Preference modulates smelling behaviour in olfactory decision tasks

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Abstract

When people are shown a pair of images and asked to identify which one is more attractive, their gaze shifts to the image they eventually choose prior to making a decision. Many researchers have examined the relationship between this gaze bias and decision processes, but not relationships between other sensory modalities and decision processes. This study examined behaviour in olfactory decision tasks. In accordance with the concept of gaze bias, the likelihood of participants smelling the item they eventually chose immediately before the decision was greater when they were instructed to identify an item that was more favoured versus less favoured. In addition, the likelihood of smelling the item that was eventually chosen last was also greater than chance when participants were instructed to identify which item was more masculine. These results suggest that a bias to sample a chosen item last is a common phenomenon regardless of sensory modality.

Keywords: preference, decision making, olfaction, odour, like, dislike

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While choosing which of two items is preferred, people compare the items by alternating looking at them. The pattern of eye fixations, including their number, timing, and duration, have been analysed because they are informative about the decision making process (Russo, 2010). Previous studies have shown that just before a preference decision is made, gaze tends to be directed to the preferred item (Glaholt & Reingold, 2009; Mitsuda & Glaholt, 2014; Nittono & Wada, 2009; Schotter, Berry, McKenzie, & Rayner, 2010; Shimojo, Simion, Shimojo, & Scheier, 2003). Furthermore, total viewing time during preference decision tasks is longer for the chosen versus non-chosen item (Glaholt & Reingold, 2009; Mitsuda & Glaholt, 2014; Nittono & Wada, 2009). These results have been explained by a computational model in which gaze on an item increases the decision value until a decision is made (Krajbich, Armel, & Rangel, 2010). However, the model cannot account for the finding that the likelihood of directing gaze to the chosen item just before the decision was attenuated when people had to choose which item they disliked more (Mitsuda & Glaholt, 2014; Schotter et al., 2010; Shimojo et al., 2003). Schotter et al. (2010) suggested that the difference in the likelihood of final gaze on the chosen item was due to an additive effect of preferential looking: people tend to look at preferred items longer. The difference in likelihood of final gaze on the chosen item across conditions indicates that this bias is not a response-related phenomenon but reflects the decision making process; however, the source of the difference remains unknown.

Gaze behaviour during decision tasks has been investigated in a number of studies. However, only a few studies have investigated sampling behaviour in sensory modalities other than vision, such as touch or smell. Lindsen, Moonga, Shimojo, and Bhattacharya (2011) showed that when people had to choose a preferred musical excerpt, they tended to sample the musical excerpt that they eventually chose just before making a decision, but this did not occur when they had to choose the excerpt they liked less. Recently, Mitsuda and Yoshioka (2015) showed a similar tendency in a preference decision task based on touch with handkerchiefs. These results indicate that the tendency for people to sample the item they eventually choose just before making a decision, called the “final sampling bias” here, might be a general phenomenon regardless of the sensory modality. However, more research is required to establish the generality of this phenomenon.

The purpose of the present study is to determine whether or not a final sampling bias exists in a two-alternative forced choice odour preference task. Odour preference plays an important role in daily activities such as food selection (Wagner et al., 2014) and sexual selection (Herz & Inzlicht, 2002; Rantala, Eriksson, Vainikka, & Kortet, 2006). Many studies have investigated the factors that affect odour preference; however, sampling behaviour when people choose a favourite odour has only been studied by Nakano and Ayabe-Kanamura (2013). They analysed sampling duration for odours when participants were asked to choose their preferred odour among multiple alternatives. However, they did not focus on a late stage of decision making or final sampling bias.

In Experiment 1, sampling behaviour was observed while participants were instructed to identify which aroma they liked more ("like task") or liked less ("dislike task"). If final sampling bias is a general phenomenon, regardless of sensory modality, then this bias should be larger for the like task versus the dislike task. In Experiment 2, a non-preference task was used, in which participants identified the aroma that was more masculine ("masculine task") or more feminine ("feminine task") to determine whether the final sampling bias is limited to preference decisions. Both experiments were approved by Ritsumeikan University Ethics Review Committee for Research Involving Human Participants.

Experiment 1

Methods

Participants

Fifteen volunteer students aged 20–24 years (8 male, 7 female) participated in Experiment 1. None declared any experience with olfactory disorders.

Materials

Thirty aromatic oils (Aroma Stick, NOL Corporation; described in the appendix) were used. Cotton balls were soaked in the aromatic oils and bottled separately.

Procedure

Participants were presented with a pair of aromas and asked to identify which one was more or less preferred. Participants sat in a chair, and two bottles were presented side-by-side on a table in front of them. Participants were instructed to freely smell the two aromatic oils inside the bottles and then to report which aroma they liked more (like task) or which aroma they liked less (dislike task) by holding out the chosen aroma bottle. To prevent any effect of right/left preference, participants were instructed to start by smelling the right aroma in the first pair, the left aroma for the second pair, and to continue alternating for each pair. Participants performed fifteen trials in each task. The thirty aromatic oils were randomly combined into pairs for each participant and for each task. All aromas were presented once in each task. No participants judged the same aroma more than once in either task. The like and dislike tasks were performed on separate days. The order of task was randomized across participants. The total experiment was completed in approximately twenty minutes each day. Participants' behaviour was recorded with a video camera.

Analysis

Smelling onset was defined using video editing software (Windows Live Movie Maker version 2011, Microsoft Cooperation) as the time when a participant held the bottle within 10 cm of their nose. The mean frame time was approximately 0.033 s (i.e. 30 frames per second). Time was rounded off to one decimal place. Therefore, the temporal resolution of the videos was 0.1 s. Smelling duration was defined as the time between the onset of smelling the left aroma and the onset of smelling the right aroma. Participants held each bottle to their nose in alternation. Neither consecutive holding of the same bottle to the nose, nor resting time without holding a bottle was observed. Smelling duration can be detected by measuring the airflow in a nostril, however, a simpler method of measuring smelling duration using video observation was adopted because it was difficult to distinguish between smelling and breathing based on airflow measurements. Furthermore, participants could evaluate the remaining scent in the nasal cavity after sniffing. Therefore, a smelling episode was defined as one or more consecutive actions between holding a bottle to the nose to holding the other bottle. Effect sizes were estimated using Cohen's d_z and Cohen's d for the standardized mean difference of effects for within-subjects and between-subjects designs, respectively (Lakens, 2013).

Results and Discussion

Table 1 summarizes the results of Experiment 1. The likelihood of choosing the aroma participants smelled last was greater than chance in the like task (t (14) = 5.15, p < .001, d_z = 1.3, d = 1.9), but not in the dislike task (t (14) = 1.13, p = .28, d_z = 0.29, d = 0.41). As expected, participants chose the last-smelled aroma more frequently in the like versus dislike task (t (14) = 2.44, p = .028, d_z = 0.63, d = 0.80); this is consistent with previous visual (Mitsuda & Glaholt, 2014; Nittono & Wada, 2009; Schotter et al., 2010; Shimojo et al., 2003), auditory (Lindsen et al., 2011), and haptic (Mitsuda & Yoshioka, 2015) preference studies. Moreover, there was no significant difference in decision time

(t (14) = 1.4, p = .17, d_z = 0.37, d = 0.47), or number of smelling episodes (t (14) = 0.81, p = .43, d_z = 0.21, d = 0.22) between the two tasks, indicating that task difficulty did not differ between the two conditions. The likelihood of choosing the aroma that was smelled first did not differ significantly from chance in either condition (like task: t (14) = 0.66, p = .52, d_z = 0.17, d = 0.24; dislike task: t (14) = 0.31, p = .76, d_z = 0.08, d = 0.11), consistent with a previous haptic (Mitsuda & Yoshioka, 2015) and auditory (Lindsen et al., 2011) preference studies.

Participants smelled the chosen aroma longer than the non-chosen aroma in the like task (t (14) = 4.1, p = .001, d_z = 1.1, d = 0.59); this is consistent with visual (Glaholt & Reingold, 2009; Mitsuda & Glaholt, 2014; Nittono & Wada, 2009) and haptic (Mitsuda & Yoshioka, 2015) studies. However, mean sampling duration (i.e., mean duration of a single sample) did not differ between the chosen and non-chosen aromas (t (14) = 0.46, p = .65, d_z = 0.12, d = 0.04). Therefore, the longer total sampling duration for the chosen aroma in the like task is due to more sampling of the chosen versus non-chosen aroma (t (14) = 4.1, p = .001, d_z = 1.0, d = 0.63). In the dislike task, there was no significant difference in total sampling duration between the chosen and non-chosen aroma (t (14) = 0.49, p = .63, d_z = 0.13, d = 0.06). These results are consistent with a previous haptic study (Mitsuda & Yoshioka, 2015). Meanwhile, the last sampling duration did not differ between the chosen aroma and non-chosen aroma in either condition (like task: *t* (14) = 0.94, *p* = .35, d_z = 0.20, *d* = 0.25; dislike task: *t* (14) = 0.58, *p* = .38, d_z = 0.23, *d* = 0.23). This is inconsistent with a previous visual (Mitsuda & Glaholt, 2014) and haptic (Mitsuda & Yoshioka, 2015) studies, in which the last sampling duration for the chosen item was significantly longer than the non-chosen item in the like task, but not in the dislike task.

(Table 1 about here)

Experiment 2

In Experiment 2, smelling behaviour during a non-preference task, in which participants identified the aroma that was more masculine (“masculine task”) or more feminine (“feminine task”), was examined to determine whether the final sampling bias is limited to preference decisions. Masculine and feminine tasks were used as non-preference tasks because a recent study found no significant correlation between pleasantness and either femininity or masculinity ratings for commercial perfumes (Lindqvist, 2012).

Methods

Participants

Fifteen students aged 20–24 years (7 male, 8 female) volunteered to participate in Experiment 2. None had participated in Experiment 1. None declared any experience with olfactory diseases.

Materials and Procedure

The aromas and procedure were the same as Experiment 1, except participants were asked to identify which aroma was more masculine or more feminine. The masculine task and feminine tasks were performed on separate days in randomized order.

Results and Discussion

Table 2 summarizes the results of Experiment 2. The likelihood of choosing the aroma smelled last was significantly greater than chance for the masculine task (t (14) = 2.8, p = .007, d_z = 0.72, d = 1.0), and slightly greater than chance for the feminine task (t (14) = 1.9, p = .075, d_z = 0.50, d = 0.70), indicating that the final sampling bias also occurs in non-preference tasks. The likelihood was not significantly different between the two conditions (t (14) = 1.1, p = .30, d_z = 0.28, d = 0.31). However, the number of samples was only significantly larger for chosen than non-chosen aromas in the masculine task (masculine task: t (14) = 2.7, p = .02, d_z = 0.70, d = 0.34; feminine task: t

(14) = 0.84, p = .42, d_z = 0.22, d = 0.11).

Decision time was longer in the masculine versus feminine task (t (14) = 4.3, p < .001, d_z = 1.1, d = 0.93). There were also more smelling episodes before a decision in the masculine versus feminine task (t (14) = 3.9, p = .002, d_z = 1.0, d = 1.1). These results indicate that the masculine task was more difficult than the feminine task.

Smell duration did not differ between the chosen and non-chosen aroma in either task (masculine task: t (14) = 0.78, p = .45, d_z = 0.20, d = 0.12; feminine task: t (14) = 1.9, p = .08, d_z = 0.49, d = 0.20). The likelihood of choosing the aroma that was smelled first did not differ significantly from chance in either task (masculine task: t (14) = 0.83, p = .42, d_z = 0.21, d = 0.30; feminine task: t (14) = 1.1, p = .29, d_z = 0.28, d = 0.40), consistent with Experiment 1.

(Table 2 about here)

(Table 3 about here)

General Discussion

In this study, whether or not a final sampling bias occurs in odour preference tasks was examined. As expected, the likelihood of participants choosing the aroma they smelled last was greater than chance level in the preference tasks. Furthermore, participants chose the last-smelled aroma more frequently in the like versus dislike task. These results indicate that the final sampling bias observed in visual tasks is a general phenomenon across sensory modalities.

Originally, the phenomenon of the final sampling bias was shown in visual preference tasks by Shimojo et al. (2003). They suggested that gaze “gradually” shifts to the chosen item when people chose the liked image from a set of two images, by the time course of the likelihood on the chosen item until decision, which was called *likelihood curve*. They also suggested that the positive feedback loop between the mere exposure effect (Zajonc, 1968) and preferential looking enhanced the preference level and increased the likelihood of persons looking at the item that they ultimately chose. However, it has been suggested that the gradual increase in the likelihood curve does not reflect the actual behaviour in single trials by Nittono and Wada, 2009. Mitsuda and Glaholt, 2014 also showed that the gaze bias is mainly related to the final gaze prior to response. Accordingly, this study focuses on the likelihood of sampling the chosen item at the response for a decision (i.e. final sampling bias), which corresponds to the magnitude of the likelihood curve employed in previous visual preference studies.

Comparing the magnitude of the final sampling bias across studies is key to determining the source of this bias. Table 3 shows the magnitude of the final sampling bias in previous studies and the present study. A few previous studies did not present the final sampling bias numerically. Therefore, the final sampling biases for these studies were scanned from the graph of the likelihood curve of sampling the chosen item.

All previous studies that used like and dislike tasks found that the final sampling bias was larger for like compared to dislike tasks. Shimojo et al. (2003) suggested that bias was smaller for the dislike task because dislike decisions were based on criteria that were more objective than preference. However, Glaholt and Reingold (2009) and Nittono and Wada (2009) found that the final gaze bias was similar in non-preference and like tasks; therefore, the final gaze bias is not limited to preference decisions. Furthermore, based on the finding that the magnitude of the bias for non-preference tasks (e.g., new versus old judgments) was intermediate between the bias for like and dislike tasks, Schotter et al. (2010) suggested that this bias was due to the additive effect of preferential looking. The results of present study, in which the magnitude of the bias for the masculine task was in-between the biases for like and dislike tasks, are consistent with Schotter et al.

At the same time, the significant difference in the number of samples between the chosen and non-chosen aromas in the masculine (not feminine) task indicates that sampling bias varies as a function of task difficulty, regardless of preference. This is consistent with Glaholt and Reingold (2009), who suggested that gaze bias reflects selective encoding of task-relevant information. Mitsuda and Yoshioka (2015) also found that the final sampling bias in a haptic preference task varied with task difficulty. A difference in bias between easy and difficult tasks was also reported in a study with visual tasks (Shimojo et al., 2003). Therefore, it is possible that the effect of task difficulty on the final sampling bias is a general phenomenon, and is not specific to one sensory modality. Furthermore, effects of task difficulty could explain differences in the final sampling bias between previous studies. However, it should be noted that there is a limitation in this study that the task difficulty, which is relevant to pairing aromas, was not controlled directly, though the paring aromas were randomized for each participant and task.

In addition to the final sampling bias, the biases in the number and duration of sampling were observed in this study. The results of this study revealed that participants smelled the chosen item significantly longer than the non-chosen item in the like task, but not in the other tasks, which is consistent with a previous haptic study (Mitsuda & Yoshioka, 2015). This could be indicative of a *preference sampling effect*, where people tend to sample the preferred item more often, as shown in preferential looking tasks (Birch, Shimojo, & Held, 1985). Another possibility is that there is a mere exposure effect (Bornstein, 1989; Zajonc, 1968), such that longer smelling duration increases preference for and the likelihood of choosing that aroma. The mere exposure effect influences odour preference decisions (Balogh & Porter, 1986; Prescott, Kim, & Kim, 2008). Furthermore, Shimojo et al. (2003) indicated that longer gaze duration increased the likelihood of choosing that item, implying that exposure effects also contribute to differences in sampling durations between items in a single trial. Therefore, the preference sampling effect and the exposure effect could be a source of the higher final sampling bias for the like task in this study. However, additional studies are required to determine if preference sampling and/or exposure effects contribute to performance in olfactory preference tasks.

In prior visual studies, the mean duration of single gaze samples differed between chosen and non-chosen items (Glaholt & Reingold, 2009; Mitsuda & Glaholt, 2014; Schotter et al., 2010). In contrast, no significant difference in mean sampling duration was observed between the chosen and non-chosen aroma in this study. In this study, the longer total sampling duration for the chosen versus non-chosen item was due to more sampling episodes for the chosen than non-chosen item. Mitsuda and Yoshioka (2015) did not find a significant difference in mean sample duration between the chosen and non-chosen items in a haptic preference task using handkerchiefs. The difference between the visual preference tasks and non-visual preference tasks was also found in the duration of the final sampling just before the decision. The final sampling duration was significantly longer when the gaze was on the chosen item than the non-chosen item in a visual preference study (Mitsuda & Glaholt, 2014). However, the final sampling duration did not differ between the chosen item and the non-chosen item in this study and a previous haptic study (Mitsuda & Yoshioka, 2015). These results indicate a qualitative difference between visual sampling (i.e. gaze) and manual sampling, such as smelling (i.e. moving a bottle to the nose and smelling) or touching handkerchiefs. Additional studies are required to clarify the difference between visual and manual sensing in decision tasks.

Another issue in the final sampling bias is the relation to the *primacy* and *recency* effect: early and late presented items are tended to be recalled well (Glanzer & Cunitz, 1966). Mantonakis, Rodero, Lesschaeve, and Hastie (2009) found that the first tasting wine had a large advantage in preference choice. The advantage of the firstly sampled item was also shown in preference tasks using humans, social groups and consumer goods (Carney and Banaji, 2012). Contrary to these findings, this study showed no significant effect in choosing the firstly sampled item. This contradiction can be explained by the different sampling manner across these studies. The participants in the former studies were asked to choose an item at the end of successive sampling determined by the experimenter. In contrast, the participants in this study were able to sample items freely until their decision. However, the slight bias in the likelihood of choosing the first sampled item in this study (0.52), which was also observed in a previous a visual (Schotter et al.,2010: 0.53) and auditory (Lindsen et al., 2011: 0.54) preference studies, might show the influence of the primacy effect. In addition, it was also reported that the last sampled item had an advantage in preference choice (Mantonakis, et al., 2009). Therefore, the primacy effect could affect the sampling behaviour and the recency effect could also be a source of the final sampling bias in this study. Future research is required to investigate these issues.

In summary, the present study revealed a final sampling bias in olfactory decision tasks, suggesting that this bias is a general phenomenon that is independent of sensory modality. The significant bias observed for non-preference tasks indicates that the final sampling bias is not limited to preference formation. In addition, the longer sampling duration for the chosen versus non-chosen item in the like task may indicate an effect of preference sampling and/or a mere exposure effect in olfactory preference decisions. These results are informative for understanding the relationship between sampling behaviour and decision processes.

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APPENDIX

List of aroma oils used for Experiments 1 and 2

Combination of musk fragrance and balsamic.
Orange, lemon, and young leaves.
Mild refreshing.
Light citrus.
Tropical.
Refreshing unisex style.
Soap.
Blueberry.
Clary sage.
Combination of rose and fruits.
Jasmine.
Honeysuckle.
Grapefruit.
Magnolia.
Sandalwood.
Lily of the valley.
Rose.
Green apple.
Raspberry ketone.
Lavender.
Coriander.
Coffee.
Rose and peach.
Spearmint and mandarin.
Strength and modest.
Peach, rose and vanilla.
Coriander and rosemary.
Fruity and floral.
Pineapple and papaya.
Lily of the valley, white lily, narcissus, and freesia.

Table 1

Summary of Experiment 1 results

	Like task		Dislike task	
Likelihood of last chosen	0.70 (0.04)		0.56 (0.05)	
Likelihood of first chosen	0.52 (0.04)		0.51 (0.04)	
Decision time (s)	6.4 (0.4)		7.6 (0.9)	
Number of samples	2.78 (0.17)		2.65 (0.15)	
	Chosen	Not-chosen	Chosen	Not-chosen
Total sampling duration	3.5 (0.2)	3.0 (0.2)	3.9 (0.5)	3.8 (0.4)
Mean sampling duration	2.4 (0.2)	2.4 (0.2)	2.8 (0.2)	2.9 (0.2)
Mean duration of final sample	2.5 (0.2)	2.7 (0.2)	3.1 (0.3)	2.9 (0.2)
Number of samples	1.50 (0.10)	1.28 (0.07)	1.36 (0.09)	1.29 (0.07)

Note. "Likelihood of last chosen" and "Likelihood of first chosen" are the likelihood of choosing the aroma participants smelled last and first, respectively. Values in parentheses indicate standard error of the mean.

Table 2

Summary of Experiment 2 results

	Masculine task		Feminine task	
Likelihood of last chosen	0.63 (0.05)		0.58 (0.04)	
Likelihood of first chosen	0.47 (0.04)		0.45 (0.04)	
Decision time (s)	9.5 (0.6)		7.5 (0.5)	
Number of samples	2.95 (0.15)		2.42 (0.10)	
	Chosen	Not-chosen	Chosen	Not-chosen
Total sampling duration	4.9 (0.3)	4.7 (0.4)	3.9 (0.3)	3.7 (0.2)
Mean sampling duration	3.2 (0.2)	3.4 (0.3)	3.2 (0.2)	3.1 (0.2)
Mean duration of final sample	3.1 (0.2)	3.0 (0.3)	3.2 (0.2)	3.4 (0.2)
Number of samples	1.52 (0.08)	1.43 (0.07)	1.22 (0.06)	1.20 (0.04)

Note. "Likelihood of last chosen" and "Likelihood of first chosen" are the likelihood of choosing the aroma participants smelled last and first, respectively. Values in parentheses indicate standard error of the mean.

Table 3

Final sampling bias in previous studies and the present study

Study	Stimuli	Like	Dislike	Other
Shimojo et al., 2003	Faces	0.83[a]	0.56[a]	0.66[a] (Roundness)
Glaholt & Reingold, 2009	Photographic art	0.81	-	0.77 (Recency)
Nittono & Wada, 2009	Graphic patterns	0.84[a]	0.80[a]	0.81[a] (Brightness)
Schotter et al, 2010	Various photographs	0.75	0.64	0.69 (Older) 0.68 (Newer)
Mitsuda & Glaholt, 2014	Faces	0.79	0.71	-
	Scenes	0.82	0.75	-
Lindsen et al., 2011	Music excerpts	0.73	0.44	-
Mitsuda & Yoshioka, 2015	Handkerchiefs	0.62	0.49	-
Present study	Aroma oil	0.70	0.56	0.63 (Masculine) 0.58 (Feminine)

Note. [a]value scanned from the graph in the paper