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"Elegant Scents Make Time Fly: Psychological Impact of Aroma on Psychological Time"

Hinayo Asai [1], Ayako Morise [1], Hitoshi Muto [1], Toshio Igarashi [1], Osamu Hirose [1], Hitoshi Sawada [1] and Seiji Hasegawa [1, 2]

[1] Research Laboratories, NIPPON MENARD COSMETIC CO., LTD., Nagoya, Japan;
[2] Nagoya University-MENARD Collaborative Research Chair, Nagoya University Graduate School of Medicine, Nagoya, Japan

1. Introduction

This study investigated scents' positive psychological effects on psychological time and development of attractive scents that cause people to forget about time. Psychological time, or the length of time we feel, has long been studied from various perspectives, and it varies based on psychological and physical states. Engaging experiences make time seem to pass quickly, while boredom or unpleasant experiences slow it down. Moreover, psychological time differs for individuals of different ages and genders [1] but also depends on an individual's psychological state. Indeed, the literature demonstrates that psychological time varies with a person's emotional valence and arousal level [2]. Fear stimuli lengthen time estimation (but the actual passage of time seems shorter), and positive stimuli feel briefer than negative stimuli [3,4].

In cosmetics development, fragrance is an important factor. The fragrance of lavender relaxes us, whereas the fragrance of rosemary arouses us, and these fragrances also cause biological changes, such as electroencephalography and heart rate variability [5]. Conversely, we know that changes in biological effects caused by fragrances relate to individual preferences and the fragrance's level of unpleasantness [6,7]. Therefore, when studying fragrances' biological effects, considering individual feelings is important.

Previous studies on time evaluation and scent have shown that perception of time is affected by differences in scent and arousal level [8,9]; time evaluation is also affected by preconception of fragrance [10]. In addition, because the mechanism of time perception differs depending on the length of time evaluated [11], scent can act inversely, depending on the length of time evaluated. When unpleasant odors were presented, study participants underestimated when the evaluation time was 400 ms but overestimated when the evaluation time was 2000 ms [12].

Thus, although various studies have been conducted on psychological time and psychological changes caused by fragrances, what specific fragrance impressions affect psychological time is not well known. In this study, therefore, we conducted the following three experiments, focusing on 30-second psychological time during which emotion was thought to be affected and psychological changes were caused by fragrance.

Experiment-1: Exploration of psychological changes caused by scents affecting time evaluation

Experiment-2: Verification of the elegant-fragrance's effect on time evaluation and investigation of its influence on brain activity

Experiment-3: Investigation of the elegant-fragranced lotion's effects on psychological time and biological changes

By conducting these experiments, we aimed to develop value-added products with fragrances.

2. Materials and methods

2.1. Experiment-1

2.1.1. Participants

This experiment involved 17 healthy Japanese female participants (25–56 years; mean age = 35.3). The study was approved by the local ethics committee.

2.1.2. Experimental procedure

After 5 minutes' rest, participants completed two 30-second timed estimations as one session, and at the end of each session, they completed a psychological rating to indicate how they felt at that moment. During the time estimation, the scent was presented by placing perfumed paper close to the nose. The first session was the unscented condition, and the next four sessions tested four scents. In conducting this test for 2 days, eight different scents—the order randomly assigned—were evaluated per person.

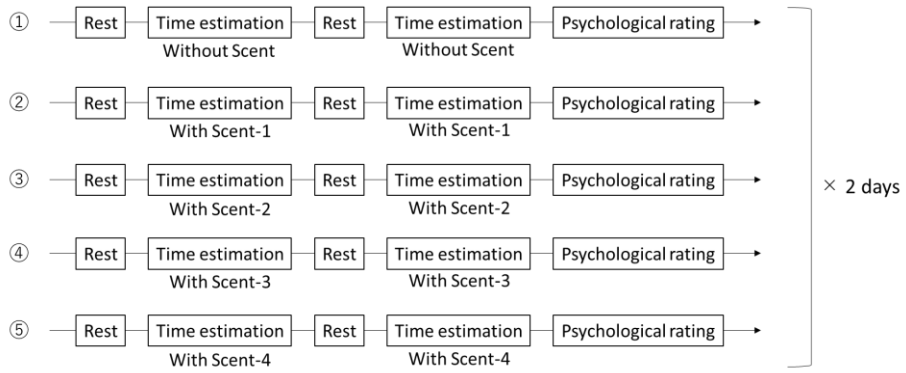


Figure 1. Experimental design.

2.1.3. Scents

Eight scents with different classifications and impressions (ylang ylang, jasmine, frankincense, vetiver, benzoin, lemon, rose, and rosemary) were used. Scents' concentrations were set at the same stimulation level when perfumed papers were placed close to the nose. As the unscented condition, DIBA (Diisobutyl Adipate), which is used as a solvent for natural scents, was presented.

2.1.4. Psychological rating

Emotional responses were evaluated through 18 items reflecting possible mood changes induced by the scents. To evaluate psychological states after inhaling the scents, participants rated them on a 6-point scale from 1 (not at all) to 6 (extremely).

2.1.5. Time estimation

While inhaling the scents, participants stopped a stopwatch when they believed that 30 seconds had passed (the method of production). This method shows that actual time is perceived as long when the estimated time is short and that actual time is perceived as short when the estimated time is long (Figure 2). In this study, a 30-second production method was selected as applicable to the timing of cosmetics' use.

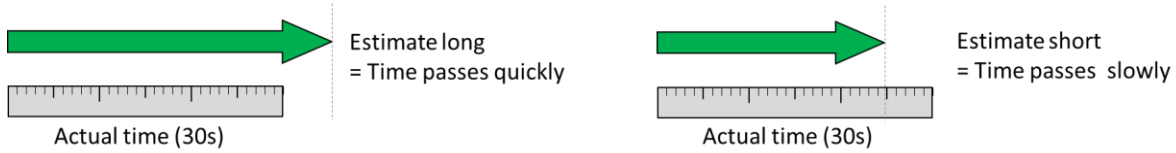


Figure 2. Time estimation by method of production.

2.1.6. Data analysis

To adjust individual differences in factor scores and time estimation values of factor analysis, differences were calculated based on each day's unscented condition, and values were standardized among individuals for the eight scents' data. Factor analysis was used on the structure of psychological-rating values. Pearson's correlation coefficient was calculated to analyze correlation between factor scores and time estimation values. For partial least squares (PLS) regression analysis, regression coefficients were calculated with time estimation values as the objective variable and factor scores as the explanatory variable. All statistical analyses were conducted with statistical software R. Statistical significance was determined by P-values <0.05.

2.2. Experiment-2

2.2.1. Participants

This experiment involved 16 healthy Japanese female participants (25–49 years; mean age = 36.4). Because of possible differences in brain activity between right- and left-handed individuals, all participants were right-handed. The study was approved by the local ethics committee.

2.2.2. Experimental procedure

After 5 minutes of rest, two sessions were evaluated, with the elegant fragrance or without the fragrance (solvent condition). Two 30-second timed estimations were considered one session. During time estimation, the fragrance was presented by placing perfumed paper close to the nose. The fragrance's order was assigned randomly to each participant.

2.2.3. Elegant fragrance

The fragrance with the highest elegance factor score and predicted by the regression equation to have the longest time estimation among several fragrance blends used primarily in skin care products by two fragrance developers was used in this experiment (data not shown). The fragrance blends several natural scents, including rose and frankincense.

2.2.4. Functional near-infrared spectroscopy

Functional near-infrared spectroscopy (fNIRS) measurements were conducted with a wearable optical topography system (WOT-100, Hitachi High-Tech Co., Japan) to examine oxygenated hemoglobin (oxy-Hb) concentration changes during time estimation (compared to before time

estimation), the most sensitive indicator of changes in regional cerebral blood flow among fNIRS measurements [13,14].

2.2.5. Data analysis

Differences between changes of fragrance and solvent conditions were analyzed using paired t-tests. Statistical significance was determined by P-values <0.05.

2.3. Experiment-3

2.3.1. Participants

This experiment involved 14 healthy Japanese female participants (25–52 years; mean age = 30.1). The study was approved by the local ethics committee.

2.3.2. Experimental procedure

Participants who had washed their faces evaluated psychological ratings (as in Experiment-1) and had their skin conditions measured after 5 minutes' rest. After that, using a cotton pad, they applied the elegant-fragranced lotion to their faces by themselves. Psychological ratings and skin measurements were performed again 5 minutes after the end of application. Heart rate variability was measured during the experiment, which was conducted twice (lotion with or without fragrance) per participant. The lotions' order was randomized.

2.3.3. Lotions

The lotion with fragrance from Experiment-2 and a non-fragranced lotion were used. Both lotions were given to participants in a cotton pad, and they applied it to their faces in their usual way.

2.3.4. Time measurement

The time from the application's beginning to its end was measured, but participants did not know we were measuring the time. To avoid preconceptions, we instructed participants to apply the lotion in their usual way and not to intentionally shorten or lengthen the application.

2.3.5. Heart rate variability

Heart rate variability (HRV) was measured with a wearable system (Muse brain system, Digital Medic, Japan). HRV is widely used in psychological research as an indicator for the autonomic nervous system. The R-R intervals (RRI), the root mean square of successive R-R intervals (RMSSD), and the standard deviation of the RR sequence (SDNN) were calculated. To confirm change in RRI during application of lotion, the slope of RRI relative to time was calculated.

2.3.6. Skin measurements

In the cheek area, the skin surface's hydration level was measured by Corneometer CM825 (Courage and Khazaka, Germany). Also in the cheek area, skin color was measured by Spectrophotometer CM-2600d (Konica Minolta, Japan).

2.3.7. Data analysis

To standardize differences in the number of items for each factor score, the total score's ratio and the participants' average value were calculated. Application time and RRI slope values were analyzed using the paired t-test, and other data were analyzed with two-way ANOVA for significant differences. Statistical significance was determined by P-values <0.05.

3. Results

3.1. Experiment-1: Exploration of psychological changes caused by scents affecting time evaluation

Exploratory factor analysis (maximum likelihood method, promax rotation) was performed with the number of factors set at four by diagonal squared multiple correlation parallel analysis. Finally, after excluding items with two factors with loadings of 0.3 or above and items with low commonality, 14 items were selected: Factor-1 was named “comfort” (calm, relieved, pleasant, relaxed, and healed), Factor-2 “fascination” (excited, upbeat, bright, attractive, and interested), Factor-3 “refreshment” (clear and refreshed), and Factor-4 “elegance” (classy and gracious). Factor scores for each scent, standardized by participant, were low for vetiver across all scores and high for lemon refreshment scores, but each scent’s factor scores varied widely. No significant differences in time estimation were observed between scents (Figure 3).

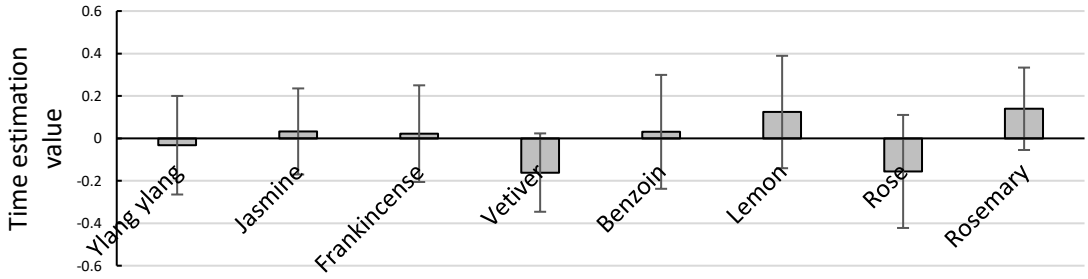


Figure 3. Time estimation for the eight scents. Mean of estimation time standardized by participant. (N = 17, mean ± S.E.)

To verify the relationship between psychological changes caused by scents and time estimation, time estimation values were compared between scents with each participant’s highest and lowest factor scores. Results showed significant differences between “comfort” and “elegance” (Figure 4). Correlation analysis between time estimation values and factor scores showed that elegance factor scores had the highest correlation coefficient among the four factor scores (Figure 5).

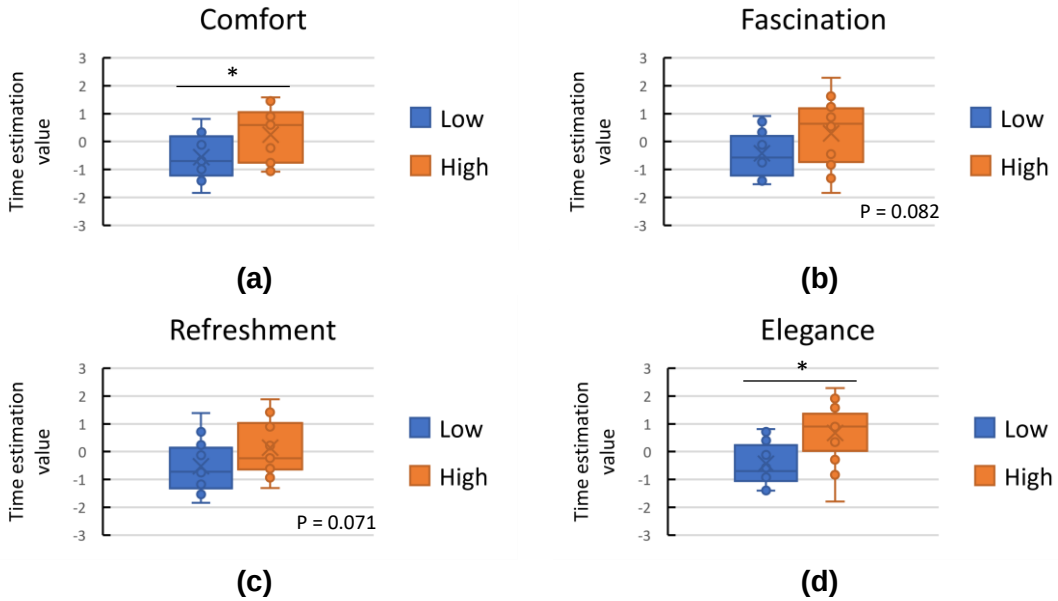


Figure 4. Comparison of time estimation values between scents with the highest and lowest factor scores: (a) “comfort,” (b) “fascination,” (c) “refreshment,” (d) “elegance.” (N = 17, *p < 0.05)

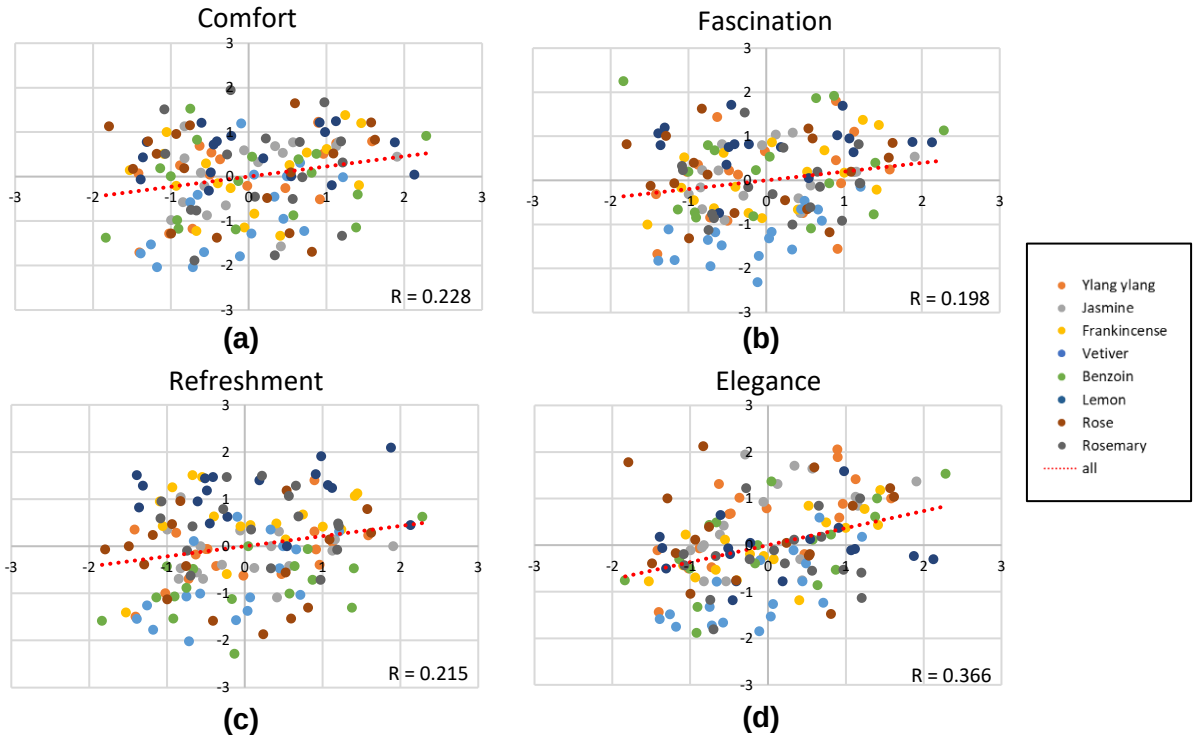


Figure 5. Correlation analysis between time estimation values and factor scores. The horizontal axis indicates time estimation values, and the vertical axis indicates psychological scores. Factor scores of (a) “comfort,” (b) “fascination,” (c) “refreshment,” (d) “elegance.” R indicates the regression line’s correlation coefficient for all values.

In PLS regression analysis, with the objective variable as time estimation values and the explanatory variables as factor scores, the number of components was selected as two at leave-one-out cross validation. The first axis was identified as the total scores’ amount, and the second axis indicated elegance factor scores. The time estimation’s bubble plots showed that plus plots indicating longer time estimation were distributed mostly in the graph’s upper right corner (Figure 6). The factor scores’ regression coefficient showed that the elegance factor was the highest of the four (Figure 7).

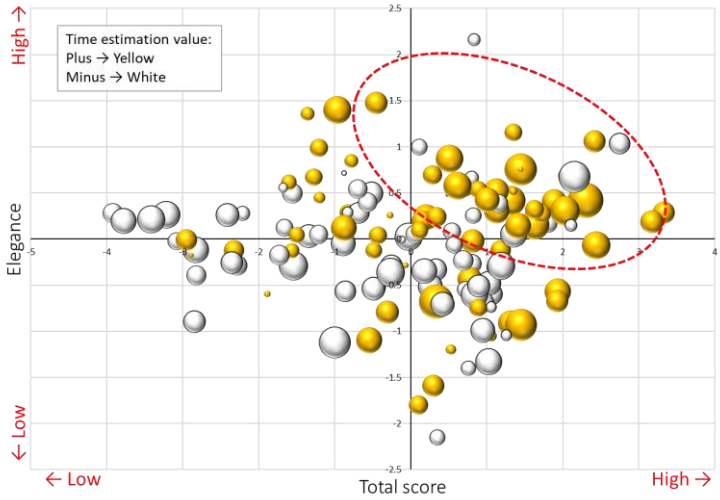


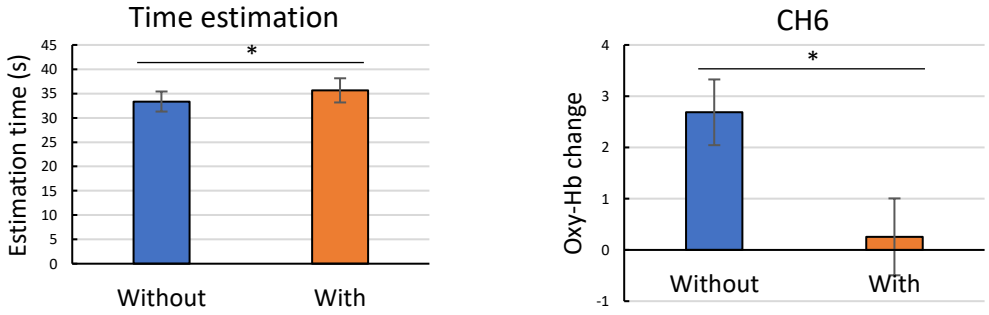
Figure 6. Distribution of factor scores and time estimation values. The scores’ plot on the two axes by PLS analysis. Bubble size and color indicate time estimation value.

Figure 7. The regression coefficient for factor scores.

These results indicated that the feeling of “elegance” from scents made time estimation longer (i.e., time seemed to pass more quickly).

3.2. Experiment-2: Verification of the elegant-fragrance’s effect on time evaluation and investigation of its influence on brain activity

In the elegant fragrance condition, time estimation was longer than in the solvent condition (Figure 8a). In addition, measurements of oxy-Hb concentration changes suppressed the CH6 region located in the right prefrontal cortex (Figure 8b). A representative example of changes in oxy-Hb concentration is shown in Figure 9.



(**a**) (**b**)

Figure 8. Comparison of time estimation and oxy-Hb concentration change in with- and without- fragrance conditions. Mean of (a) estimation time; (b) oxy-Hb changes of CH6 before and during inhaling fragrance. (N = 16, mean ± S.E., *p < 0.05)

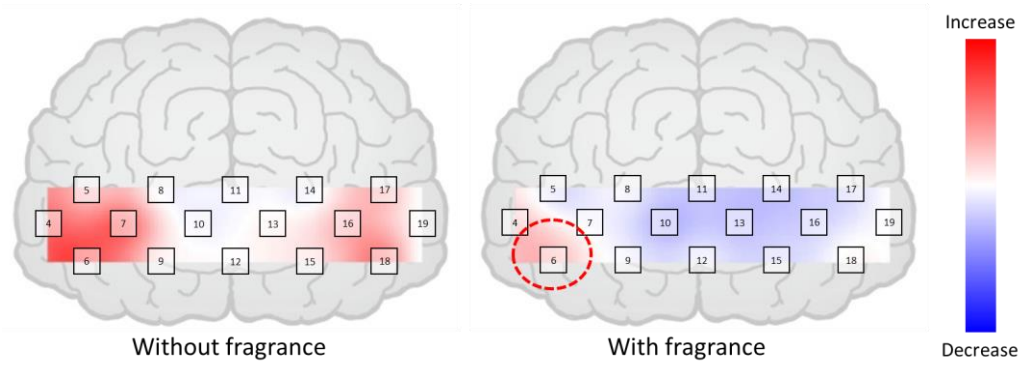


Figure 9. Representative example of changes in oxy-Hb concentration before and during fragrance inhalation.

3.3. Experiment-3: Investigation of the elegant-fragranced lotion's effects on psychological time and biological changes

For psychological rating, factor scores for "comfort," "refreshment," and "elegance" were significantly higher for the change in the lotion with fragrance compared to that in the lotion without fragrance (Figure 10).

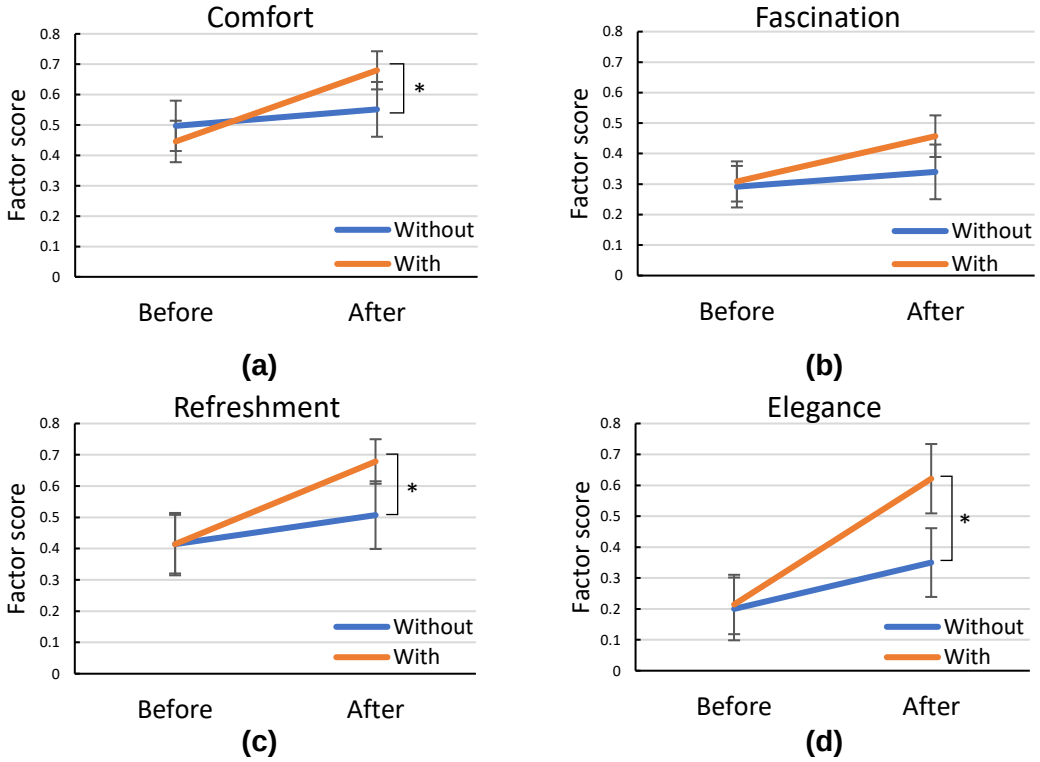


Figure 10. Comparison of psychological changes before and after lotion use with and without fragrance. (N = 14, mean ± S.E., *p < 0.05). Factor scores of (a) "comfort," (b) "fascination," (c) "refreshment," (d) "elegance."

Participants took longer to apply the fragranced lotion (Figure 11a). For HRV, no differences were observed between RRI, RMSSD, and SDNN. However, the time-series change in RRI during application showed a positive slope when unfragranced lotion was used, whereas the slope was close to zero with fragranced lotion. The slope was also significantly lower in the fragranced than in the unfragranced condition (Figure 12). As for skin measurements, no difference was observed in the water content of the stratum corneum, but the L* value that indicates skin lightness was significantly higher in the fragranced condition (Figure 11b).

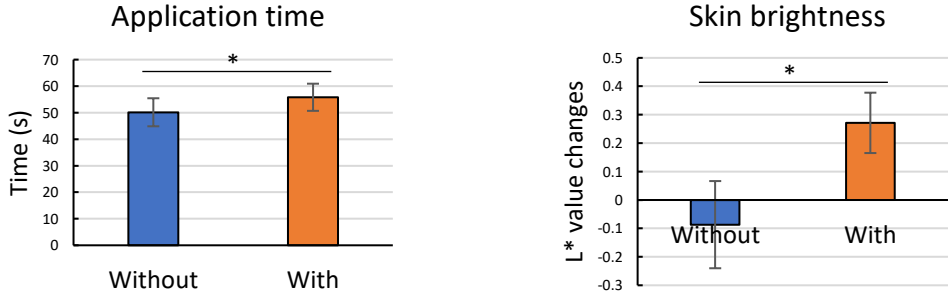
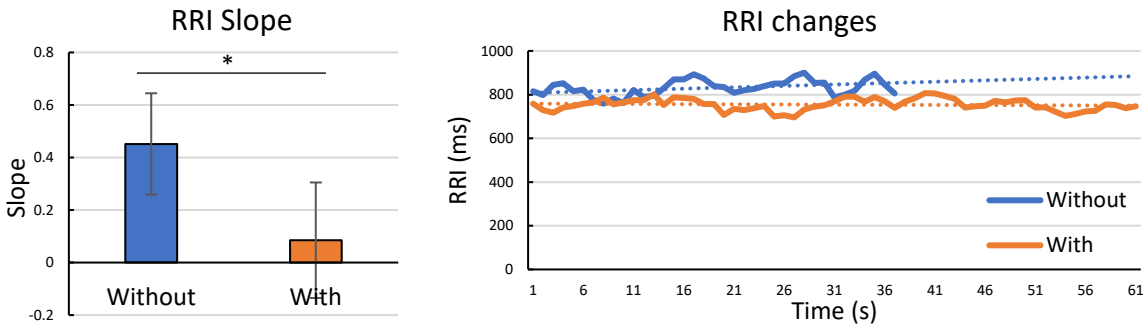


Figure 11. Comparison of application time and changes in skin brightness with and without fragranced lotion. (N = 14, mean ± S.E., *p < 0.05)



(**a**) (**b**)

Figure 12. Comparison of RRI slopes (a) and the representative example of RRI changes (b) with and without fragranced lotion during application. (N = 14, mean ± S.E., *p < 0.05)

4. Discussion

This study revealed the characteristics of fragrances that influence psychological time, and the biological effects caused by the fragrance. Experiment-1, with natural scents, revealed that psychological states affect time estimation and suggested that psychological changes related to elegance affected psychological time. Experiments-2 and -3 revealed the elegant fragrance's biological changes in suppression of oxy-Hb activity in the right prefrontal cortex, HRV, and skin brightness. Previous fMRI research has reported activation of the right anterior insular cortex and right inferior frontal gyrus for accurate perception of time intervals [15]. Although the fNIRS captured only activity on the frontal surface, in the previous study, similar regions were suppressed when participants inhaled the elegant fragrance, suggesting that the fragrance suppressed activity in regions related to time perception, perhaps distorting their sense of time. Furthermore, the RRI slope gradually changed toward relaxing when unfragranced lotion was used, whereas the change did not occur with fragranced lotion. Because the RRI slope has been related to concentration level [16], it was suggested that the elegant fragrance increased concentration on skin care behaviors and accelerated the passing of time. In addition, because blood flow and water content in the skin's surface affect brightness, the elegant fragrance and its time-extending effect may have changed blood flow and enhanced moisture. These results suggest that fragrances that extend the time required for skin care may also serve to improve skin condition.

Although this study focused on the sense of time, we know that fragrance by itself has various psychological and biological effects. Even when the same fragrance is used, positive psychological changes vary across individuals. This study was conducted only with Japanese women, so possibly, factors related to feelings about fragrances and psychological time differ between countries and cultures. This study also examined the biological effects of precious fragrance that many people find elegant, such as rose and frankincense, and analyzed how elegant fragrances change psychological time. However, many other fragrances make people feel elegant. Therefore, further research on differing types of fragrances could be applied to development of products that reduce stress and encourage careful skin care over time.

5. Conclusion

We have identified fragrance-induced psychological and biological changes that affect psychological time. Results show that not only fragrance preference but also psychological changes related to "elegance" greatly influence psychological time. Furthermore, results suggest that the elegant fragrance suppressed brain activity and accelerated psychological time through focus on skin care. In cosmetics development, elegant fragrances' use can be

expected to provide a wonderful experience that makes “time fly” and improves skin health. We expect that further studies will lead to development of fragrances that make time fly as an approach to enhancing cosmetics and other products’ sensory value.

6. References

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