 ± 32.96	2419.42 ± 461.83	2.5 ± 0.5	0.08~0.17	0.034 ± 0.001	44.6
$\underline{A}^{TV}$	10 ± 7	2 ± 2	3.7 ± 2.5	83.10 ± 16.54	936.87 ± 70.83	7603.2 ± 554.3	36.0	0.135 ± 0.004	606
$\underline{S}^{TA}$	16 ± 15	3 ± 3	4.8 ± 3.0	13.51 ± 0.94	221.92 ± 26.40	228.5 ± 81.6	0.16~0.17	0.229 ± 0.004	36.3~39
$\underline{F}^{TA}$	11 ± 7	2 ± 2	4.0 ± 2.3	203.47 ± 32.96	2419.42 ± 461.83	2.5 ± 0.5	0.08~0.17	0.034 ± 0.001	44.6
$\underline{A}^{TA}$	12 ± 11	2 ± 2	3.5 ± 1.9	83.10 ± 16.54	936.87 ± 70.83	7603.2 ± 554.3	36.0	0.135 ± 0.004	606
$\underline{S}^{TVA}$	15 ± 11	3 ± 3	4.9 ± 2.8	13.51 ± 0.94	221.92 ± 26.40	228.5 ± 81.6	0.16~0.17	0.229 ± 0.004	36.3~39
$\underline{F}^{TVA}$	12 ± 7	2 ± 2	3.9 ± 2.3	203.47 ± 32.96	2419.42 ± 461.83	2.5 ± 0.5	0.08~0.17	0.034 ± 0.001	44.6
$\underline{A}^{TVA}$	12 ± 8	2 ± 2	3.3 ± 2.5	83.10 ± 16.54	936.87 ± 70.83	7603.2 ± 554.3	36.0	0.135 ± 0.004	606

F_z^{ave} was 3 ± 3 N for $\underline{S}^{TVA}$ and 2 ± 2 N for both faux fur and abrasive cloth under TVA. F_z^{ave} was the highest with the artificial skin and the lowest with faux fur and the abrasive cloth under T, TV, and TA. The grip time t was 4.9 ± 2.8 s for $\underline{S}^{TVA}$ and 3.9 ± 2.3 s and 3.3 ± 2.5 s, respectively, for faux fur and abrasive cloth under TVA. The longest t was with the artificial skin, and the shortest one was with the abrasive cloth under T, TV, and TA conditions.

Table S3 presents findings for exactly which tactile sensations reminded the subjects of their humanity: $S^{humanity}$ correlated with smoothness, slipperiness, roughness, softness, dryness, and warmness under TVA, with R = 0.69, 0.62, 0.60, 0.57, −0.49, and 0.49, respectively. Figure 7 shows that $S^{humanity}$ was the highest when smoothness was also the highest. The rank correlation coefficient R was 0.69, and the relationship was found to be significant (p < 0.001). The distributions shown in Figure 7 indicate a relationship between smoothness and humanity scores. The artificial skin had the highest $S^{humanity}$ and S^{smooth} = 2–10, whereas the abrasive cloth had the lowest S^{smooth}, 0.0–2.4. S^{smooth} for faux fur was widely distributed in the range of 0–10.

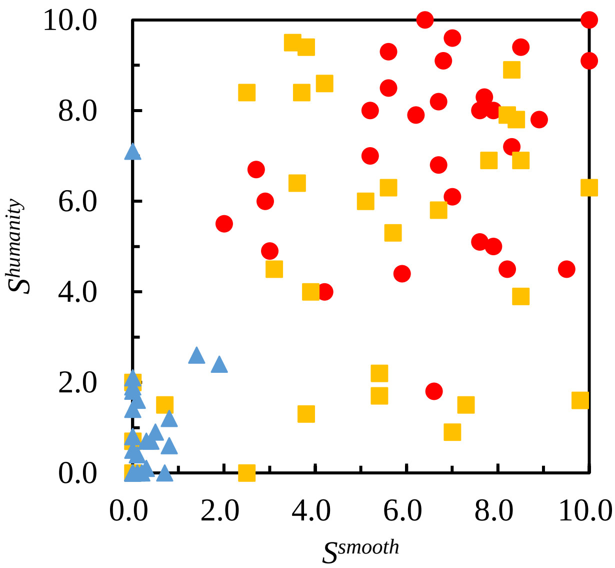

Figure 7. Correlations between humanity score and smooth feeling under TVA. Material representation: artificial skin (●), faux fur (■), and abrasive cloth (▲).

3.5. Dominant Tactile Factors of Attraction in Handshaking under the T Condition

Under T, in which subjects shook hands without being presented with a picture or music, the attraction had the strongest correlation with slight warmth (*nukumori*); Figure 8 shows a higher $S^{attraction}$ with a higher $S^{slight\ warm}$. The rank correlation coefficient was significant, with R calculated at 0.79 (Table S3, p < 0.001). The scores for faux fur, which had the highest attraction, and artificial skin (second highest) were both widely distributed: faux fur [$S^{attraction}$ = 0.0–8.2 and $S^{slight\ warm}$ = 0.0–8.1] and artificial skin [$S^{attraction}$ = 0.0–9.5 and $S^{slight\ warm}$ = 0.0–7.9]. The abrasive cloth had the lowest scores: $S^{attraction}$ = 0.0–2.1 and $S^{slight\ warm}$ = 0.0–2.0.

Table S3 shows the tactile sensations that triggered a slight warmth (*nukumori*) in the subjects. Slight warmth (*nukumori*) correlated with warmth, softness, roughness, slipperiness, and moistness under T, with R = 0.62, 0.55, −0.53, 0.48, and 0.45, respectively. Figure 9 demonstrates that $S^{slight\ warm}$ intensifies with higher warmth or softness scores. This correlation is consistent with previous findings of the involvement of warmth and softness in eliciting the sense of slight warmth (*nukumori*) [12]. In Figure 9, faux fur with the highest $S^{slight\ warm}$ had S^{warm} = 1.0–10 and S^{soft} = 5.4–10, while the abrasive cloth with the lowest $S^{slight\ warm}$ had S^{warm} = 0.0–5.2 and S^{soft} = 0.0–1.5. The artificial skin was widely distributed, with S^{warm} = 0.0–7.8 and S^{soft} = 0.0–10.0.

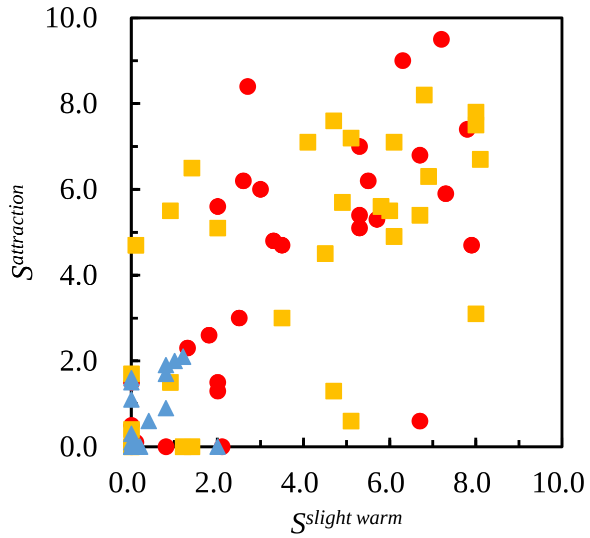

Figure 8. Relationship between scores of attraction and slight warmth. Material representation: artificial skin (●), faux fur (■), and abrasive cloth (▲).

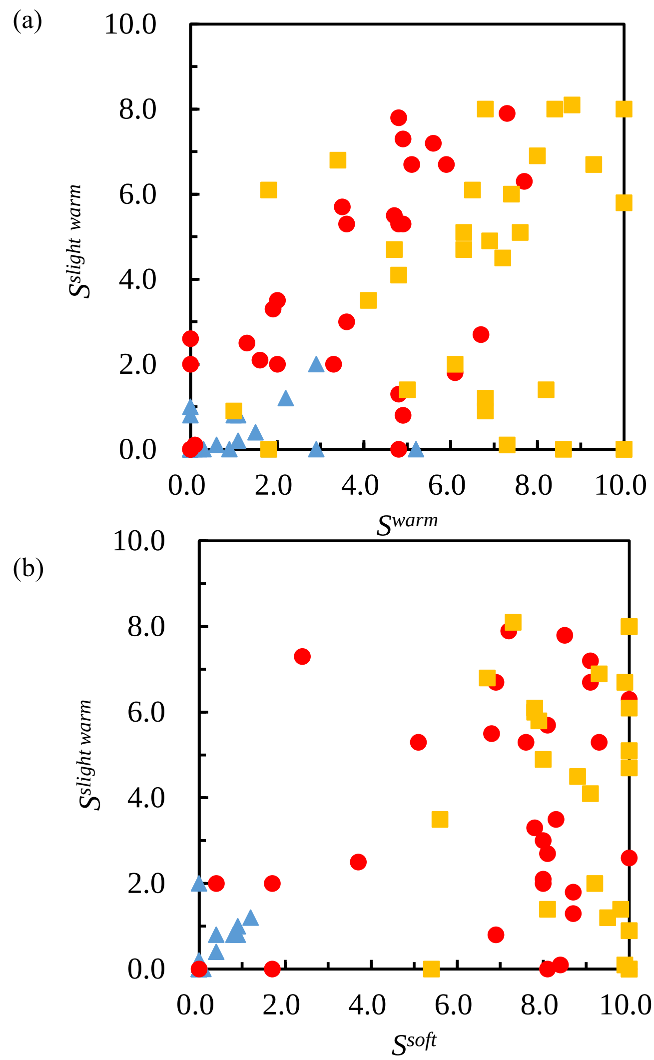

Figure 9. Relationship between scores of slight warmth and other tactile feels: (**a**) warmth and (**b**) softness. Material representation: artificial skin (●), faux fur (■), and abrasive cloth (▲).

3.6. Handshake Attraction and Behavior

We also attempted to determine how the attraction generated by a handshake affected human behavior, but we found no significant differences in $F_z{}^{max}$, $F_z{}^{ave}$, and t by material type or stimulus (Table 1). We categorized all 360 attraction scores into three groups in descending order: 1–120 (upper), 121–240 (middle), and 241–360 (lower) and compared the relationships among all the mechanical data and attraction. Figure 10 shows a relationship between attraction and grasp duration, with durations for the upper, middle, and lower groups being 4.3 ± 2.7 s, 4.1 ± 2.6 s, and 3.2 ± 1.5 s, respectively. We found p values of <0.05 between the upper and lower groups when the Friedman test adjusted by the Bonferroni method was applied: p values were 0.467, 0.014, and 0.467 between the lower-middle, lower-upper, and middle-upper groups, respectively.

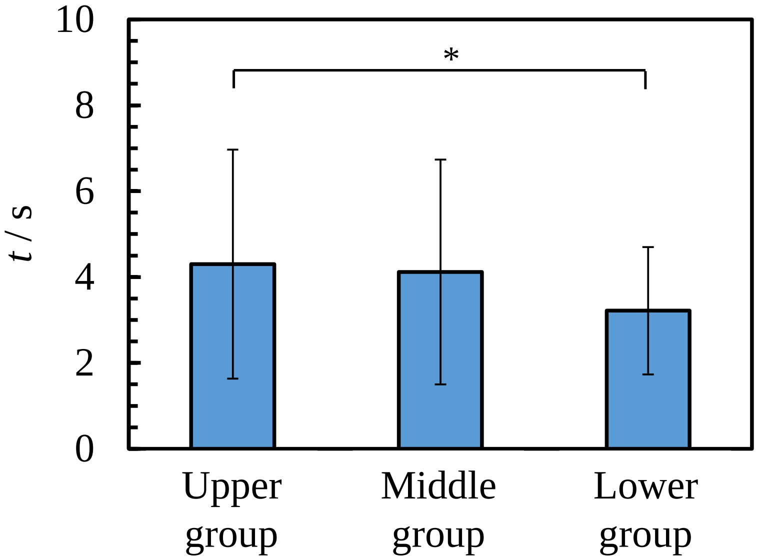

Figure 10. Grip duration values. All 360 attraction scores were categorized into three groups in descending order: Upper group, 1–120; middle, 121–240; and bottom, 241–360. *: $p < 0.05$.

The trend of a longer grip time with higher $S^{attraction}$ aligns with previous studies: humans want to perceive more attractive objects for longer periods. Langlois et al. showed color slides of adult female faces to infants to examine how the infants responded, and they looked longer at attractive faces [32]. Aharon et al. also found that subjects spent more time looking at attractive faces than unattractive ones [33]. However, researchers have conversely found that people find others more attractive when they spend more time looking at them. Shimojo et al. showed subjects two choices of facial images and had them choose the more attractive image; many subjects judged that the image of faces they had seen for a long time was more attractive [19].

3.7. Factors Influencing Tactile Feel

Sensory evaluations revealed that the sense of attraction apropos handshakes was most strongly correlated with smoothness through humanity under the TV, TA, and TVA conditions and was associated with warmth or softness through slight warmth (*nukumori*) under the T conditions. We performed a Friedman test to ascertain the factors determining these three tactile sensations. The null hypothesis of no difference in smoothness for artificial skin, faux fur, or abrasive cloth was rejected, indicating that the material influences the tactile sensation (Table S4, $p < 0.001$). The influence of material was confirmed for warmth and softness ($p < 0.001$).

4. Discussion

4.1. Handshakes and Attraction

Based on multiple comparison tests and Spearman's rank correlation analysis, we showed the relationship between attraction, perception, and physical parameters under the TVA condition, in which subjects looked at a picture and shook hands while hearing a song (Figure 11). The diagram shows higher scores for attraction and humanity if the subjects grasp the device covered in smooth material. This is held under TV and TA (Figure S1). The handshake attraction score depends on the perception of humanity under multisensory stimulation.

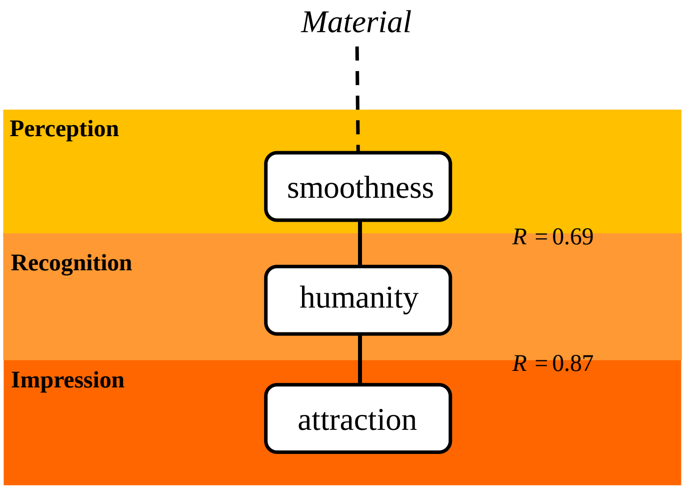

Figure 11. Relationships among attraction, humanity, and tactile factors under TVA conditions. Numeric values are the rank correlation coefficient R between two factors. The dashed line indicates that certain effects are confirmed by the Friedman test.

Many researchers have established connections between attraction and perceptions of humanity. Nowak et al. found that subjects rated presented images as more attractive when they resembled humans more because anthropomorphism correlated with attraction [17]. Westerman et al. had participants evaluate the attraction of 15 icons, and subjects gave higher attraction scores for pictures of a person, avatars, and images that resembled a person [34]. Separately, Green et al. found that people gave higher humanity and attraction scores to shorter faces with narrow chins [35].

In contrast, we found a completely different diagram of attraction through stimulation that was only tactile. Figure 12 displays a diagram for handshake attraction under T in which the sensing of slight warmth (*nukumori*) was high if the subjects held warm or soft material. The rank correlation yielded constant R values explaining attraction in terms of softness or warmth at 0.56 and 0.52, respectively, while R for slight warmth was computed at 0.80 (Table S3). This result suggests that the sensing of warmth does not necessarily enhance attraction and that "slight warmth (*nukumori*)" is desirable.

4.2. The Physical Origin of Humanity

Figure 7 shows that $S^{humanity}$ increased with higher S^{smooth}, particularly with the artificial skin with characteristic smoothness, and previous researchers also identified smoothness as a characteristic of humanity. Shirado et al. and Guest et al. evaluated the tactile feel of various human and artificial skins and showed that smooth feel is one of the important factors for the human skin-like texture [13,15].

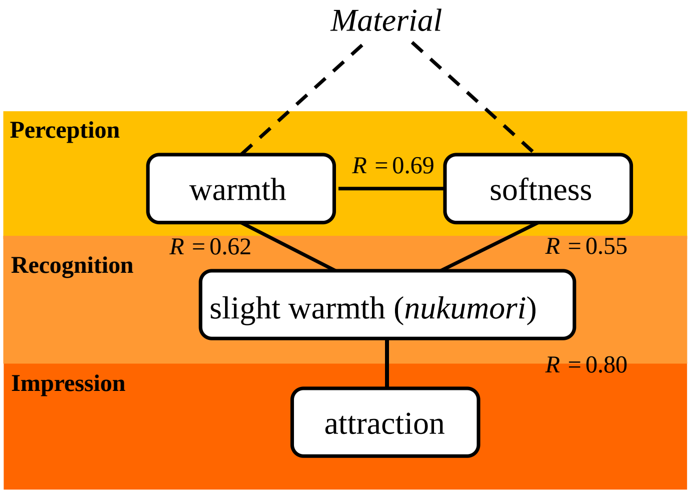

Figure 12. Relationships among attraction, humanity, and tactile factors under T conditions. Numeric values are the rank correlation coefficient R between two factors. The dashed line indicates that certain effects are confirmed by the Friedman test.

What physical stimuli evoke smoothness? One dominant factor in this sensation is static versus dynamic movement. The smooth feeling is affected by the pressure distribution caused by the deformation of the skin and the surface roughness in the static motion when the subject presses an object vertically with a finger [36–39]. In contrast, the feeling is affected by the skin vibration caused by the surface roughness and the friction in the dynamic motion when the subject strokes an object horizontally. Surface roughness is related to both static and dynamic motion. As shown in Figure 7, the artificial skin with the smallest S_a, 14 µm, had a high S^{smooth} value, while the abrasive cloth with a S_a value of 83 µm had a low score. In another study, Blake et al. showed that when a dot on the surface of the material was lower, the sensation was smoother [40], and Chapman et al. showed that smoothness was perceived regardless of the dot height when the distance between the dots was short [41]. Kikegawa et al. also found increasing smoothness of solid materials with decreasing surface roughness [42].

Researchers have also reported on the frictional properties of smoothness. Kawasegi et al. studied materials with a rough surface and found that participants perceived smoothness when the change in the friction force was small [43]. Shimizu et al. evaluated the tactile feel of the human skin after a skin-care cream was applied and found that the smoothness was evoked by a lower friction coefficient [44].

4.3. Effects of Multimodal Stimulation on Handshake Attraction

The relationship between attraction, perception, and physical parameters differed under the different conditions: The attraction score was related to the humanity tally under the TV, TA, and TVA conditions, and humanity was associated with slight warmth (*nukumori*) under T. We aimed to determine why the factors of attraction depended on the handshake conditions. Different senses are integrated into tactile stimuli in the multimodal condition, significantly altering perceptions and feelings vis-à-vis external stimuli [45]. We would like to postulate a scenario about the condition-caused differences in the factors of attraction: Multimodal stimulation enhanced certain sensations, specifically smoothness and humanity. Subjects may have more strongly sensed humanity while shaking hands as they gazed at a human face and listened to a song than when they were exposed solely to tactile stimuli. Numerous researchers have noted the significant visual and auditory influences on tactile perception [46–48]. Visual information is known to strongly affect a subject's senses and judgment; an illusion may be created when tactile and visual information differ [44].

We further posit that the priming effect may not be negligible. The priming effect is defined as the influence of a preceding stimulus on the processing of a subsequent stimulus [49]. For example, Logeswaran et al. asked subjects to give impressions of three different facial images after listening to music and found that the faces looked happier when they listened to happy music beforehand and sadder when they listened to sad music beforehand [50,51]. In the present study, subjects looked at a picture of a pop idol (a visual stimulus) and/or listened to the idol's music under TVA, TV, and TA conditions before grasping the handshake device. The music and images were presented along with the commencement of the test, and the subject was exposed to the visual and auditory stimuli for several seconds before shaking hands with the device.

5. Conclusions

For this study, we had a group of participants grasp a handshaking device covered with one of three materials while they looked at a picture of a pop idol, listened to one of the idol's songs, or both or neither. In this study, we presented subjects with stimuli that elicited three sensory responses: tactile sensations from skin contact, visual sensations from looking at pictures, and auditory sensations from listening to music. We found that when subjects grasped an evaluation device covered with artificial skin with their dominant hand while looking at a picture of a pop idol or listening to a song, their attraction scores increased due to the smooth feel and human-like feeling. On the other hand, when no pictures or songs were presented, a simple feeling of slight warmth (*nukumori*) correlated with the attraction score. The attractiveness of the handshake evoked by tactile stimuli was enhanced by visual and auditory stimuli and was highest when all three senses were combined. The stated propositions remain hypotheses for the present. The postulations must be further tested through more systematic experiments.

This interdisciplinary study analyzed the handshake, a greeting exhibiting friendship, from both psychological and physical perspectives. In particular, we focused on the specific situation of a handshaking party and discovered a new attribute: attraction is enhanced through multimodal stimulation via the tactile, visual, and auditory senses. To the best of the author's knowledge, such a party denoted a unique event hosted by a Japanese pop idol, and such occurrences could generate cultural anthropological value in the future. Additionally, the results of the present study could be applied to varied industrial domains, especially virtual reality and entertainment. These sectors need to construct immersive systems offering multimodal stimuli to humans that can induce strong feelings such as joy, anger, sorrow, and pleasure.

The relationships among emotional, sensory, and physical stimuli during a handshake are not completely understood. The use of virtual reality and objective measures, such as physiological responses or behavioral observations, can be useful to solve such a complex problem. Virtual reality allows for more distinct stimuli to be applied to subjects, while objective measures allow for quantitative analysis [52–55]. The findings of this study revealed materials and conditions suitable for evoking a sense of attraction and will certainly benefit the design of such novel technologies.

Supplementary Materials: The following supporting information can be downloaded at: https://www.mdpi.com/article/10.3390/technologies11040086/s1, Figure S1: Relationship diagram between attraction, humanity, tactile, and physical factors under TV condition (a) and TA condition (b). Numeric values are the rank correlation coefficient R between two factors. The dashed line indicates that certain effects are confirmed by the Friedman test. Table S1: Score of sensory evaluation; Table S2: Results of significance tests with multiple comparison analyses performed by Friedman's method with adjustment by Bonferroni's method; Table S3: Spearman's rank correlation coefficient between attraction, humanity, slight warmth (nukumori), tactile factors, mechanical factors, and physical factors; Table S4: Results of the Friedman test for smooth, warm, and soft feels.

Author Contributions: Conceptualization, T.K. and Y.N.; methodology, T.K. and Y.N.; validation, T.K. and Y.N.; formal analysis, T.K. and Y.N.; investigation, T.K.; resources, Y.N.; data curation, T.K. and Y.N.; writing—original draft preparation, T.K.; writing—review and editing, Y.N.; visualization, T.K. and Y.N.; project administration, Y.N.; funding acquisition, Y.N. All authors have read and agreed to the published version of the manuscript.

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Institutional Review Board Statement: The study was conducted in accordance with the Declaration of Helsinki and approved by the Ethical Review Committee of Yamagata University on 28 August 2020.

Informed Consent Statement: Informed consent was obtained from all subjects involved in the study.

Data Availability Statement: Data supporting the reported results can be found in the main text and Supporting Information.

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