Final sampling bias in haptic judgments: how final touch affects decision making

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Abstract

When people make a choice between multiple items, they usually evaluate each item one after the other repeatedly. The effect of the order and number of evaluating items on one's choices is essential to understanding the decision-making process. Previous studies have shown that when people choose a favorable item from two items, they tend to choose the item that they evaluated last. This tendency has been observed regardless of sensory modalities. This study investigated the origin of this bias by using three experiments involving two-alternative forced-choice tasks using handkerchiefs. First, the bias appeared in a smoothness discrimination task, which indicates that the bias was not based on judgments of preference. Second, the handkerchief that was touched more often tended to be chosen more frequently in the preference task, but not in the smoothness discrimination task, indicating that a mere exposure effect enhanced the bias. Third, in the condition where the number of touches did not differ between handkerchiefs, the bias appeared when people touched a handkerchief they wanted to touch last, but not when people touched the handkerchief that was pre-determined. This

finding suggests a direct coupling between final voluntary touching and judgment.

Keywords

Preference, decision making, haptic, tactile sense, mere exposure effect

Introduction

Choosing something from multiple items is an essential behavior in our daily life. Making the correct choice of the "best" item requires a fair evaluation between items. However, it is difficult because the sampling order and the number of samples (e.g., looking, hearing, smelling, and touching) affects our choice. For example, items presented first and last tend to be better recalled (Glanzer & Cunitz, 1966; Murdock, 1962), which are called *primacy* and *recency* effects, respectively. The serial position in presenting items also affects preference judgments (Biswas, Grewal, & Roggeveen, 2010; Carney & Banaji, 2012; Li & Epley, 2009; Mantonakis, Rodero, Lesschaeve, & Hastie, 2009; Pandelaere, Millet, & Van den Bergh, 2010). However, when people choose one from multiple items, they usually do not care about the number of sampling items, or the order and duration of sampling. Therefore, their choices might be affected by sampling patterns unconsciously. It is essential to examine this phenomenon in order to better understand the decision-making process.

Many previous studies have investigated the effects of serial position when

multiple items were presented once in serial order but not when people sampled items freely. When people make a choice between multiple items using visual information, they usually look at items repeatedly one after the other, especially when the difference of the values between the items is small. Further, it seems that people sometimes look at an item for a short duration just for the purpose of checking. These behaviors lead to various looking patterns and make the relation between the order of looking at items and a choice complex.

As far as we know, no paper has shown any statistically significant bias in the likelihood of choosing an item that was looked at first when people look at multiple items freely. However, many studies have recently reported that the item that was looked at last tends to be chosen more often. Shimojo, Simion, Shimojo, and Scheier (2003) have shown that, in two-alternative forced-choice tasks using images, the likelihood of choosing the image looked at last was significantly greater than chance. The magnitude of the bias was greater for preference judgment tasks than non-preference judgment tasks. The tendency for people to often choose the item they

looked at last has been also confirmed by many other studies (Glaholt & Reingold, 2009, 2011; Krajbich, Armel, & Rangel, 2010; Mitsuda & Glaholt, 2014; Nittono & Wada, 2009; Schotter, Berry, McKenzie, & Rayner, 2010). Furthermore, this tendency has been observed in aural (Lindsen, Moonga, Shimojo, & Bhattacharya, 2011), olfactory (Mitsuda, 2015), and haptic-preference judgment tasks (Mitsuda & Yoshioka, 2015). In other words, the likelihood of choosing an item that was heard, smelled, or touched most recently before making a decision was significantly greater than chance. Mitsuda (2015) named this bias in choosing items the "final sampling bias" (FSB) and found that the FSB (i.e. the likelihood of choosing the item sampled last) tends to be greater in preference judgment tasks than non-preference tasks. One possible source of the FSB is the recency effect, as a previous study has shown that items presented last tend to be chosen more often in preference judgment tasks (Li & Epley, 2009). However, other studies have shown that items presented first tend to be chosen more frequently (Carney & Banaji, 2012; Mantonakis et al., 2009; Pandelaere et al., 2010), which is in contrast to the recency effect. Considering the robust phenomenon of the FSB, the magnitude of

the recency effect seems small for the FSB.

Other than the recency effect, there are two possible sources of the FSB. The first is the direct connection between the sampling and the choice (i.e. the contribution of sampling not only to getting information regarding items, but also to the decision). The second is that the final sample causes the mere exposure effect, wherein mere exposure to an item that is more frequent or of longer duration increases preference for that item (Bornstein, 1989; Zajonc, 1968), and this increased preference results in the tendency to choose the sampled item more often.

The first possibility is related to the importance of voluntary sampling in decision making. Shimojo et al. (2003) showed that an image presented for a longer duration tended to be chosen more often compared with another image in a visual preference judgment task. Furthermore, this bias appeared when the two images were presented side-by-side alternately, which required participants' eye movements, but not when the two images were presented in the center of the screen alternately, which did not require eye movement. This result implies that eye movements contribute to not only obtaining

visual information, but also to decision making. Similarly, voluntary sampling behaviors, such as hearing, smelling, and touching, might be directly connected to decision making. This possibility of voluntary sampling may explain why the FSB appeared not only in the preference task, but also in the non-preference task. However, it does not explain the reason for which the FSB was greater in preference tasks than in non-preference tasks.

The second possibility is related to the fact that the item sampled last tends to be sampled more often than the other item in a trial, assuming that people sampled items one-by-one alternately. When the total number of samples is an even number in two-alternative forced-choice tasks, the two options have equal number of samples; however, for odd numbers, the option sampled last receives one more sample than does the other option. The total number of samples is always even or greater for the item that is being sampled than for the other. Therefore, the increase in preference by the mere exposure effect is greater for the item that is being sampled than it is for the other, which leads to the tendency to choose the item being sampled more often. This possibility can explain why the FSB in preference judgment tasks is greater than in

non-preference tasks. However, previous studies regarding the mere exposure effect have only shown that preference for an item that is presented more frequently is greater than preference for other items. However, no studies have shown that just one difference in the number of samples in two-alternative forced-choice tasks can cause a difference in preference level. For example, in the study by Shimojo et al. (2003) described above, a significant effect appeared when they presented an image for 900 ms and another image for 300 ms, and repeated this presentation six times. However, this effect did not emerge when they repeated the presentation twice. Therefore, the difference in the total number of samples could modulate the FSB but is not a main source of the FSB.

The current study hypothesized that the main source of the FSB is the direct connection between voluntary sampling and decision making, and that the difference in the total number of samples between items enhances the magnitude of the FSB. To verify this hypothesis, we conducted three experiments of haptic two-alternative forced choice-tasks using handkerchiefs.

In Experiment 1, we compared the FSB between a preference task and a

non-preference task. The FSB in non-preference tasks has been reported in visual tasks (Glaholt & Reingold, 2009, 2011; Nittono & Wada, 2009; Schotter, Berry, McKenzie, & Rayner, 2010) and in olfactory tasks (Mitsuda, 2015), but not in haptic tasks. Per the hypothesis that the main source of the FSB is the direct connection between voluntary sampling and decision making, the FSB should appear regardless of task and sensory modalities. Therefore, the FSB in Experiment 1 should appear not only in the preference task, but also in the non-preference task.

In Experiment 2, we checked if the difference in the number of samples and the duration of sampling affects the choice in preference and non-preference tasks. Although it has been reported that the mere exposure effect occurs in haptic tasks (Jakesch & Carbon, 2012), it has not been shown if the small difference in sampling duration and the number of samples between items creates a difference in preference level. According to our hypothesis, the likelihood of choosing a handkerchief touched more often than another handkerchief should be greater than chance in the preference task, but not in the non-preference task.

In Experiment 3, we compared the FSB when people sampled items voluntarily and when people sampled items per a pre-determined pattern, in the condition where the total number of sampling items and the sampling duration were equivalent. According to our hypothesis, the FSB should appear via a direct connection between voluntary sampling and decision making, and not owing to the effect of final touch, such as the recency effect. Therefore, the FSB should appear in voluntary samplings, but not in passive samplings. All of these experiments were approved by the Ritsumeikan University Ethics Review Committee for Research Involving Human Participants and were conducted in accordance with the Declaration of Helsinki.

Experiment 1

We aimed to determine whether the FSB in haptic tasks was not limited to preference tasks. To do so, we compared the FSB in a smoothness discrimination task (i.e. non-preference task) with that in a haptic preference task using handkerchiefs that provided different touch sensations.

Method

Participants. Twenty male students (M_{age} = 22.1 years, *SD* = 0.7) from Ritsumeikan University were recruited. They received 2000 Japanese Yen (JPY) for their participation. All the participants provided written informed consent.

Materials. Forty-five types of handkerchiefs made of cotton, silk, hemp, artificial fabrics, terrycloth, etc. were collected at the market. They differed in texture or weave. Some of them had embroidery. Two each of the 45 types of handkerchiefs (i.e. 90 handkerchiefs) were used for the experiment. In each trial, a pair of handkerchiefs was presented on a desk behind a curtain in front of participants so that they could choose a handkerchief by tactile sensation without seeing it (see Figure 1).

Procedure. Participants were asked to select a handkerchief they liked more in the preference task or a handkerchief that felt smoother in the smoothness task. The instruction was made orally in Japanese ("*sukinahou wo erande kudasai*" for the preference task and "*namerakanahou wo erande kudasai*" for the smoothness task). At the beginning of every trial, participants put their dominant hand on the hand rest (width 10 cm, depth 24 cm, height 7 cm) between the handkerchiefs and their non-dominant

hand on a keyboard. The experimenter told the participants what handkerchief to touch first (i.e., “touch the right handkerchief first” or “touch the left handkerchief first”) in alternating order. After hearing a start signal, the participants touched the handkerchiefs alternately with their dominant hand and reported their choice by pressing the “X” key for the right handkerchief or the “Z” key for the left handkerchief after moving their dominant hand back to the hand rest. The participants could touch the handkerchiefs as many times as they wanted until deciding. The duration of touching each handkerchief was measured at 60 Hz by a position sensor (Patriot, Polhemus, Colchester, VT) fixed on the back of their dominant hand.

Participants performed 60 trials each for preference and smoothness tasks. To avoid fatigue among participants and any effects of touching the same handkerchief that was touched previously, we performed the recording on two separate days. Thus, participants performed 30 trials each for the two tasks on a separate day. The task order was counterbalanced across participants. They had a 10-minute break between the tasks. The entire experiment was completed in approximately one hour each day.

In each block of recordings, 30 types of handkerchiefs were randomly selected from 45 types of handkerchiefs and paired with each other. Then, 15 pairs of two different handkerchiefs were made. In addition, the remaining types of handkerchiefs (15 types) were paired with the same handkerchief. Then, 15 pairs of two different handkerchiefs and 15 pairs of two identical handkerchiefs were made. Consequently, 30 pairs of handkerchiefs, which consisted of 15 pairs of two different handkerchiefs and 15 pairs of two identical handkerchiefs, were used for each block of recordings. The 30 types of pairs were presented in random order. The pairs of the two identical handkerchiefs were added to increase task difficulty, as in a previous study (Mitsuda & Yoshioka, 2015). No participants noticed that two identical handkerchiefs were paired in half of the trials without seeing them.

On a separate day, after the 2-day recordings, participants rated the preference and smoothness of 45 handkerchiefs on a 5-point scale (preference: 1 = strongly dislike to 5 = strongly like; smoothness: 1 = not smooth at all to 5 = very smooth) by touching them one-by-one without seeing them.

Analysis

Decision time was defined as the duration between the start signal and the time that participants pressed a key to indicate their response. The number of samples was defined as the number of times participants moved their hand from one handkerchief and placed it on another handkerchief. A hand movement where a hand left a handkerchief, but returned without passing the border between the handkerchiefs, was counted as a single sample. Hand movements where a hand passed the border but returned without touching the other handkerchief were not observed. If participants pressed a key before moving their dominant hand back to the hand rest, the trial was excluded and an additional trial using different pair of handkerchiefs was performed. The decision time, number of samples, and the likelihood of choosing the handkerchief that was sampled last (i.e. FSB) were averaged across participants, and a paired samples *t*-test was employed for comparisons between conditions. The within-subjects effect size d_z (i.e. difference within subjects divided by the standard deviation of the difference within subjects) was calculated (Lakens, 2013).

Results and discussion

The FSB was significantly greater than chance (.5) not only in the preference task (M = .61, SEM = .03, $t(19) = 3.40$, $p < .01$, $d_z = 0.76$), but also in the smoothness task (M = .59, SEM = .03, $t(19) = 2.78$, $p < .05$, $d_z = 0.62$). This result is consistent with that of previous studies that have used visual (Glaholt & Reingold, 2009, 2011; Mitsuda & Glaholt, 2014; Nittono & Wada, 2009; Schotter et al., 2010; Shimojo et al., 2003) and olfactory tasks (Mitsuda, 2015). Moreover, there was no significant difference in the FSB between the preference and smoothness tasks ($t(19) = 1.05$, $p = .31$, $d_z = 0.24$). These results verified that the FSB appears regardless of sensory modalities and task.

The likelihood of choosing the handkerchief that was touched first did not differ significantly from chance in either condition (preference task: M = .51, SEM = .02, $t(19) = 0.51$, $p = .61$, $d_z = 0.11$; smoothness task: M = .51, SEM = .02, $t(19) = 0.29$, $p = .78$, $d_z = 0.07$). The total number of samples in the preference task (M = 2.5, SEM = 0.1) did not differ from the smoothness task (M = 2.5, SEM = 0.1; $t(19) = 0.40$, $p = .68$, $d_z = 0.09$); however, decision time in the preference task (M = 9.3s, SEM = 0.7 s) was

significantly longer than in the smoothness task (M = 8.2 s, SEM = 0.7; $t(19) = 3.00$, $p < .01$, $d_z = 0.67$).

To investigate the FSB in detail, we analyzed the FSB by the total number of samples in each trial (see Figure 2). The FSB in trials with two samples (i.e. trials where participants sampled each handkerchief once before making a decision; 63% of trials) was not significant in either task (preference task: $M = .52$, $SEM = .04$, $t(19) = 0.55$, $p = .58$, $d_z = 0.13$; smoothness task: $M = .54$, $SEM = .01$, $t(18) = 1.23$, $p = .21$, $d_z = 0.29$). Meanwhile, the FSB in trials with three samples (25% of trials) was significantly greater than chance in both the preference task ($M = .70$, $SEM = .04$, $t(19) = 4.86$, $p < .001$, $d_z = 1.1$) and the smoothness task ($M = .67$, $SEM = .05$, $t(18) = 3.44$, $p < .01$, $d_z = 0.79$). The FSB in trials with four samples (9% of trials) was significant in the preference task ($M = .71$, $SEM = .09$, $t(16) = 2.28$, $p < .05$, $d_z = 0.55$) but not in the smoothness task ($M = .58$, $SEM = .11$, $t(12) = 0.78$, $p = .45$, $d_z = 0.21$), which might be due to the small number of trials and the fewer number of participants who sampled

handkerchiefs four times in a trial. The FSB in trials with more than four samples (3% of trials) were not analyzed owing to the small number of trials and participants.

The rating of individual handkerchiefs conducted after the recording showed a slight correlation between preference and smoothness (r = .22). However, in the smoothness task, the FSB in trials where the chosen handkerchief was preferred to the not-chosen handkerchief (i.e. the correlation between preference and smoothness might affect the choice; 55.3% of trials) was .57, and it was smaller than the FSB of the other trials (44.7% of trials; M = .59, $t(19) = 0.47$, p = .64, $d_z = 0.11$). Moreover, the FSB of the other trials was significantly greater than chance ($t(19) = 2.52$, $p < .05$, $d_z = 0.56$). Therefore, the FSB in the smoothness task was independent of the correlation between preference and smoothness.

In the preference task, the FSB was .61 (SEM = .03) for the pairs of two identical handkerchiefs and .60 (SEM = .03) for the pairs of two different handkerchiefs, which did not differ significantly ($t(19) = 0.80$, p = .43, $d_z = 0.18$). The FSB in the non-preference task also did not differ significantly ($t(19) = 0.51$, p = .62, $d_z = 0.11$)

between the pairs of two identical handkerchiefs (M = .60, SEM = .04) and the pairs of two different handkerchiefs (M = .58, SEM = .03).

Experiment 1 used the same handkerchiefs as those in a previous experiment by Mitsuda (2015). The preference task procedure was also the same, except that in the previous study, the participants were asked to report on the favorability of each handkerchief using a 5-point scale after their decision. In the previous study, the participants provided two different ratings of two identical handkerchiefs in 39% of the trials in which participants compared two identical handkerchiefs without notice. This result showed that the participants had a different feel of touch between the two identical handkerchiefs, which may be due to the different touching behavior. Therefore, in this study, we considered that the participants were not able to discriminate between the two types of pairs, which caused no differences in the FSB between the two types of handkerchief pairs in this experiment. In the following experiments, we analyzed their behavior without dissociating the two types of handkerchief pairs.

Experiment 2

In Experiment 2, we aimed to determine if differences in the number of samples and the sampling duration between handkerchiefs causes a bias in choice. Participants were instructed to touch handkerchiefs per the instructed order and duration and to choose one according to preference or smoothness.

Method

Participants. Sixteen male students from Ritsumeikan University (M_{age} = 21.8 years, *SD* = 1.5) who were not involved in Experiment 1 were recruited.[1] They received 2400 JPY for their participation. All the participants provided written informed consent.

Materials. Three types of handkerchiefs were added to the 45 types of handkerchiefs used in Experiment 1 to increase the number of trials and to examine the FSB more accurately.

Procedure. The procedure was similar to that of Experiment 1, except that participants were instructed to touch the handkerchiefs according to a pre-determined order and duration. The participants performed the preference and smoothness tasks in

[1] There were a fewer number of participants in Experiments 2 and 3 owing to limited research funds and experimenter availability.

three conditions. In condition 1, participants touched each handkerchief for 4 s once and reported their choice (see Figure 3(a)). Condition 1 aimed to check if there was any bias from touching last. In condition 2, participants first touched one handkerchief for 4 s and the other for 8 s before reporting their choice (see Figure 3(b)). Condition 2 aimed to check if the difference in sampling duration between handkerchiefs affects choice. To cancel the effect of touching order, participants first touched one handkerchief for 8 s and the other for 4 s in half of the trials. The duration of the first touch was alternated across every trial. In condition 3, participants first touched a handkerchief for 2 s, then the other handkerchief for 4 s, and then the handkerchief touched first again for 2 s (see Figure 3(c)). Condition 3 aimed to check if the difference in the number of samples affected choice. In this condition, the handkerchief touched first was touched twice and the other was touched once. The total duration of touching did not differ between the handkerchiefs.

The participants were instructed to move their dominant hand per a beep sound controlled by a computer. A beep sound alarmed at the beginning of each trial, the onset

of moving a hand to the other handkerchief, and the onset of moving a hand to the hand rest for a decision. Participants were instructed to report on their decision after moving their hand to the hand rest by pressing a key as in Experiment 1. Any trials where the hand did not get to the destination (i.e. the other handkerchief or hand rest) within 1 s of the beep or where the hand moved to the destination before the beep were excluded and performed again using other handkerchiefs. Participants practiced using dummy handkerchiefs until they became familiar with the tasks before the recording.

In each condition, participants performed 32 trials per task using 16 pairs of different handkerchiefs and 16 pairs of identical handkerchiefs. The pairs of handkerchiefs were randomly selected after every recording session. Participants performed the preference and smoothness tasks for each respective condition on the same day, thus requiring three days to record the three conditions. The entire experiment was completed in approximately one hour each day. The order of task and condition was counterbalanced across participants.

Results and discussion

When participants sampled handkerchiefs evenly (i.e. in condition 1), there was no significant FSB in the preference (M = .47, SEM = .04, $t(15) = 0.79$, p = .44, d_z = 0.20) or smoothness task (M = .46, SEM = .04, $t(15) = 1.04$, p = .32, $d_z = 0.26$). When participants sampled a handkerchief for a longer duration than the other (i.e. condition 2), the likelihood of choosing the handkerchief that was sampled longer did not differ significantly from chance in the preference (M = .50, SEM = .04, $t(15) = 1.20$, p = .25, $d_z = 0.30$) or smoothness task (M = .53, SEM = .04, $t(15) = 1.31$, p = .21, $d_z = 0.33$). However, when participants sampled a handkerchief twice and the other once (i.e. condition 3), the likelihood of choosing the handkerchief that was sampled twice (M = .56, SEM = .02) was significantly greater than chance in the preference task ($t(15)$ = 2.66, $p < .05$, $d_z = 0.66$), but not in the smoothness task (M = .50, SEM = .02, $t(15) = 0.0$, $p = 1.0$, $d_z = 0.0$).

All the non-significant results described above have a risk of type II error owing to the small number of participants. Post-hoc power analyses show that more than 100 participants are required for sufficient power. Accordingly, we conducted the binominal

tests using all the trial data across participants (i.e. 512 trials) and reconfirmed that the likelihoods were not significantly biased from chance ($ps > .1$).

To conclude, the FSB in the preference task was significantly affected by the difference in the number of samples, but not by the sampling duration. In the smoothness task, the FSB was not significantly affected by the number of samples or the sampling duration. These results show that the difference in the number of samples can modulate the FSB in the preference task. Meanwhile, the difference in sampling duration did not affect the choice of handkerchief. Increasing the difference in sampling duration might cause a bias in choice of handkerchief, as in a previous visual study (Shimojo et al., 2003). However, the maximum difference in the number of samples is one in a two-alternative forced-choice task, as two items are sampled alternately. Therefore, the maximum difference in the total sampling duration between two handkerchiefs is estimated as the mean of a single sampling duration. The mean duration of a sample was 3.3 s in Experiment 1, which was shorter than the difference in the sampling duration in condition 2. Therefore, the FSB in the preference task of

Experiment 1 could be increased by a difference in the number of samples, but not by the sampling duration, between the two handkerchiefs.

The magnitude of the FSB when the number of samples differed between handkerchiefs (i.e. condition 3) for the preference task (M = .56) was significantly smaller than it was in the trials of Experiment 1 where there were three samples (M = .70, $t(34) = 2.76$, $p < .001$, Cohen's $d = 1.37$), although it must be noted that the procedures and the participants differed between the two experiments. Moreover, the FSB in the smoothness task appeared in Experiment 1 but not in condition 3. These results reveal that the main source of the FSB is not due to the difference in the number of samples. Given this, we hypothesized that the coupling between voluntary sampling and the final judgment would be the main source of the FSB and sought to verify this hypothesis in Experiment 3.

Experiment 3

In this experiment, we compared the FSB in situations where participants sampled a handkerchief that they wanted to touch at the final sample versus when the

sampling pattern was pre-determined. The total number of samples and the sampling duration did not differ between the two conditions. Per our hypothesis that the coupling between voluntary sampling and the final judgment is the main source of the FSB, the FSB should be significant when participants sample the last handkerchief voluntarily, but not when the last sample is pre-determined.

Method

Participants. Sixteen male students from Ritsumeikan University (M_{age} = 18.8 years, *SD* = 0.5 years) who were not involved in Experiments 1 or 2 were recruited. They received 2000 JPY for their participation. All the participants provided written informed consent.

Materials. Identical to Experiment 2, 48 types of handkerchief were used.

Procedure. The preference task and the smoothness task were performed in two conditions. In condition 1 (see Figure 4 (a)), participants were instructed to sample a handkerchief for 3 s, another for 3 s, the first handkerchief again for 3 s, and then put their hand on the hand rest. After keeping their hand on the hand rest for 5 s,

participants sampled the handkerchief that they wanted to touch. After 3 s, they moved their hand back to the hand rest and reported their choice by pressing a key, as in Experiments 1 and 2. The instruction to touch the handkerchief that they wanted to touch at the fourth sampling was made orally in Japanese ("*dochiraka sawaritaihou wo sawatte kudasai*") before the recording.

Condition 2 was conducted as a control condition (see Figure 3(b)). Participants were instructed to sample handkerchiefs alternatingly, twice for each handkerchief. The duration of a single sample was 3 s; therefore, the four successive samples required 12 s. After taking successive samples, participants were instructed to move their hand back to the hand rest and report their selection by pressing a key, as in Experiments 1 and 2. The difference between conditions 1 and 2 was the fourth sample. Participants sampled the handkerchief that they wanted to touch in condition 1. In condition 2, they sampled a pre-determined handkerchief.

As in Experiment 2, all the hand movements were directed by a beep sound, and irregular trials were excluded and measured again using other handkerchiefs.

Participants practiced using dummy handkerchiefs until they became familiar with the task before the recording.

In each condition, participants performed 32 trials per task using 16 pairs of different handkerchiefs and 16 pairs of identical handkerchiefs, which were randomly selected for each recording block. Participants performed the preference and smoothness tasks for each respective condition on the same day, thus requiring two days to record the two conditions. The task and condition order was counterbalanced across participants. The entire experiment was completed in approximately 75 min each day.

Results and discussion

When participants sampled the two handkerchiefs twice for each handkerchief in the pre-determined order (i.e. condition 2), the FSB did not differ significantly from chance for the preference task ($t(15) = 0.48$, $p = .64$, $d_z = 0.12$) or the smoothness task ($t(15) = 0.71$, $p = .49$, $d_z = 0.18$). The binominal tests using all the trial data across participants also showed no significant bias in the preference task ($p = .45$) or the smoothness task ($p = .76$). This result was equivalent to that of condition 1 in

Experiment 2, where participants sampled each handkerchief once. However, when participants sampled the handkerchief they wanted to touch last (i.e. condition 1), the FSB was significantly greater than chance in both conditions (preference task: $M = .65$, $SEM = .04$, $t(15) = 3.91$, $p = .001$, $d_z = 0.98$; smoothness task, $M = .59$, $SEM = .04$, $t(15) = 2.56$, $p < .05$, $d_z = 0.64$).

In condition 1, the ratio of trials where participants selected the second handkerchief (i.e. the handkerchief that was not touched in the third sample) for the fourth sample was 75.2% in the preference task and 81.1% in the smoothness task. In the rest of the trials, participants touched the handkerchief that was sampled in the third sample again in the fourth sample. One participant sampled the second handkerchief for the fourth sample in all the trials in smoothness task, and we eliminated this participant in the following analysis.

Table 1 shows the FSB as a function of task, as well as which handkerchief was sampled in the fourth sample in conditions 1 and 2. Data were analyzed using a two-way repeated measures ANOVA involving task (preference vs. smoothness) and

handkerchief sampled in the fourth sample (the same handkerchief vs. the other handkerchief). Results showed that the FSB in the preference task was significantly greater than in the smoothness task ($F(1,14) = 8.27$, $p < .05$, $\eta_p^2 = 0.37$). In addition, the FSB was significantly greater in trials where participants sampled the third handkerchief again in the fourth sample than in the other trials ($F(1,14) = 8.06$, $p < .05$, $\eta_p^2 = 0.37$). There was no significant interaction between task and handkerchief sampled in the fourth sample ($F(1,14) = 0.52$, $p = .48$, $\eta_p^2 = 0.04$).

Table 1. Final sampling biases in two-alternative forced-choice tasks in Experiment 3

	Sampling pattern	Preference task	Smoothness task
Condition 1	a(4 s)-b(4 s)-a(4 s)-A(4 s)	0.80 (0.05)	0.68 (0.06)
	a(4 s)-b(4 s)-a(4 s)-B(4 s)	0.62 (0.04)	0.56 (0.04)
Condition 2	a(4 s)-b(4 s)-a(4 s)-b(4 s)	0.52 (0.04)	0.52 (0.03)

Note: Values in parentheses indicate standard error of the mean. Sampling pattern represents the order and duration of touching two handkerchiefs (a and b). Small letters (a and b) indicate that samples were pre-determined. Capitalized letters (A and B) indicate that the handkerchief was determined by the participants.

To conclude, the results showed that the FSB appeared when participants voluntarily chose a handkerchief for the last sample, but not when participants sampled the handkerchiefs in a pre-determined order, even if there was no difference in the total number of samples between the two handkerchiefs. Moreover, the FSB appeared in the preference and smoothness tasks, indicating that voluntarily sampling last directly connected with participants' final decision, regardless of preference.

There are three possible factors explaining why the FSB in condition 1 differed as a function of task and the handkerchief at the fourth sample. The first possibility is that there was a bias caused by the difference in the total number of samples presented, which was shown in Experiment 2. When participants touched the same handkerchief at the third and the fourth sample, the handkerchief was sampled three times, but the other was sampled just one. This difference in the number of samples could increase the FSB by the mere exposure effect.

The second possibility is that participants may have exhibited a tendency to touch the handkerchief they preferred, similar to that involved in preferential looking. We call

this tendency "preferential touching." At the end of the third sample in condition 1, the third sampled handkerchief had been sampled one more time than the other. Therefore, the preference level of the handkerchief touched at the third sample should tend to be greater than the other handkerchief. If preferential touching had existed, participants would tend to touch the third sampled handkerchief again at the fourth sample and choose it.

The third possibility is that people exhibited a tendency to touch the handkerchiefs evenly. This tendency could increase the trials in which participants chose the third sampled handkerchief, but sampled the other handkerchief at the fourth sample, which degraded the FSB when participants touched the handkerchiefs evenly.

It is difficult to estimate the magnitude of the effect of each of these possibilities on the FSB because these effects were interwoven in Experiment 3. However, in the condition where these factors could not have caused the FSB (i.e. when participants touched the handkerchiefs evenly in the smoothness task), the FSB was significantly greater than chance when participants voluntarily sampled a handkerchief at the fourth

sample, but equal to chance when participants sampled it in the pre-determined order. This result shows that voluntary sampling contributes to the final judgment regardless of the mere exposure effect and preferential touching, and it is the main source of the FSB.

General Discussion

We conducted three experiments involving two-alternative forced-choice tasks using handkerchiefs. Experiment 1 showed that the FSB also appeared in the smoothness task regardless of preference. Experiment 2 showed that the handkerchief that was sampled once more compared to the other tended to be chosen more often, but not in the smoothness task. Experiment 3 showed that the FSB appeared when participants sampled a handkerchief voluntarily last, but not when participants sampled a pre-determined handkerchief last. These results show that the FSB appears regardless of sensory modalities and task via a direct coupling between sampling and choice. In addition, the mere exposure effect enhances the magnitude of the FSB in preference tasks.

Direct coupling between voluntary sampling and the final judgment could be a clue to understand the decision-making process. The final decision in two-alternative forced-choice tasks can be made by a difference in the value related to the choice and the evidence. For example, the diffusion decision model assumes that a decision is made when the accumulation of noisy evidence about a decision exceeds a threshold, which can account for the relationship between the speed and accuracy of decisions (Forstmann, Ratcliff, & Wagenmakers, 2016; Ratcliff, 1978). However, the difference in the value and the evidence are determined by both items, which should be acquired regardless of what item is sampled. For example, in a preference task, the difference in the value and the evidence would be observed equally when the less preferred item is sampled and when the preferred item is sampled. Therefore, the item that is being sampled should not affect the choice. However, the results in this study showed that sampling patterns modulated the choice.

In previous studies that have shown evidence of the FSB, participants sampled items one-by-one (e.g., Mitsuda & Yoshioka, 2015; Shimojo et al., 2003). Therefore,

they had to make a decision by comparing the feel of an item that was being sampled and remember the other item that was sensed in a previous sample. The difference between a live feeling and a feeling in memory, or a mechanism of comparing the two different types of feelings, could be another source of the FSB, which requires further investigation.

An interesting application of these results involves their use for marketing. According the present results, when a customer plans to purchase one item from two possible choices, presenting an item more frequently and last is expected to facilitate choosing that item. However, the current results demonstrate that this effect appears only when the customer samples the last item voluntarily, but not when he or she samples it passively. Therefore, guiding customers to sample a particular item last without their detection is required in order to facilitate their choosing the item.

Finally, we describe some limitations of this study. In two-alternative forced-choice tasks, the effect of the first sample is coupled with that of the last sample because the first sampled item is the same as the last sampled item in trials with an odd

number of samples. In the same fashion, the first sampled item is different from the last sampled item in trials with an even number of samples. In Experiment 1, there was no significant effect of the first sample, which shows that the first sample did not modulate the FSB significantly in this study. However, the precise effect should be examined using tasks with more than two items in which the first and last samples are decoupled.

Next, in Experiment 3, participants were always required to sample handkerchiefs four times. Therefore, in part of the trials, they might have already made a decision at the third sample, and the fourth sample might have been just for confirmation. In that case, the third sample might have been the final sample before making a decision, and, in effect, the fourth sample might not have reflected the final sample. However, just checking the fourth sample could change the value of the item and the decision, which we sometimes experience in daily life.

Furthermore, even if the touching was just for confirmation, participants had to select a handkerchief to touch, and they selected the handkerchief that they were willing to choose. If the confirmation was performed to increase information about the two

handkerchiefs, participants may have touched the handkerchief that they were not willing to choose because both handkerchiefs provide equal information about the difference between the two handkerchiefs. Therefore, participants' tendency to sample the handkerchief that they were willing to choose just for confirmation also shows the importance of sampling an item before making a decision to choose it. However, the causal relationship between the final voluntary sample and the decision requires further investigation. In case that the final sample was for confirmation, the sample might reinforce the decision or the decision might drive the final sample to the chosen handkerchief. This study could not clearly dissociate these two possibilities owing to participants' tendency to sample the two items evenly. In future studies, it is necessary to break down sampling patterns in order to determine the difference between considerations and confirmations of a decision.

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Declaration of Conflicting Interests

There are no conflicts of interest to declare.

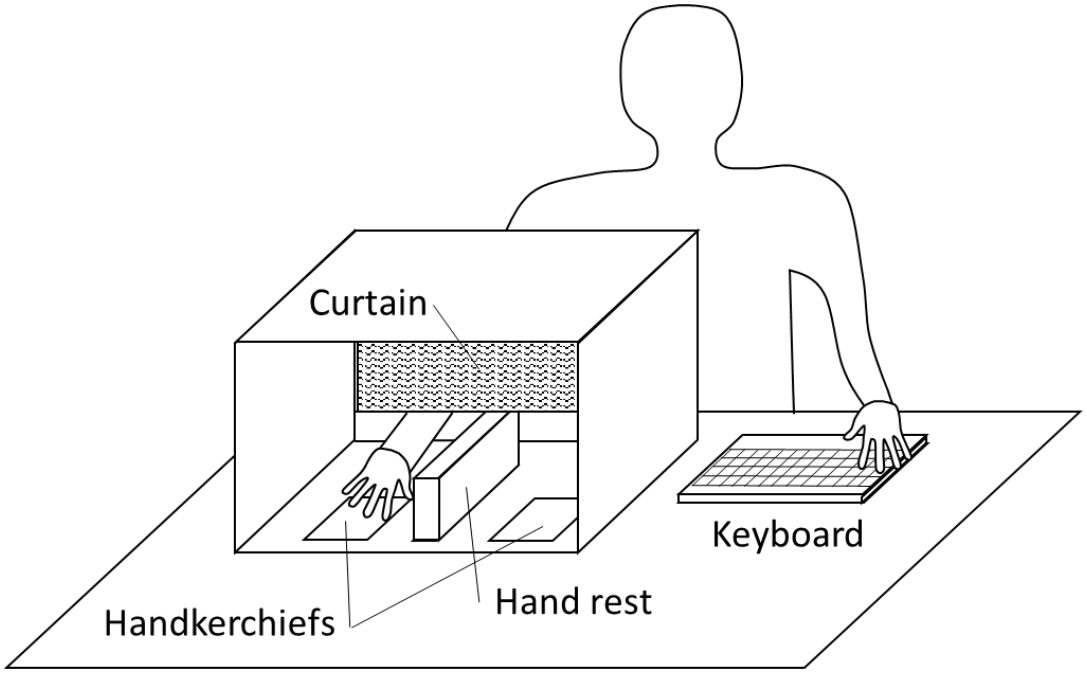

Figure 1. Experimental apparatus

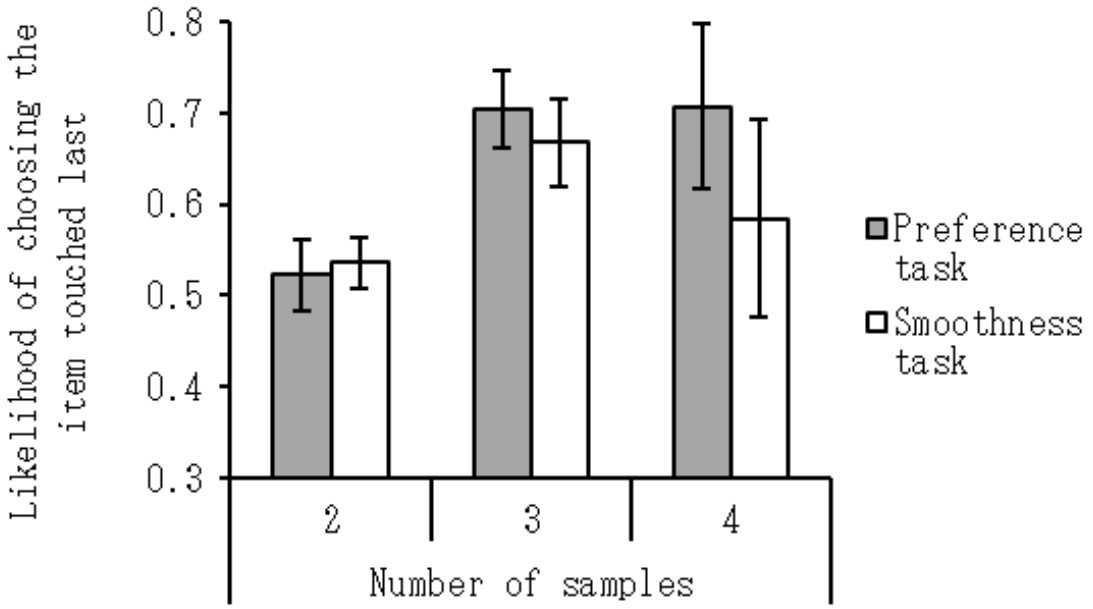

Figure 2. The likelihood of choosing the item touched last by the number of samples in Experiment 1

Note: Error bars represent standard error of the mean

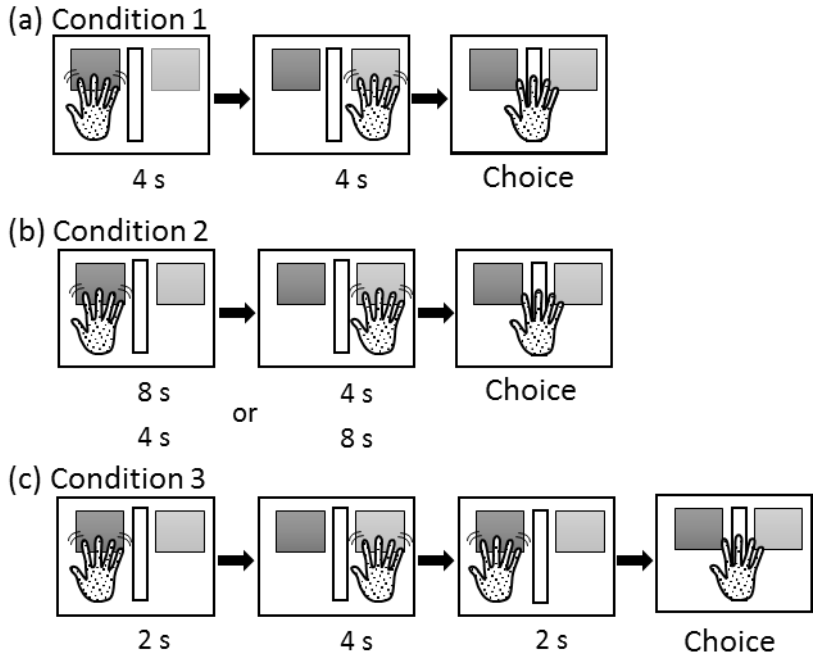

Figure 3. Predetermined sampling patterns of two handkerchiefs before choosing one in Experiment 2

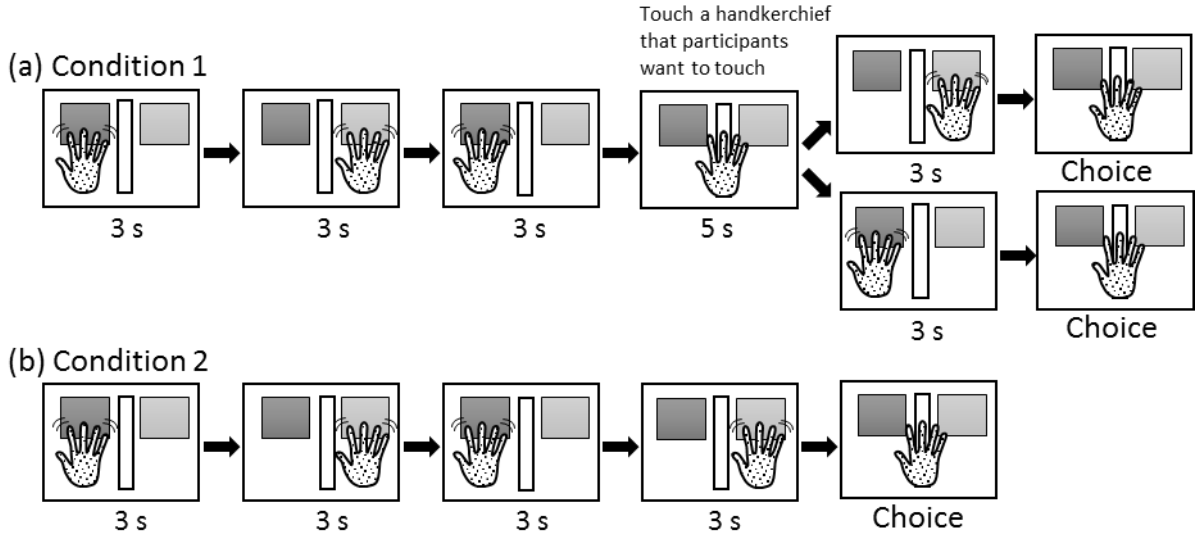

Figure 4. Sampling patterns of two handkerchiefs before choosing one in Experiment 3

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