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Tablet Screen-Touch Behavior with Audiovisual Stimulus Consequences in the Common Marmoset (*Callithrix Jacchus*)

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The common marmoset is a nonhuman primate with a body size similar to an adult rat (approximately 250 – 450 g). This study examined the use of marmosets for behavior research on learning, focusing on the behavioral consequences of audiovisual stimuli (neither food nor liquid used as a reinforcer). A tablet (iPad®) was placed in each marmoset's individual living cage during the experiment. On the tablet screen, nine small soundless videos of different nonhuman primate species were simultaneously presented. If the marmoset touched any of them, the touched video was zoomed-in on the screen; this was accompanied by the sound of primates chattering as the response consequence. After 2 months of repeated training sessions (10 min/day, 2 or 3 days/week), eight of the ten marmosets established the screen-touch behavior. In an extinction test for the response consequence, the screen-touch response to any of nine primate videos was examined after the presentation of a black screen instead of the above consequence. The number of touch responses decreased compared with baseline control values in three marmosets, whereas responses did not decrease in four marmosets. For the latter marmosets, it was considered that the stimulus changes from the videos to the black screen played a possible reinforcer to maintain the behavior in this test. These findings indicate that the screen-touch behavior, a new learned behavior in the nonhuman primate, could be an operant behavior with an audiovisual response consequence.

Keywords: audiovisual consequence, common marmoset, sensory learning, tablet screen-touch behavior

コモンマーモセットのタブレット画面タッチ行動に対する視聴覚刺激の影響

コモンマーモセットはラットの成獣と同程度の大きさ(平均 250-450g) の非ヒト霊長類である。この研究では、視聴覚刺激（強化子として食物も液体も用いない）が行動に与える影響に焦点を当て、学習に関する行動研究にマーモセットを用いることを検討した。実験中、各マーモセットの個別の生活ケージにタブレット（iPad®）を設置した。タブレットの画面には、異なる種類の霊長類の小さな 9 つの無音動画が同時に映し出された。マーモセットがそのいずれかに触れると、触れた映像がスクリーン上で拡大表示され、反応の結果として霊長類の鳴き声が流れた。1 日 10 分、週 2〜3 日のトレーニングを 2 ヶ月間繰り返した結果、10 匹中 8 匹がスクリーンに触れる行動を獲得した。反応結果の消去テストでは、上記の結果の代わりに黒画面を提示した後、9 種類の霊長類ビデオに対するスクリーンタッチ反応を調べた。接触反応の回数は、3 頭のマーモセットではベースラインのコントロール値と比較して減少したが、4 頭のマーモセットでは減少しなかった。後者のマーモセットについては、ビデオから黒画面への刺激の変化が、このテストでの行動を維持するための強化子となった可能性が考えられた。これらの結果は、非ヒト霊長類の動物種における新たな学習行動である画面タッチが、視聴覚的な反応結果を伴うオペラント行動である可能性を示唆している。

キーワード：視聴覚的結果、コモンマーモセット、感覚学習、タブレット画面タッチ行動

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Comportamiento táctil sobre la pantalla de la tableta con consecuencias del estímulo audiovisual en el tití común (Callithrix Jacchus)

El tití común es un primate no humano con un tamaño corporal similar al de una rata adulta (aproximadamente 250 - 450 g). El presente estudio examinó el uso de titíes para la investigación comportamental durante el aprendizaje, centrándose en las consecuencias conductuales de estímulos audiovisuales (no se utilizaron alimentos ni líquidos como reforzadores). Durante el experimento, se ubicó una tableta (iPad®) en la jaula individual de cada tití. En la pantalla de la tableta se presentaron simultáneamente nueve vídeos sin sonido de diferentes especies de primates no humanos. Si el tití tocaba alguno de ellos, el vídeo tocado se ampliaba en la pantalla, lo que fue acompañado por el sonido de los primates comunicándose como consecuencia de la respuesta. Después de 2 meses de sesiones de entrenamiento repetidas (10 min/día, 2 o 3 días/semana), ocho de los diez titíes establecieron el comportamiento de tocar la pantalla. En una prueba de extinción para la consecuencia de respuesta, se examinó la respuesta táctil de la pantalla a cualquiera de los nueve vídeos de primates después de la presentación de una pantalla negra en lugar de la consecuencia previa. El número de respuestas táctiles disminuyó en comparación con los valores de control iniciales en tres titíes, mientras que las respuestas no disminuyeron en cuatro titíes. Para estos últimos titíes, se consideró que los cambios de estímulo de los vídeos a la pantalla negra jugaron un posible reforzador para mantener la conducta en esta prueba. Estos hallazgos indican que la conducta de tocar la pantalla, una nueva conducta aprendida en los primates no humanos, podría ser una conducta operante con una consecuencia de respuesta audiovisual.

Palabras clave: consecuencia audiovisual, tití común, aprendizaje sensorial, comportamiento táctil sobre la pantalla de una tableta.

The common marmoset (*Callithrix Jacchus*) is a nonhuman primate with a body size similar to a large adult rat (*Rattus Norvegicus*). approximately 250 – 450 g). The advantages of the marmoset as an experimental primate in the biomedical sciences have been recognized worldwide (Servick, 2018) (National Institutes of Health's 2019 Marmoset Community White Paper; https://www.marmohub.org/white-papers-1). Briefly, its advantages are small body size, gentle nature, and low zoonotic risk, leading to easy handling and care in the laboratory; its high birth rate, resulting in efficient reproduction and development of transgenic models; its short life span, which enables the study of normal aging and age-related diseases; and a brain structure similar to humans. Thus, it is suitable for neuroscience studies that require a developed prefrontal cortex, developed cognitive function, social behavior, vocal communication, developed motor function, and other features.

The present study explored the utility of the marmoset in the behavioral research of learning. Multiple research groups have already used the marmoset during learning studies with food or liquid reinforcement (Adriani et a., 2013; Glavis-Bloom et al., 2022; Mitchell et al., 2014; Nakamura et al., 2018; Yamazaki et al., 2016). These studies indicated that the marmoset is practical and easier to use for learning studies than than the rhesus monkey (*Macaca Mulatta*) with a heavier body weight and more aggressive nature. These studies also indicated that the marmoset is useful in the analysis of learning behavior in relation to the brain mechanisms because the marmoset brain structure is more developed than the rodent and relatively closer to the humans.

Several learning behavioral studies have used touch-sensitive technology, such as the Cambridge Neuropsychological Test Automated Battery (CATB) (Ozonoff et al., 2004), to measure multiple aspects of the learning process in marmosets and other animals (Crofts et al., 1999; Kangas & Bergman, 2017; Spinelli et al., 2005). In these studies, food or liquid reinforcement procedures were used to induce learning behaviors. However, to our knowledge, no studies have induced touch screen operant behavior through audiovisual or sensory stimulus consequences, rather than food or liquid reinforcement which typically involve deprivation, in the marmoset. Accordingly, the potential role of sensory stimuli as reinforcers of behavioral responses in the marmoset has not been established. Identification of sensory stimuli as potential reinforcers was considered a worthy aim.

In the present study, we attempted to establish a learning behavior in the marmoset using audiovisual stimulus consequences after a tablet (iPad®) screen-touch response (Experiment 1). A touch-response to any one of nine small soundless videos of different nonhuman primate species on the screen led to zooming-in on the touched video and the use of primate chattering sound as an audiovisual stimulus consequence. In Experiment 2, we evaluated extinction of the screen-touch behavior by removing the audiovisual stimulus consequence after the touch behavior had been established. The main aim of this study was to see if a different type of reinforcer other than food or liquid could be used for learning behavior.

Materials and Methods

Animals

Ethics

The protocol of the present study was reviewed and approved by the Animal Care and Use Committee of the present institute (the approval no. 14039). The criteria used by the committee complied with those mandated by Japanese law for the humane treatment and management of animals. The study was designed and conducted under the principle of the three R's: replacement, reduction, and refinement.

Husbandry

Fourteen healthy adult common marmosets were used in the present study. The sample size of the marmosets used for the present experiments was based on availability. The size was the maximum available number at the time of animal selection. Only male marmosets were available for the present study because all female marmosets at the research institute had been reserved for reproduction studies. Marmosets were obtained from CLEA Japan, Inc. (Tokyo, Japan; https://www.ciea.or.jp/en/laboratory_animal/marmoset.html). Their body weights and ages at the start of the experiment were 270–450 g and 2–7 years, respectively. They had no prior experimental histories involving learning behavior interventions or encounters with tablet or computer/television screens. The list of individual marmosets (ID) used in the present study is shown in Table 1.

Table 1

List of marmosets used for each experiment

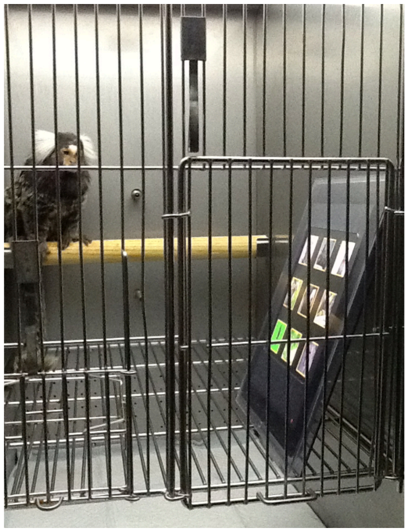
Experiment	Sample size (n)	Marmoset (ID)									
Experiment 1	10	AP21	AP22	AP23	AP24	AP25	AP27	AP28	AP29	AP30	AP31
Experiment 2	7	AP21	AP23	AP29	AP37	AP39	AP42	AP44	-	-	-

Note. All marmosets were male (their body weights: 270–450 g and ages: 2–7 years at the start of Experiment).
Experiment 1. Training of screen-touch behavior with an audiovisual stimulus consequence.
Experiment 2. Extinction of screen-touch behavior via removal of the audiovisual stimulus consequence.

Before the animal selection of the present study, all marmosets were socially kept in their group living cages (2 ~ 4 marmosets/cage) complied with the operating procedure to use the marmoset at the present institute. After the selection and during the experimental period for the present study, each marmoset was housed in an individual stainless-steel cage (50 cm high, 30 cm wide, and 48 cm deep) with wire walls and flooring (Figure 1). Approximately 50 g/day of balanced diet pellets (CMS-1M; CLEA Japan; https://www.clea-japan.com/en/products/general_diet/item_d0130) were given to each marmoset at the same time each afternoon. On days in which an experimental session was performed, the pellets were supplied after the session. The experimental sessions were conducted once per day in the afternoon, usually two or three times per week. Our pilot study performed with other marmosets than the ones in the present study showed that iPad® touching responses were stabilized in this session frequency rather than giving daily sessions. Tap water was available ad libitum from feed valves in each marmoset's cage. The animal room was illuminated from 08:00 to 20:00, and the temperature and humidity were maintained at 24–27°C and 40–60%, respectively.

Figure 1

A marmoset in its individual living cage



Note. A touch-sensitive tablet (iPad®) was placed in the cage immediately before the experimental session. The 10-min experimental session was conducted once per day, usually two or three times per week. The tablet screen presented nine small soundless primate videos, as shown in Figure 2.

Tablet and software

The tablet model used for the study was iPad® (Apple Inc., Cupertino, USA). Five iPads® (model MC769J/A) with a screen size of 9.7 in (24.6 cm) were used. The software (the part name: Marmoset Toy) was developed by Capeleaf Technologies (Yokohama, Japan; https://www.capeleaf.com/). This software allowed nine small soundless videos of moving nonhuman primates to be presented simultaneously on the iPad® screen (Figure 2). The locations of the nine small videos were not randomized; they were kept constant throughout the experiment. Each video on the screen was square (3 cm/side) and separated by 1.8 cm horizontally or vertically from the other videos.

The iPad® recorded the touch responses to the small soundless playing videos and produced an audiovisual consequence: zooming-in on the touched video on the screen, the disappearance of the other videos, and the sounds of nonhuman primate chattering (played via the iPad® speaker). The zoomed-in video was a 9 × 9 cm square located in the center of the screen. Each zoomed-in video was paired with one set of nonhuman primate chattering sounds. Videos and chattering sound recordings of nonhuman primates were separately purchased from Shutterstock.com and Stockmusic, respectively, by Capeleaf Technologies via the Internet in 2015. As these sources were purchased separately from different companies, the sounds were not able to match with the primate species shown in the zoomed-in video. The physical force required to activate the small videos was the factory default setting by Apple Inc. Touch responses to the spaces between the videos as well as other area of the iPad® were not recorded and did not elicit changes on the screen. Because of an annual commercial contract between our institute and Capeleaf Technologies, the software was available only for the present study via Apple Inc.'s ad hoc distribution method.

The supplier's material code names for the nine nonhuman primate videos are listed below, together with the numbers of each row (R) and column (C) for the locations in which they were shown on the iPad® screen (Figure 2). The supplier's material code names for the nonhuman primate chattering sounds are also listed below in parentheses:

R1 and C1: Black-capped squirrel monkey feeding (Ape).
R1 and C2: Gorilla baby sitting on his mother (Chimpanzee).
R1 and C3: Java macaque monkey (Chimpanzee 2).
R2 and C1: Khatta (Chimpanzee 3).
R2 and C2: Monkey 1 (Chimpanzee 4).
R2 and C3: Monkey and baby (Gorilla).
R3 and C1: Monkey eating fruit in front of green screen (Monkey).
R3 and C2: Monkey forest in Thailand (Monkey 2).
R3 and C3: Monkey portrait (Monkey 3).

Figure 2

Locations of nine different nonhuman primate videos on the iPad® screen, arranged in rows (R) and columns (C)

Note. These videos were soundless. The video locations were constant throughout the experiment (i.e., not randomized across trials as well as across sessions). Touching any of the videos resulted in zooming-in on the touched video only, along with playback of nonhuman primate chattering diffused through the iPad® speaker. Each chattering sound was not matched to the same primate species in each video. The videos and nonhuman primate chattering sounds were obtained from internet-based companies (see Tablet and software in Materials and Methods). The original source codes for the videos and nonhuman primate chattering sounds are listed in the text. Touch responses to spaces between the videos were neither detected nor recorded.

Experiment 1. Training of screen-touch behavior with an audiovisual stimulus consequence

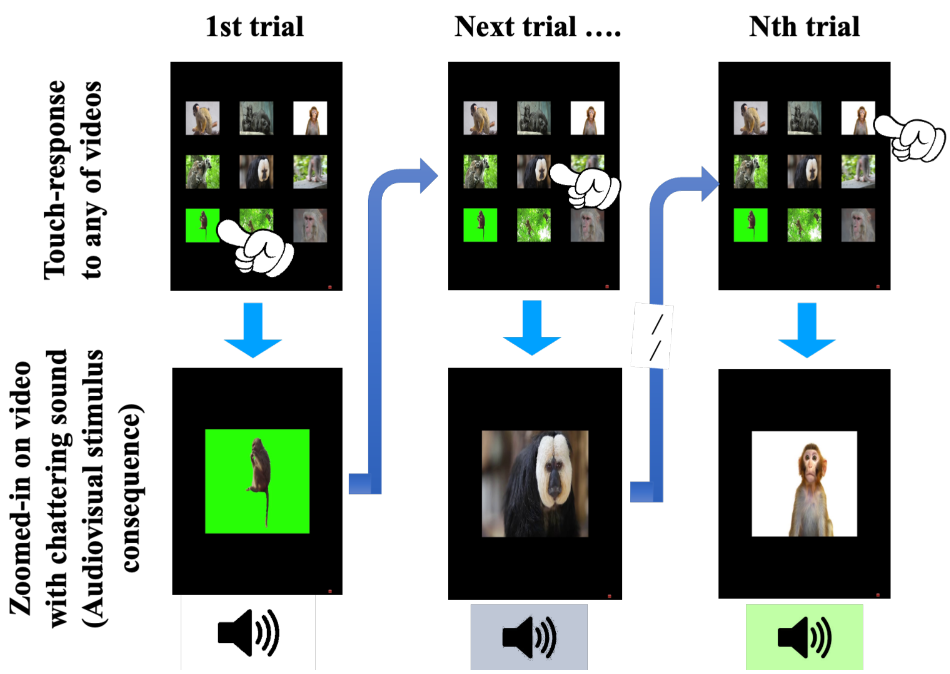
Touch-response training sessions were given to marmosets in their individual living cages, as shown in Figure 1. The iPad® was placed in the cage immediately before each experimental session. The 10-min session was conducted once per day, usually two or three times per week over 2 months.

To observe the touch response learning process in detail, data of 10 out of the 14 marmosets used for the present study were analyzed from the beginning of the shaping touch responses to the iPad® placed horizontally on the floor at the 0-degrees condition. The 10-min training sessions consisted of multiple trials. At the start of the first trial, nine small soundless playing videos of different nonhuman primate species were presented on the screen, as shown in Figure 3. If the marmoset touched any one of the nine videos, the other videos disappeared and the touched video was zoomed-in on the screen, accompanied by a nonhuman primate chattering sound. These stimuli were presented for 5 s as a touch response consequence. The trial was completed when the consequence (the combined presentation of the zoomed-in video and the nonhuman primate chattering sound) ended. Two seconds after the completion of the first trial, the next trial began in the same manner as the first. Within a trial, if 10 s passed without any touch response, that trial was terminated, and the next trial began, as described above. A session consisted of up to 10 min of multiple trials. If the 10 min threshold was exceeded in the middle of a trial because of the marmoset response, the session ended after the completion of that trial. The experimental parameters such as session time, inter-trial time, and audiovisual stimulus presentation time were determined by the results of the pilot study using other marmosets than in the present study. For example, it was found that a longer session time was not appropriate for maintaining the stabilized iPad® touch responses. This was different from the case of food or liquid reinforced behavior of animals with an appropriate degree of deprivation treatment.

Screen-touch responses were observed from the first shaping of the responses by a successively inclined iPad® through 0-degrees, 30-degrees and finally 70-degrees against the cage wall. If five or more touch responses occurred at the 0-degrees condition (horizontal placement), the iPad® was leaned against the wall at 30-degrees. If five or more touch responses occurred at the 30-degree inclination condition, the iPad® was leaned against the wall at 70-degrees (the final inclination condition). The touch-response establishment criterion was five or more touch responses per 10-min session in the 70-degree inclination condition for at least three consecutive sessions. When the touch responses reached the establishment criterion, the combination of the zoomed-in video and the chattering sound was considered to play inducing the intended learned behavior. The data for learning process observation in this Experiment 1 consisted of iPad® inclination conditions of 0-degrees, 30-degrees and 70-degrees against the cage wall.

Figure 3

iPad® touch training sessions conducted once per day, 2 or 3 days/week for 2 months



Note. Each session consisted of multiple trials. In each trial, nine soundless videos of different nonhuman primate species were simultaneously presented on an iPad® screen. A marmoset's touch response to any of the nine videos (indicated by the finger mark as an example) produced the audiovisual consequence (zooming-in on the video on the screen, as well as the nonhuman primate chattering sound playing from the iPad® speaker for 5 s). The subsequent trials were conducted in the same manner as the first with inter-trial intervals of 2 s. If no touch response to any video occurred within 10 s of the start of a trial, it was terminated, and the next trial was conducted 2 s afterwards in the same manner as above. A session consisted of up to 10 min of multiple trials. If the 10-min threshold was exceeded in the middle of a trial because of the marmoset response, the session ended after the completion of that trial.

Experiment 2. Extinction of screen-touch behavior via removal of the audiovisual stimulus consequence

Seven out of all 14 marmosets used for the present study were used for this experiment. Three of these marmosets were also used in Experiment 1. A year later, four additional marmosets were trained for this experiment in the same manner as in Experiment 1. These additional marmosets attained the same touch-response criterion described in Experiment 1.

First, to reconfirm the baseline level, the marmosets completed five baseline measurement sessions with the same procedures as in Experiment 1. Then, the extinction sessions were conducted. The procedures for the extinction sessions were identical to those in Experiment 1 except that the response consequence (i.e., zoomed-in video and chattering sound) was not presented. Instead, for the same 5-s period after the touch response to any of the nine videos, a black screen was presented without chattering sound as the touch-response consequence. Six marmosets completed 25 extinction sessions each. The remaining marmoset completed only 13 extinction sessions because this marmoset showed statistically significant level of decreased number of responses in the session against the values in the control baseline sessions before the extinction sessions.

Extinction was assessed by comparing the number of touch responses in the last five extinction sessions (i.e., extinction test sessions) to the number in the five baseline sessions conducted before extinction sessions. After the extinction test sessions, five post-extinction baseline sessions (i.e., baseline sessions after extinction sessions) were conducted in the same manner as the baseline sessions completed before the extinction sessions. These additional baseline sessions served as reference controls for the extinction test sessions; they also confirmed the stability of the screen-touch responses to an audiovisual stimulus consequence after the extinction sessions.

Statistical Analysis

The averaged data for all two experiments are expressed as means and standard deviations (SDs). For Experiment 1, quantitative data from the touch-response training as learning process and the established touch-response patterns are presented in a table and graphs without any statistical test.

For Experiment 2, the means and SDs of the touch responses of each marmoset were calculated under three conditions: the five baseline sessions (identical procedure as in Experiment 1), the last five extinction test sessions after 8 and 20 extinction training sessions in marmoset AP39 and in the other six marmosets, respectively, and the five baseline sessions (identical procedure as in Experiment 1) after the extinction test sessions. One-way repeated measure analyses of variance (ANOVAs) tests were performed to compare touch-responses among the three conditions for each marmoset. For marmosets with significant ANOVA results, Dunnett's tests were performed to compare the baseline measurements collected before the extinction sessions with data obtained during the five extinction test sessions, as well as data from baseline sessions after the extinction test sessions. The significance threshold was set to $p < .05$.

Results

Experiment 1. Training of screen-touch behavior with an audiovisual stimulus consequence

Data of ten marmosets trained to touch any of the nine videos on the iPad® screen to receive an audiovisual stimulus consequence were used for learning process observation by changing the rigid inclination conditions of the iPad® against the cage wall. As shown in Table 2, screen-touch responses in training sessions are presented for each marmoset. The number of marmosets that attained the establishment criterion (i.e., five or more touch responses on an iPad® screen placed at 70-degrees against the cage wall over three consecutive sessions) increased with repeated training sessions. Marmoset AP27 reached the criterion first in its tenth session, while other marmosets gradually reached the criterion thereafter. Marmoset AP21 was the last to pass the criterion in its twenty-third session over a 2-month period. Two marmosets (AP28 and AP30) did not attain the criterion within 20 sessions. They exhibited only sporadic touch responses to the videos when the iPad® screen was inclined at 30-derees against the cage wall. Therefore, they never advanced to the 70-degrees condition. Thus, the observation period of the iPad® touch responses for the learning process extended at most to the twenty-third session. For the baseline stability of the screen touch behavior after the acquisition, see the baseline data with variability (SDs) of means in Experiment 2 (Figure 8).

Table 2

Screen-touch responses in 10-min training sessions for individual marmosets

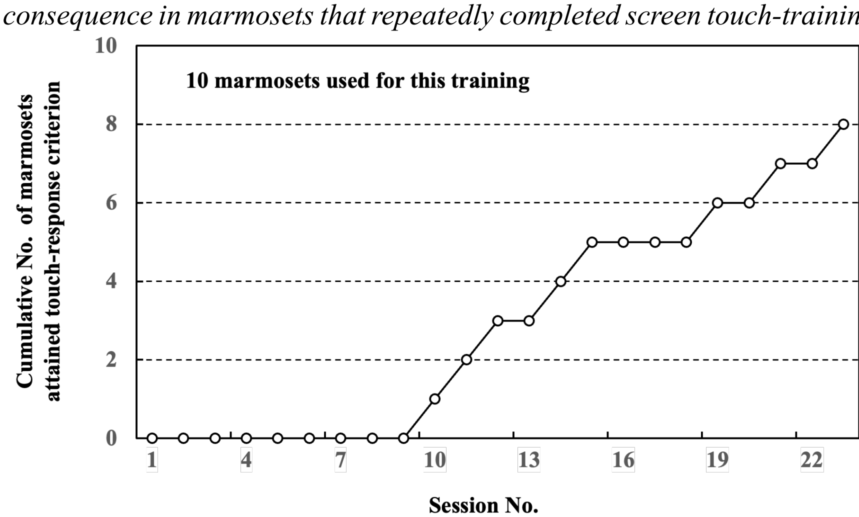
	Marmoset AP21		AP22		AP23		AP24		AP25		AP27		AP28*		AP29		AP30*		AP31	
Session No.	Tablet posi-tion	No. of touch response	Tablet posi-tion	No. of touch response	Tablet posi-tion	No. of touch response	Tablet posi-tion	No. of touch response	Tablet posi-tion	No. of touch response	Tablet posi-tion	No. of touch response	Tablet posi-tion	No. of touch response	Tablet posi-tion	No. of touch response	Tablet posi-tion	No. of touch response	Tablet posi-tion	No. of touch response
1	0°	0	0°	0	0°	0	0°	0	0°	8	0°	0	0°	0	0°	0	0°	0	0°	2
2	0°	7	0°	5	0°	2	0°	0	0°	1	0°	18	0°	0	0°	0	0°	0	0°	0
3	0°	10	0°	9	0°	4	0°	0	0°	16	0°	10	0°	7	0°	7	0°	0	0°	1
4	0°	8	0°	3	0°	15	0°	4	0°	10	0°	16	0°	2	0°	19	0°	9	0°	4
5	0°	5	0°	2	0°	17	0°	5	0°	20	30°	15	0°	12	0°	6	0°	2	0°	15
6	0°	3	0°	3	0°	21	0°	9	30°	13	30°	18	0°	13	0°	22	0°	11	0°	3
7	0°	10	0°	13	30°	12	0°	9	30°	15	30°	21	0°	18	0°	28	0°	9	0°	7
8	0°	5	0°	20	30°	10	0°	9	30°	9	70°	14	30°	1	0°	12	0°	17	0°	12
9	0°	22	0°	14	30°	10	30°	1	70°	15	70°	17	30°	1	30°	18	30°	0	0°	11
10	0°	13	30°	15	70°	13	30°	1	70°	16	70°	13	30°	8	30°	15	30°	1	0°	17
11	30°	20	30°	5	70°	15	30°	9	70°	8	-	-	30°	4	30°	17	30°	18	30°	17
12	30°	15	30°	13	70°	17	30°	6	-	-	-	-	30°	7	70°	17	30°	8	30°	10
13	30°	6	30°	11	-	-	30°	3	-	-	-	-	30°	7	70°	24	30°	2	30°	8
14	30°	12	30°	7	-	-	30°	10	-	-	-	-	30°	5	70°	24	30°	1	70°	8
15	30°	16	30°	7	-	-	30°	11	-	-	-	-	30°	4	-	-	30°	0	70°	12
16	30°	7	30°	11	-	-	30°	8	-	-	-	-	30°	9	-	-	30°	15	70°	9
17	30°	7	30°	13	-	-	70°	12	-	-	-	-	30°	8	-	-	30°	1	-	-
18	30°	10	30°	8	-	-	70°	14	-	-	-	-	30°	4	-	-	30°	0	-	-
19	30°	11	70°	11	-	-	70°	9	-	-	-	-	30°	3	-	-	30°	0	-	-
20	30°	8	70°	6	-	-	-	-	-	-	-	-	30°	4	-	-	30°	0	-	-
21	70°	12	70°	12	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
22	70°	10	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
23	70°	13	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-

Note. Data presented for the sessions up to the establishment criterion attained in each marmoset.
Tablet position: Angle (°) of iPad® inclined to the cage wall.
**: Two marmosets did not attain the criterion within 20 sessions.*

In Figure 4 an overview learning progress of screen-touch behavior in training sessions is presented. The cumulative number of marmosets that attained the established criterion indicates that 80% of the marmosets (8 of 10) achieved the criterion within 2 months.

Figure 4

Learning curve of touch-responses to any of nine soundless videos on iPad® screen for an audiovisual stimulus consequence in marmosets that repeatedly completed screen touch-training sessions (session duration: 10 min)

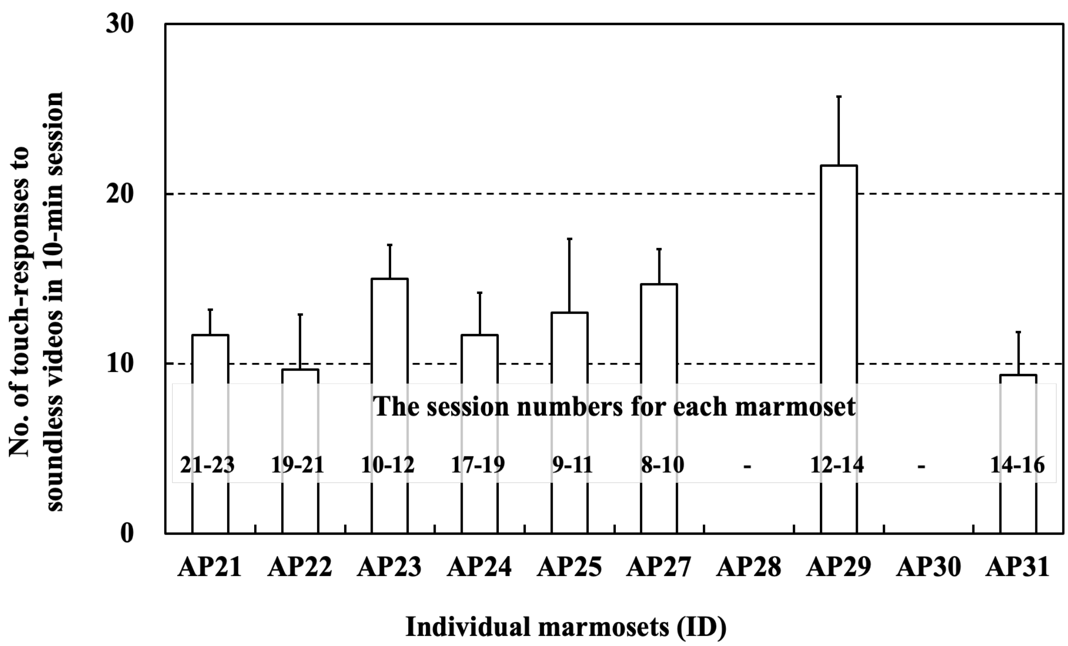


Note. The cumulative number of marmosets (out of 10) that attained the establishment criterion is presented over a maximum of 23 training sessions in a 2-month period. The criterion was five or more touch responses over three consecutive training sessions to any of the nine soundless videos on the screen when the iPad® was inclined at 70° against the cage wall.

For a more detailed examination of the learning process, the mean number of touch responses over three consecutive sessions (i.e., the session in which the response criterion was achieved, along with its preceding two sessions) for each marmoset is presented in Figure 5. The numbers of the three consecutive sessions are superimposed onto each bar. The bars for two marmosets, AP28 and AP30, are not presented because they did not reach the establishment criterion. The mean number of touch responses across the three days in the eight marmosets was almost 10 or more per session. The highest mean value of touch-responses was attained by marmoset AP29: more than 20 per 10-min session.

Figure 5

Mean and standard deviation of total video touch-responses over three consecutive sessions (i.e., the session in which the response criterion was achieved, along with its preceding two sessions) for each marmoset

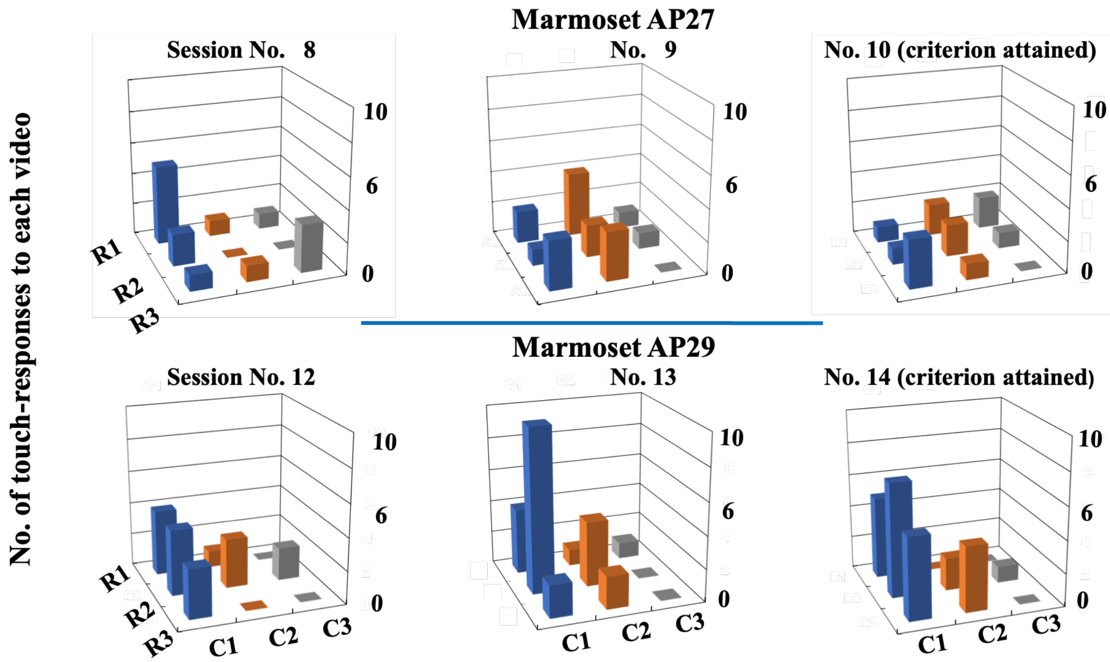


Note. The numbers of the three sessions are superimposed onto each bar. The establishment criterion for the video touch response is described in the legend of Figure 4. Two marmosets, AP28 and AP30, did not reach the establishment criterion by 20 sessions, so their bars are not presented.

Figure 6 depicts representative histograms of the response frequencies of two marmosets, AP27 and AP29, to each of the nine soundless videos on the screen. The right, center, and left positions illustrate the response frequencies in the sessions where the criterion was achieved, one session prior, and two sessions prior, respectively. The screen locations of these videos are shown in terms of the row (R) and column (C) on the screen in Figure 2. The touch-response distributions generally varied among videos in these marmosets as well as across sessions in each marmoset. In marmoset AP27, touching to the video at R1 and C1 ("Black-capped squirrel monkey feeding (Ape)") with a chattering sound ("Chimpanzee 2") was prominent in session 8. Thereafter, a general frequency increase in the touching to other videos in session 9 and roughly even frequency distribution in session 10 (criterion attained) were observed. In marmoset AP29, touching to videos at C1 column was higher than other videos in sessions 12, 13, and 14 (criterion attained) with a prominent touching to the video at R2 and C1 ("Black-capped squirrel monkey feeding") with a chattering sound ("Ape") in session13. This prominent number of touching decreased in session 14.

Figure 6

Representative histograms of touch responses to nine videos in the session in which the establishment criterion was attained (right) and the two sessions prior (center and left) for marmosets AP27 and AP29

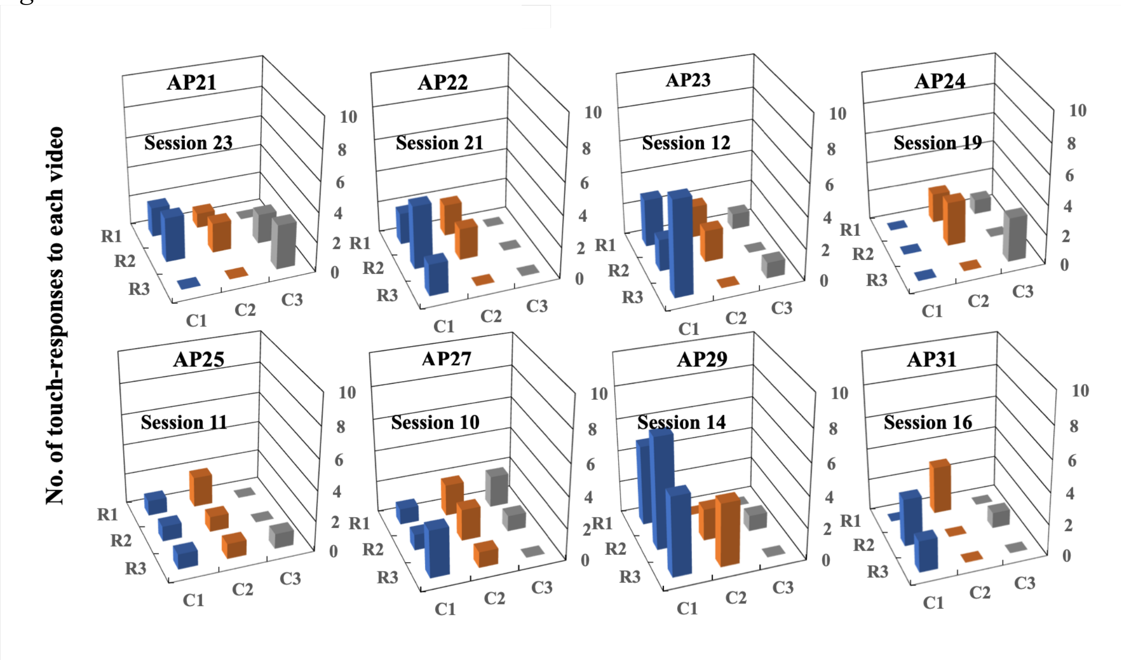


Note. The locations of the touched videos on the Pad® screen are expressed in terms of row (R) and column (C) as shown in Figure 2.

In Figure 7, histograms of the response frequencies of all eight marmosets in the sessions who attained the criterion are presented. Biased frequency distribution to the nine videos were observed in all marmosets but the degrees of the biased frequency differed across marmosets.

Figure 7

Histograms of touch responses to nine videos in the session in which the establishment criterion attained in eight marmosets



Note. The locations of the touched videos on the Pad® screen are expressed in terms of row (R) and column (C) as shown in Figure 2. The marmoset ID and the session attained the criterion for each marmoset are presented in each histogram.

Experiment 2. Extinction of screen-touch behavior by removal of the audiovisual stimulus consequence

We examined the extinction of touch-responses in terms of whether the touch-responses to any of the nine soundless videos decreased if the response consequence was a blank (black) screen with no primate chattering sound (Figure 8). Twenty-five extinction sessions were conducted in six marmosets. On the other hand, thirteen extinction sessions were conducted in one marmoset (AP39) because this marmoset displayed clear extinction earlier than the other six marmosets.

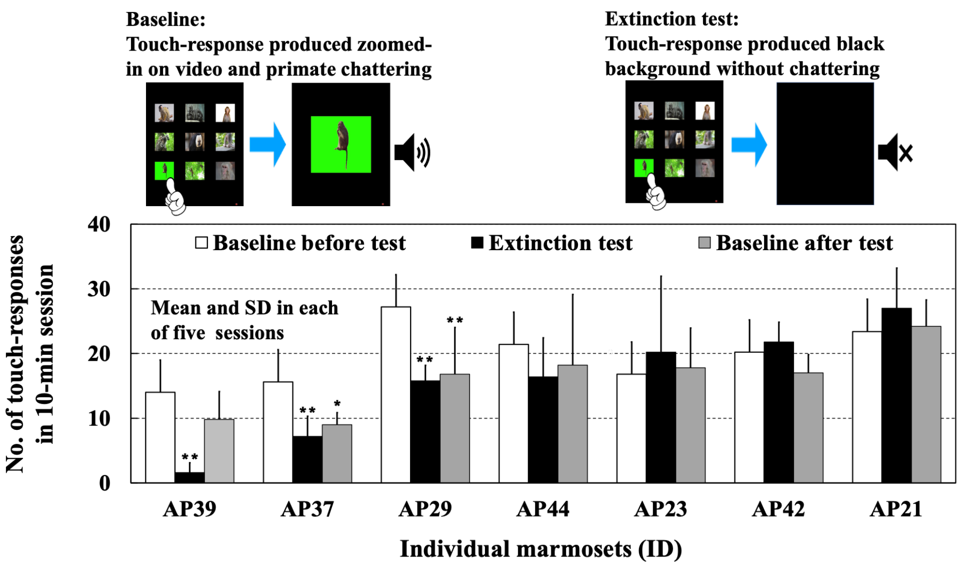
Among these sessions, the touch response data from the last five extinction test sessions (sessions 21–25 for the six marmosets and sessions 9–13 for marmoset AP39) were compared with baseline sessions conducted before and after the extinction sessions. The procedures of the baseline sessions were identical to those of Experiment 1. Extinction test sessions (for 21–25) were selected based on the assumption that extinction, if it occurred, would be most easily detected in these last test sessions.

The means and standard deviations of the touch responses for all three conditions (baseline sessions before the extinction sessions, extinction test sessions, and baseline sessions after the extinction sessions; five sessions each) are presented for each marmoset in Figure 8. A repeated measures ANOVA for the number of touch responses in each marmoset detected significant differences among the conditions in marmosets AP39 ($F(2,12) = 18.36$, $p < .01$), AP37 ($F(2,12) = 7.34$, $p < .01$), and AP29 ($F(2,12) = 9.78$, $p < .01$). For the other four marmosets, the ANOVA did not detect a significant difference.

In the marmosets where the ANOVA results were significant, Dunnett's test results suggest that only three of the seven marmosets exhibited evidence of extinction as it follows. For marmoset AP39, the number of touch-responses significantly decreased during extinction test sessions compared with baseline sessions conducted before the extinction sessions, but no significant differences were detected between baseline sessions before and after the extinction sessions. These results indicated that extinction had occurred, and that the responses had recovered after the extinction sessions. In marmosets AP37 and AP29, the number of touch responses in the extinction test sessions was significantly reduced compared with baseline sessions before the extinction sessions; the level of touch responses in baseline sessions after the extinction sessions did not recover to the level in baseline sessions before the extinction sessions. In the other four marmosets, the number of touch responses in the extinction test sessions, as well as the number in baseline sessions after the extinction session, did not significantly differ from baseline sessions before the extinction sessions. In summary, extinction, represented by a decreased number of touch responses after removal of the audiovisual stimulus consequence, was observed in three marmosets but not in other four marmosets.

Figure 8

Extinction of touch responses to any of the nine soundless videos via removal of the audiovisual stimulus consequence (refer to iPad® screen diagrams above as examples)



Note. Touch response data from the last five extinction test sessions (sessions 9–13 for AP39 and sessions 21–25 for the other six marmosets) were used for the analysis The extinction test sessions were compared with baseline sessions that occurred before and after the extinction sessions, as shown in bar graphs. The mean touch responses in the extinction test sessions and baseline sessions after the extinction sessions were statistically compared with mean touch responses in baseline sessions before the extinction sessions (*: $p < .05$, **: $p < .01$ with Dunnett's test after one-way analysis of variance).

Discussion

Tablet screen-touch behavior with an audiovisual stimulus consequence

As shown in Experiment 1, touch behavior for any of the nine nonhuman primate videos on an iPad® screen was established in eight of ten marmosets after repeated training sessions over a 2-month period without any pretreatment of food or liquid deprivation.

One of the main topics to be considered is whether the present screen-touch behavior is operant in nature. In other words, did the enlarged primate videos with chattering sounds act as a reinforcer in shaping and maintaining the screen-touch behavior? If the observed touch-response to the videos was an operant response, then it would be considered sensory reinforced operant behavior. Accordingly, clear evidence of extinction would have been observed when the audiovisual response consequence was removed. However, this evidence was present for three marmosets in Experiment 2 (Extinction of screen-touch behavior by removal of the audiovisual stimulus consequence). It might be stated that the present screen touching is operant behavior maintained by audiovisual stimulus consequence at least in three out of seven marmosets. For the present marmosets which did not show extinction, the screen touching in the extinction sessions was considered to be maintained by a change from the videos to the black screen. In that sense, the sensory change itself could be a reinforcer for these four marmosets which did not show the present extinction. If so, it could be stated that the present screen-touch behavior could be a sensory reinforced operant behavior.

Although the above statement is not confirmed yet and there are many unresolved problems and limitations in the present study, our data indicated that the screen-touch behavior was at least a learned behavior with audiovisual stimulus consequence established by repeated training sessions. In our daily experiences, we observed that the marmosets initially paid attention to new objects introduced into their individual cages, but they eventually ignored these objects. This phenomenon of becoming indifferent to new objects is known as stimulus adaptation. We observed that sustained tablet screen-approach or screen-touch behavior was not induced in other naïve marmosets when an iPad® was introduced into the cage without the stimulus consequence. As these were our personal observations, additional control experiments (the response noncontingent experiment and the response contingent experiment as described in the following) may be required to examine the definite factors that shape and maintain screen-touch behavior in future studies.

In a potential response noncontingent control experiment, nine soundless videos could be presented for 5 s on an iPad® screen as in the same manner as in Experiment 1, but an enlarged video with chattering sound could be presented for 5 s regardless of the screen-touch response. Other conditions as well as the timings would be identical to the same as in Experiment 1. The touch responses to any of the soundless videos would be recorded. If the number of touch responses to any of the soundless videos in this control experiment would not be increased by training sessions, the screen-touch behavior in Experiment 1 would be determined as an operant behavior reinforced by the sensory stimuli.

In a potential response contingent control experiment, the nine soundless videos from the present study could be presented on an iPad® screen with the same timing as in Experiment 1, but the touch-response consequence would be a black screen. The conditions would be identical to the extinction test in the present study. But this response contingent experiment would be given to marmosets from the beginning to see that the stimulus change to the black screen could shape touch response to any of the nine soundless videos. This response contingent control experiment would test whether the screen-touch behavior emerged when the consequence was a black screen. Then, the stimulus change to the black screen would be finally determined to act as a reinforcer. These two control experiments (response non contingent and response contingent experiments) could enhance our understanding of the nature of the present screen-touch response as an audio-visually reinforced operant behavior.

Significance of performing studies on sensory reinforced behavior using experimental animals

Other than food or liquid reinforced operant behaviors, there have been many kinds of positively reinforced operant behavioral studies conducted using animals. These studies consisted of intravenously administered drugs as reinforcers in the rat (Weeks, 1962) and in the rhesus monkey (*Macaca Mulatta)* (Deneau et al., 1969), intracerebral stimulation with weak electrical currents as reinforcer in the rat (Olds, 1958), with chemical substances (Bielajew & Harris, 1991) or inhaled cigarette smoke as reinforcer in the rhesus monkey (Ando & Yanagita, 1981). These behaviors were reported to be strongly maintained by these reinforcers. In other words, various kinds of these reinforcers are able to shape and maintain these behaviors in the experimental animals without any special pretreatment of deprivation which are usually required to establish food and liquid reinforced behaviors.

Concerning the sensory reinforced behavior, there were historical reports on studies of the light on-set reinforced operant in the rat (Kish, 1955) and the watching operant for the moving electric toy train, visual chances of an array of food, feeding sounds, etc., in the monkey (Butler & Harlow, 1954). Our speculation, on the other hand, is that sensory reinforcers in these studies seemed to be not strong enough to shape and maintain operant behaviors in the experimental animals comparing to other reinforcers described above.

In our human life, various kinds of sensory or audio-visually reinforced behaviors are widely prevailed and penetrated. Therefore, understanding of these behaviors could be highly important, especially thinking of dependence syndrome (addiction) on excessive video game playing and long-time smartphone watching. Nevertheless, the analyses of these sensory reinforced behaviors using the experimental animals have not been reported so much as other reinforced behaviors. Therefore, we thought that it is significant to establish the present model on sensory reinforced operant behavior by using the experimental primate.

Use of the marmoset as an experimental primate in learning research

According to the present study and our previous research regarding liquid- or food-reinforced operant behaviors in the marmoset, the rhesus monkey (Ando et al., 2003), and the rat (Ando, 1975; Ando & Yanagita, 1992), the marmoset is considered to have potential utility as an experimental primate in learning research. However, although liquid-reinforced lever-pressing operant behavior could be shaped under conditions of moderate water deprivation in marmosets, this behavior was not strongly stabilized compared to behaviors in rhesus monkeys and rats with adequate deprivation pretreatment. The marmoset may not be sufficiently resilient to endure the degree of deprivation necessary for operant training compared to the macaque monkey and the rat. Operant behavioral baselines in rhesus monkeys (Ando et al., 2003) and rats (Ando, 1975) were easily shaped and maintained. These baselines are sensitive, stable, reliable, and useful for examining the effects of psychoactive substances in preclinical behavioral pharmacology studies. We have an impression that it might be difficult to obtain stabilized baseline behaviors in marmosets via liquid reinforcement. However, further research is needed to make appropriate comparisons between species.

In the present study, we examined the possibility of using marmosets for sensory reinforced operant experiments in the absence of food or liquid deprivation pretreatment. Although we established learning behavior, some problems and limitations remain for further studies. To our knowledge, no other studies have examined learning behavior using audiovisual stimulus consequences in the marmoset although the study on videos as reinforcer in the bonnet monkey (*Macaca Radiata*) have been already reported (Brannon et al., 2004). Our findings are likely to be useful to other researchers focused on sensory reinforced behavior in the experimental animals, as well as researchers investigating the use of the common marmoset as an experimental primate.

Future themes

The present study was performed to develop a model for audiovisual-stimulus induced behavior in the marmoset, but applications of this model require further investigation. An important avenue of research is the investigation of brain mechanisms underlying sensory reinforced operant behavior, especially in relation to the role of the prefrontal cortex. Future research based on the present study may enhance our understanding of human audiovisual reinforced behaviors related to the use of computers, tablets, smartphones, and others; it may also provide insights regarding factors that influence audiovisual-stimulus dependence syndrome in humans in the future.

Conclusion

This study demonstrated that tablet screen-touch behavior in the marmoset could be shaped and maintained by an audiovisual stimulus consequence, probably as a reinforcer. We expect that the present study might trigger other studies on sensory reinforcement in the common marmoset or other primate species. The questions and the limitations in the present study could be solved and cleared up in future studies. The common marmoset, a small experimental nonhuman primate, recognized worldwide as a useful laboratory primate, is expected to be also useful in the study area of sensory reinforced operant behavior in the field of neuroscience.

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