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RESEARCH ARTICLE

Effects of attentional behaviours on infant visual preferences and object choice

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Abstract
Many developmental studies have examined the effects of joint attention. However, it has been difficult to compare effects of initiating joint attention and responding to joint attention in infants. Here, we compared the effects of initiating joint attention and responding joint attention on object information processing, object preference, and facial preferences in infants. Thirty-seven infants (10 to 12 months of age) were shown stimuli in which a female gazed towards or away from an object. Participants were assigned to initiating joint attention condition or responding joint attention condition. Results suggest that initiating joint attention promoted object information processing, whereas responding joint attention did not. Both joint attention conditions affected the facial preference for the person who engaged joint attention. In addition, after initiating joint attention, infants chose objects gazed by other person more often than after responding joint attention. It appears that attentional behaviours that precede the perception of certain stimuli affect infants' cognitive responses to those stimuli.

Keywords Eye gaze · Visual preferences · Object choice · Initiating joint attention · Responding joint attention

Introduction

Eye gaze is one of the most important signals for nonverbal communication (Senju and Johnson 2009). It plays a critical role in directing and coordinating attention during triadic interactions between self, other, and the environment (Grossmann et al. 2013). Such triadic interactions have been called joint attention (JA) (Carpenter et al. 1998). Furthermore, JA has been examined in relation to language acquisition (Tomasello 1988; Mundy and Gomes 1998), and it has been suggested that JA facilitates social learning in young infants (Csibra and Gergely 2006, 2009). Also, JA appears to influence adults' preference for objects and human faces (Bayliss et al. 2013).

Infant research has provided evidence showing that eye gaze cueing towards objects affects infants' information processing of objects. For example, Reid and Striano (2005) familiarized infants with two objects, one that was gaze cued by an adult face and the other remained uncued. Thus, in this experiment, triadic elements comprised infants, adults and gaze-cued objects. After the familiarization period, both objects were presented simultaneously on left and right sides of a screen in front of the infants. The uncued object was viewed longer by the infants than the gaze-cued object. This outcome suggests that infants acquired information about the gaze-cued object during the familiarization phase, and that the longer time spent gazing at the uncued object reflected the infants' exploration and curiosity with respect to the unfamiliar object. Such preferential looking can be considered a novelty preference for uncued objects. Such facilitation of object information processing is also supported by studies utilizing EEG recordings (Hoehl et al. 2008; Striano et al. 2006). For instance, Hoehl et al. (2008) showed that the ERP component which reflects memory encoding was

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greater when an infant's eye gaze was directed towards an object than when it was directed away from that object.

Although infant studies suggest in that the amount of gazing time (to an object) reflects the degree of information processing for a particular object, Okumura et al. (2013) have proposed that the use of gaze cuing may also create preferences for cued objects in subsequent choice tests. They found that although infants spent more time looking at an uncued object than a cued object, the cued object was chosen significantly more often than the uncued object in the object reaching task. These results suggest that cued eye gazing may affect choice behaviour in infants.

Adult research has shown that gaze cuing directed towards an object can subsequently affect an individual's choice of that object (Bayliss et al. 2013). Also, gaze-cuing situation affects not only object preference, but also face preference for gaze shifter. Human faces that produce JA gaze shifting (i.e. looking in the same direction as the participants) are preferred (Bayliss et al. 2013). This suggests that JA gaze may influence face preference. Although the effect of facial familiarity on gaze-cued object processing has been examined (Hoehl et al. 2012), no study has tested the effects of JA gaze cuing on face and object preferences in infants.

Generally, the joint attending, associated with JA, falls into two categories: responses to the bidding of others or spontaneous initiations (Mundy and Newell 2007). Responsive joint attention (RJA) refers to infants' ability to react to, i.e. follow the direction of, another's gaze thereby sharing a common point of reference. On the other hand, the initiation of joint attention (IJA) refers to a response category involving one infant's use of eye contact to direct the attention of others to objects, to events, and even themselves.

From an early developmental stage, infants start to follow parents' eye gaze, using RJA to increase the likelihood of attending to a correct object in incidental novel-word-learning opportunities (Baldwin 1995). Many infant studies have used eye tracking to examine object learning by means of RJA (Okumura et al. 2013).

Although RJA has been considered in the context of relationships with inanimate objects, including triadic interactions, it has been suggested that IJA encompasses the more social aspects of JA (Mundy and Newell 2007). In fact, the IJA figures in the context of autism spectrum disorders (ASD). Specifically, IJA impairment has been described as "the lack of spontaneous sharing experiences with others such as showing" in the current American and European psychiatric diagnostic systems (Mundy 2003). Bayliss et al. (2013) has shown that IJA affects preference for human faces that follow adult participants' gaze. Therefore, it is possible that social preference for others involved in the triadic interactions may also be affected by IJA in infants.

Some evidence has suggested that, respectively, different cognitive functions are involved in IJA and RJA. For instance, Mundy et al. (2016) indicated that children's recognition memory was significantly better for pictures studied in IJA situations than for those in RJA situations. This suggests that children can process information better in IJA situations. Although the nature of joint attending may differ in RJA versus IJA, developmental studies have mainly focused on the RJA behaviour of infants using paradigms involving cued gazing. Therefore, it is necessary to examine the effects on infants of adult gaze in IJA situations and compare them with RJA effects.

In the present study, we used a mock-IJA situation for infants (Ishikawa and Itakura 2018) and examined the effects of IJA on learning and preferences, we then compared the results for an IJA condition with those from the RJA condition. In an initial familiarization phase, 10–12-month-old infants were presented with two pictures of female faces depicted as turning their eye gaze either towards (JA condition) or away from (No-JA condition) an object presented on the left or right side of this depicted face. After this initial phase, two objects or two faces were then presented, respectively, in a gaze testing phase designed to assess the gaze of the infants. In addition, to examine the effects of eye gaze on the infants' choice of object, we conducted an object choice test. This test consisted of placing two real objects in front of a participant. In many infant studies that have used eye gaze as a cue, gaze shifters presented on the screen have typically shifted their gaze regardless of infant attention to the objects (infant RJA). Therefore, to induce infants to pay attention towards an object preceding gaze shifters (infant IJA), we presented one object per trial, and gaze shifters shifted their gaze after the target objects were presented (i.e. infant gaze was followed by a gaze shifter presented on the screen).

We predicted that, in the IJA condition, infants would look longer at the No-JA object than at the JA object in order to process the novel object in the object looking test. By contrast, they should choose the JA object more frequently than the No-JA object in the object reaching test. We also predicted that infants would show a preference for the JA face over the No-JA face. In addition, IJA would have much more effects on object processing, object preference, and face preference than RJA.

Materials and method

The experimental protocol was approved by the Research Ethics Review Board of the Department of Psychology, Kyoto University, Kyoto, Japan. The parents or caregivers of all participants provided written informed consent before their infants participated in this study.

Participants

In total, thirty-seven infants participated to this study. In the IJA condition, participants were eighteen 11–12-month-old infants (7 males, 11 females; mean age 372 days; range 352–390 days). In the RJA condition, participants were nineteen 10–12-month-old infants (12 males, 7 females; mean age 320 days; range 286–376 days). This sample size was decided on the basis of the findings of the previous infant study (Okumura et al. 2013). There is a slight difference of ages between IJA and RJA; however, infants over 9 months old are capable of following the gaze of others (Gredebäck et al. 2008); they also understand the relationship between an onlooker and an object (Woodward 2003). One infant who did not reach for any of the objects was excluded from the analyses because of inattentiveness.

Apparatus and stimuli

A Tobii (Stockholm, Sweden) T60 Eye Tracker, integrated with a 17-inch TFT monitor, was used to present stimuli and to record eye movements with a 60 Hz sampling rate (Tobii Studio 2.2.8, Tobii Technology). Participants were seated approximately 60 cm from the monitor. A five-point calibration was conducted prior to recording. The experiment consisted of two separate phases: a familiarization phase followed by a test phase (Fig. 1). To check the difference in infant learning phase, we also analysed the looking time in the familiarization phase. The stimuli used in the familiarization, test phases, and area of interests (AOIs) for the analyses are shown in Fig. 1.

In the familiarization phase, all faces were 5° wide and 7° high. There were three types of faces: (1) a direct gaze face for a pre-cuing stimulus, (2) a right-gazing face, and (3) a left-gazing face. An object was placed approximately 10° to the left or right of the centre of the screen per trial. We used four female faces and two toys for stimuli, edited in Adobe Illustrator CS5 (San Jose, CA). Totally, 60 images were created for familiarization phase. All female faces had the same level of attractiveness in the adult pilot study. We used the same toys used in the previous studies examined infant visual preference (Okumura et al. 2013; Ishikawa and Itakura 2019).

In the looking test phase, two faces or two objects were presented, respectively, and the order of presentation was counterbalanced across participants.

Procedure

In the familiarization phase, infants viewed six trials in each of two conditions (JA, No-JA). In the mock-IJA condition (shown in panel a of Fig. 1), we modified the procedure of

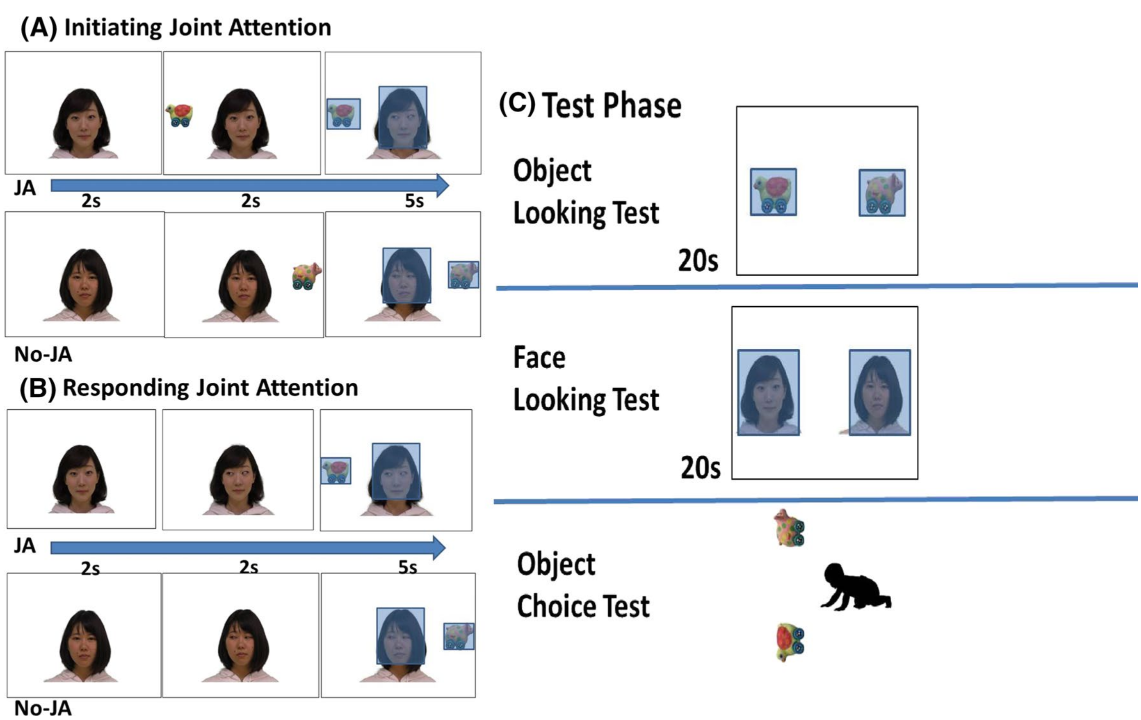

Fig. 1 Stimuli are used in the initial and test phases, including AOIs for analysis. All images were originally created for this study and persons represented in the figure have permitted to publish the images in all formats. **a** Illustration of the initial phases of an experimental trial in initiating joint attention condition. **b** Illustration of the initial phases of an experimental trial in responding joint attention condition. **c** Illustration of the test phases

Ishikawa and Itakura (2018), and each trial began with a picture of a female directly gazing towards the infant (2s); after this, one of two objects appeared on either the left or right side of the face (2s). Finally, the female turned her gaze direction either towards (JA) or away from (No-JA) the object (5s). By contrast, in the RJA condition (panel b of Fig. 1), each trial began with a picture of a female directly gazing towards the infant (2s), and after that the female shifted her gaze direction either right or left, (2s) with no objects in either direction. Finally, in the third presentation one of the two objects appeared on either congruent (JA) or incongruent (No-JA) place with the female gaze direction (5s). In other words, RJA condition was set up as Posner cueing paradigm (Posner 1980). The object's location changed in an ABBABA order. The pairs of objects and faces in each condition were counterbalanced across participants. All facial stimuli maintained a neutral facial expression.

After the familiarization phase, two looking tests were conducted (panel c of Fig. 1). In these tests, infants could look at objects or at faces. During these looking tests, either two objects or two faces were presented sequentially on a white background for 20 s. The order of presentation and the position of the objects/faces were counterbalanced across participants.

Finally, following the looking tests, an object choice test was conducted. The female assistant hided two objects on her back at first and then presented two objects for about 60 cm in front of the infant at the same time without looking any object. After infants were shown two real objects (JA object and No-JA object), their reaching behaviours were recorded.

Data analysis

In order to check that all infants watched familiarization phase enough, we set up the exclusion criteria for trials which had fixation time on the screen less than 2 s for each condition in the familiarization phase. However, no trial was excluded on these criteria (mean: 3.24 s, SD 1.11 s, range 2.15–4.92 s).

We used a clearview fixation filter for the eye-tracking data. Fixation was defined as gaze recorded within a 50 pixel diameter for a minimum of 200 ms, and this criterion was applied to the raw eye-tracking data to determine the duration of any fixation. The recorded sample's average percentage was 73.58% (SD 8.01%, range 62–91%).

In the familiarization phase, two AOIs were defined: (1) covering the face area (defined as "Face AOI"), and (2) covering the object area (defined as "Object AOI"). There were two AOIs in each of the two looking tests, one in which the infants gazed at the faces for a period of time, and the other in which the infants gazed at an object for a period of time. The first AOI was in the gazed object or face (named as "JA object" or "JA face" AOI) and the other was in the un-gazed object or face (named as "No-JA object" or No-JA face" AOI). In order to ensure that the observed effects arose from mock-IJA, the experimenter and the assistant checked that all infants looked at the object before the gaze shifter presented on the screen shifted their gaze direction (Ishikawa and Itakura 2018). All trials were confirmed as mock-IJA situations. Also, to ensure that observed effects arose from RJA, we checked that all infants looked at the face when the gaze shifter shifted her gaze direction. All trials were confirmed as RJA situations.

All eye-tracking data in the test phases were analysed based on the proportion of time the infants spent looking at either the face or the object. For analysis of fixation time in familiarization and test phase, we used the same statistical method as Ishikawa and Itakura (2018). Fixation time in the object looking test ($W = .963$, $p = .684$) and face looking test ($W = .969$, $p = .758$) was normally distributed, respectively, as determined by Shapiro–Wilk normality tests.

In the object choice test, all reaching behaviours were recorded and the experimenter and the assistant judged which object was reached by each infant. All coding was completely consistent between two coders.

Results

Mock-IJA condition

In the analysis of the total fixation time in the object looking test, we conducted a two-tailed t-test against chance levels (50%) for each of the JA and No-JA conditions. A significant difference between chance levels and No-JA objects was found ($t(17) = 2.188$, $p = .043$, $d = .76$), with a longer gaze duration at the No-JA object (54.89%) than at the JA object (45.11%).

In the analysis of the total fixation time in the face looking test, we also conducted a two-tailed t-test against chance levels (50%) for each of the JA and No-JA conditions. A significant difference between chance levels and the JA face was revealed ($t(17) = 3.31$, $p = .004$, $d = 1.05$), with a significantly longer gaze duration on the JA face (57.53%) than on the No-JA face (42.47%).

Finally, on the object choice test, infants robustly chose the JA object over the No-JA object (14 of 18 infants, binomial test, two-tailed, $p = .031$).

RJA condition

In the analysis of the total fixation time in the object looking test, we conducted a two-tailed t-test against chance levels (50%) for each of the JA and No-JA conditions, there was no significant difference between chance levels and each of the JA (52.11%) and No-JA (47.89%) objects ($t(19) = .449$, $p = .659$, $d = .015$).

In the analysis of the total fixation time in the face looking test, we conducted a two-tailed t-test against chance levels (50%) for each of the JA and No-JA conditions, a significant difference between chance levels and the JA face was revealed ($t(19) = 2.924$, $p = .009$, $d = .95$), with a significantly longer gaze duration on the JA (58.37%) face than on the No-JA face (41.63%).

Finally, on the object choice test, infants robustly chose the No-JA object over the JA object (15 of 19 infants, binomial test, two-tailed, $p = .0192$).

Comparison between IJA and RJA

To compare between the effects of IJA and RJA in the familiarization phase, a 2×2×2 mixed-effect ANOVA with two levels of JA condition (JA, No-JA), two levels of AOI (Face, Object) and two levels of JA types (IJA, RJA) was conducted. A significant main effect of AOI was found (F (1, 34) = 11.956, $p = .001$, $\eta_p^2 = .260$, Fig. 2), with longer fixation time on the face AOI than object AOI. Also, a significant main effect of JA types was found with a longer looking time in the IJA than RJA (F (1, 34) = 8.374, $p = .007$, $\eta_p^2 = .198$). The main effect of JA condition was non-significant, and there was no interaction effect between JA condition, AOI and JA types ($p > .05$).

In the analysis of the object looking test (Fig. 3), we conducted a two-tailed t-test between the IJA and RJA. The total fixation time to the No-JA object was compared between IJA and RJA, and no significant difference was found between the two JA types (t (34) = 1.294, $p = .204$, $d = .44$).

In the analysis of the face looking test (Fig. 4), we conducted a two-tailed t-test between the IJA and RJA. The total fixation time to the JA face was compared between IJA and RJA because both JA types showed significant longer looking time to JA face than No-JA face. There was no significant difference between IJA and RJA ($t(34) = -.221$, $p = .827$, $d = .07$).

Finally, we conducted a Fisher's exact test with the percentage of object choice between IJA and RJA. As a result, a significant choice bias was found between IJA and RJA ($p = .0009$) and infants robustly chose the JA object after IJA than after RJA (Fig. 5).

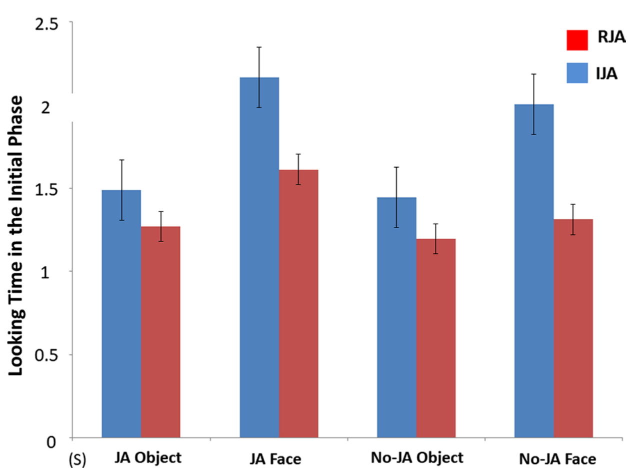

Fig. 2 Mean fixation duration for four AOIs in the initial (familiarization) phase

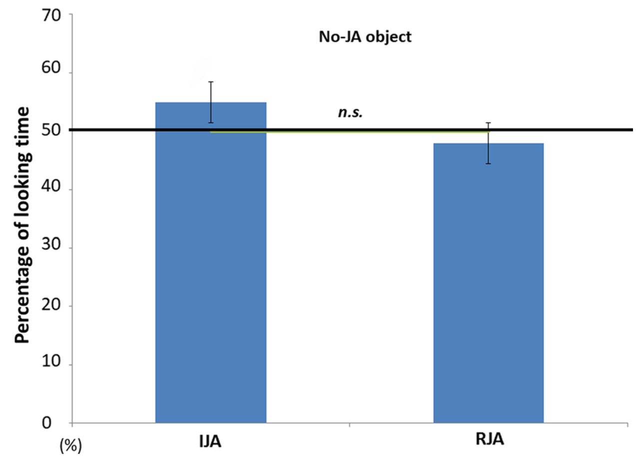

Fig. 3 Mean percentage of looking time for the object looking test

Discussion

We investigated how a shift in an adult's gaze between objects affects the processing and preference of these objects for infants in mock-IJA situations. Also, we compared the effects of JA on object visual preference, face preference and object preference between IJA and RJA. As a result, on the object looking test, infants looked at a No-JA object

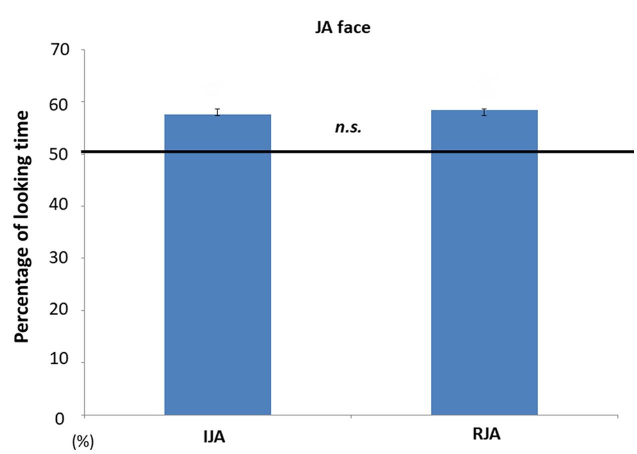

Fig. 4 Mean percentage of looking time for the face looking test

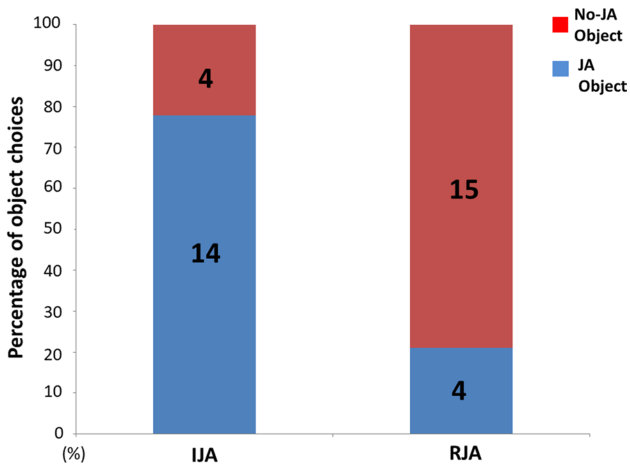

Fig. 5 Percentage of object choices in the object choice test

only after IJA; however, there was no looking bias after RJA. Most importantly, as predicted, infants demonstrated a greater bias for choosing the JA object after IJA than evident following RJA. In addition, our results suggest that both IJA and RJA may affect social preference in infants. This is the first study to examine the effect of JA gaze on facial preferences among infants.

Looking time in the familiarization phase

We found a significant main effect of JA types with a longer looking time in the IJA than RJA. This result replicated the previous study (Kim and Mundy 2012). Also, there was a significant main effect of AOI with a longer looking time to the face area than the object area. It has been shown that newborns also have face preference (Valenza et al. 1996); therefore, looking bias in the familiarization phase may reflect the preference for faces against objects.

However, there was no interaction effect between JA condition, AOI and JA types. It would be expected that infants look longer to the JA object than No-JA object only in the IJA condition. It is possible that the presentation time of objects affected the looking behaviour in the familiarization phase. In the IJA condition, we presented one of the two objects on either the left or right side of the face, after that the female turned her gaze direction either towards or away from the object. On the other hand, in the RJA condition the female shifted her gaze direction either right or left with no objects in either direction, and after that one of two objects appeared on either congruent or incongruent place with the female gaze direction. Therefore, the total presentation time of objects was different between IJA and RJA in the familiarization phase. We analysed looking time for each AOI only at the last scene of the familiarization trial, because we presented the same images between IJA and RJA conditions at this time point. It is considered that the total stimulus presentation time may have affected infant looking behaviour in the familiarization phase.

Object visual preference

Our examination of infant gaze on objects after IJA also replicated previous findings that infants prefer to spend more time looking at No-JA objects (Reid and Striano 2005). It may be that the longer time spent looking at the No-JA object reflects a preference for novelty items. Some studies have suggested that eye gaze may facilitate object processing (Okumura et al. 2013; Marno et al. 2014). Thus, JA objects may have been processed to a greater degree than No-JA objects. Also, our results in the object looking test showed longer looking time towards No-JA objects than JA objects; therefore, a novelty preference for No-JA objects may be observed in the looking test because the infants were seeking to process the novel objects.

Previous studies, conducted in RJA situations (Reid and Striano 2005), have required infants to follow another's gaze with the result that they find a significant bias favouring a No-JA object. However, the present findings, using the RJA paradigm, did not show any looking bias. This is because we adapted the Posner paradigm to compare RJA with IJA. Mundy and Jarrold (2010) suggested that infant social learning would be enhanced when JA includes another's intentionality. In the Posner paradigm, gaze direction is used as cueing preceding targets appear, so there was no object when the gaze shifter changed her gaze direction; therefore, RJA could be regarded as incidental. Our results of object looking test may suggest that IJA enhances infant object processing more than RJA in infants.

Object preference

In the object choice test, we found a significant difference between IJA and RJA. That is, following the IJA, infants chose JA objects significantly more often than following the RJA. Bayliss et al. (2013) showed that IJA has stronger effects on object choice than RJA in adults. The present study showed the same results in infants.

The effects of IJA on object preference can be explained by the brain reward system. In neuroscientific studies, it has been indicated that IJA has stronger activation in reward systems than RJA (Schilbach et al. 2010). Although it is technically difficult to measure infant reward system activation because reward systems are deep inside the brain, our behavioural data suggest that IJA enhances reward system activation in infants.

Face preference

When presented with faces to gaze at, infants looked longer at the individual who engaged in a JA gaze than at the person who performed a No-JA gaze in both IJA and RJA situations. These results are consistent with those of Bayliss et al. (2013), who also found in their adult study that participants showed a preference for individuals who engaged in JA gaze. We discover that infants also show a significant preference for the person who engages in JA gaze in both IJA and RJA situations.

The preference for faces that engage in a JA gaze may arise when infants perceive that they are imitated by others. Edwards et al. (2015) suggested that looking at the same object may be a rewarding experience similar to that of an infant who perceives he/she is being imitated by others. Therefore, infants might also perceive they are being imitated by others in JA situations and show a preference for faces who engage in JA gaze.

A cognitive difference between IJA and RJA

In sum, our results suggest that IJA levy stronger effects on object processing and object preference than RJA, but there IJA and RJA do not yield differences in face preference.

A review by Mundy (2018) concluded that differences between IJA and RJA are "self-motivation" and "social reward". Based on our results, it is possible that these two perspectives have, respectively, different impacts on infant behaviour.

In terms of object cognition, high self-motivation in IJA situation may promote infant object processing and object preference. In adult studies, because of higher self-motivation in IJA than RJA appears to enhance information processing of an attended target (Mundy and Newell 2007); moreover, object choice is also affected in an IJA paradigm (Bayliss et al. 2013). In this context, "self-motivation" is described as motivation to pay attention to targets; hence, the high "self-motivation" in IJA affects only object processing and object preference.

On the other hand, it has also been argued that IJA has greater social rewards than RJA (Mundy and Acra 2006). In an adult study that compared face preference between IJA and RJA, the IJA led to a stronger impact on face preference than did RJA (Grynszpan et al. 2017). However, in the present study, infants around 12 months old did not show differences in face preference associated with IJA versus RJA. This result suggests that high social reward in the IJA paradigm may be acquired developmentally. This is the first study to compare face preference between IJA and RJA in infants; comparison with other ages should be conducted in the future studies.

Finally, the two characteristics of IJA, namely high self-motivation and high social reward, may influence, respectively, different perspectives and have different processes of development.

Limitations

There are some limitations in the present study.

First, age differences between participants in the IJA and RJA conditions should be noted. In the RJA condition, slightly younger infants participated because RJA can be observed from 9 months of age or earlier (Brooks and Meltzoff 2005; Moore and Corkum 1998, Leekam et al. 1998). Although the younger age range was reasonable, it may have affected infant cognitive abilities.

Second, in contrast to previous infant studies examining the effects of RJA, our RJA applied a Posner paradigm. For comparison with the infant mock-IJA task, we sought to set up an infant RJA task that presented only one object on the screen. Previous studies have presented two objects on the screen and a female gazed at one of these objects (Okumura et al. 2013). In the current study, we used a different paradigm for infant RJA task; therefore, our results may be affected by this method. To compare infants' performances in IJA task and RJA tasks, as used in the previous studies, a gaze contingent task that responds to infant eye gaze position in real time should be applied in the future studies.

Conclusions

This is the first study to have compared effects of IJA and RJA on infant object visual preference, object preference, and face preference. Results indicate that IJA may promote object processing and object preference to a greater degree than RJA does. In addition, no difference was found on face preference between IJA and RJA; however, both IJA and RJA enhanced face preference for persons engaged in JA gaze.

Future studies comparing the effects of IJA and RJA in infants should be conducted with gaze contingent JA task to examine the cognitive differences between IJA and RJA.

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Author contributions M.I. developed the study concept and conducted experiments and data analysis. All authors approved the experiment design and discussed about the results. S.I. supervised this study.

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Compliance with ethical standards

Conflict of interest Authors have no conflicts of interest.

Ethical standard Our experimental protocol was approved by the Research Ethics Review Board of the Department of Psychology, Kyoto University, Kyoto, Japan (protocol no. 28-P-12). The study was carried out in accordance with the provisions of the World Medical Association Declaration of Helsinki.

Informed consent All participants gave their written informed consent to participate. All stimuli were originally created for this study, and persons represented in the figure were given informed consent and permitted to publish the images in all formats.

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