The Differentiation of Activity in Infants' Exploration of Objects

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If an activity during manipulative play is exploratory, it should, in contrast to other activity, be used differentially for objects that vary in novelty. In a study of 5-month-olds, different definitions of exploratory mouthing were tested, and results suggested that mouthing followed immediately by a look fulfilled some criteria for an exploratory activity. In the next study of 5- to 11-month-olds, mouthing with looks after and examining, a measure of visual–manipulative inspection, met the criteria for exploratory activity; other kinds of mouthing and visual–manipulatory activity did not. Exploratory mouthing decreased with age and examining increased. The exploratory function of mouthing apparently was not due to concurrent manual activity providing haptic information. The conclusion is that some activities are exploratory and information-gathering and other activities are nonexploratory and serve other functions.

Exploratory behavior in infants of different species has been a topic of investigation for many years (Weisler & McCall, 1976). Recently, the manipulative activity of human infants has been scrutinized for evidence that it is intentional and specific to object properties (e.g., Bushnell, Shaw, & Strauss, 1985; E. J. Gibson, 1988; Lockman & McHale, 1989; Palmer, 1989; Ruff, 1984). In the course of playing with and manipulating objects and toys, however, infants engage in many different kinds of activities. Only some activities may be exploratory and instrumental in learning about the object; other activities may not be exploratory at all or may be exploratory at some times and not others.

One exploratory activity for which there is already considerable information is visual–manipulative examining. Uzgiris (1967) referred to examining as one among many schemata within a Piagetian framework; in her words, "in examining, . . . the infant turns it [the object] around, pokes at it, feels its surface, manipulates its parts while observing the object and the effect of his manipulations on it" (p. 324). Examining therefore is focused visual inspection of an object accompanied by manipulation of the object with the hands. Our previous work (Ruff, 1986) has shown that, when the infant is faced with a novel object, examining has temporal priority over other activities such as mouthing and banging. It also declines dramatically with increasing exposure to an object and recovers to novelty.

These are important criteria for determining whether an action is exploratory (Ruff, 1989).

A major purpose of the present research was to learn more about the mouth as an exploratory tool. Unlike examining, which seems to be exclusively exploratory (Ruff, 1989), mouthing serves several functions. From the beginning of life, the mouth plays a salient role in feeding and need gratification (Rochat, Blass, & Hoffmeyer, 1988). Perhaps, for this reason, infants also find the mouth an important means of comforting and soothing themselves; very early hand–mouth coordination makes such a role possible (Korner & Kraemer, 1970). In addition, the mouth is a potentially important part of the haptic system (J. J. Gibson, 1966) and may play a role in infants' acquisition of information about objects.

Evidence for such a role comes from several studies. Pecheux, Lepeceq, and Salzarulo (1988) conducted a study involving oral familiarization with a rigid object inserted into a nipple; during oral test trials with either the same object or a different rigid object in the nipple, 2-month-old infants showed more nonrhythmic oral activity with novel than familiar objects. It has also been reported that infants from 1 to 12 months (Gibson & Walker, 1984; Gottfried, Rose, & Bridger, 1977; Meltzoff & Eichenbaum, 1979) recognize the shape and substance of objects visually when the objects have been previously explored only orally.

However, positive results on unimodal and cross-modal tasks do not answer the question of how mouthing is used during play in which all modalities are potentially available. The discovery of how whole systems function in different contexts is an important part of our understanding of behavior and development; it should not be assumed that infants do acquire information by mouthing in all situations because they can do so under restricted conditions. The studies reported here involved observing infants in the context of independent and relatively unrestricted play to see how they spontaneously organize their activity, especially mouthing, to serve both exploratory and other functions. Because the novelty of objects is a primary motivator for activity designed to gather information, it was expected that if mouthing is exploratory it would vary systemat-
ically with the novelty of objects, that is, decline with increasing familiarization and recover to the presentation of novel objects.

The data from previous studies (Ruff, 1984, 1986) suggested that mouthing might not be exploratory: It did not decline with increasing exposure to the object, it was not used differentially for different changes in the object, and it tended to occur after examining. However, a failure to differentiate among types of mouthing may have obscured patterns that existed only for particular types of mouthing. In studies of infants younger than 6 months, investigators have found it useful to differentiate between sucking and mouthing. Rochat (1983) reported that infants from birth to 4 months showed differentiated oral activity and that older infants differentiated nipples of different shapes and types of material with nonrhythmic patterns of mouthing, but not with sucking. Along the same lines, Pecheux et al. (1988) found that infants in the first 2 months sucked smooth and nubby spheres equally but showed more nonrhythmic oral activity with the nubby sphere. In the current research, we explored distinctions within the category of mouthing that would be appropriate for infants of 5 to 12 months.

We report results from two observational studies of infants. The infants in both studies were observed under naturalistic conditions; the data, however, were subjected to specific tests based on explicit hypotheses about the effect of relative novelty on exploratory and nonexploratory activity. The first study involved 5-month-olds who were expected to show a great deal of mouthing. This study provided the basis for differentiating types of mouthing by investigating which types declined with increasing familiarity with the object. The second study was a cross-sectional investigation of 5- to 11-month-olds, covering an age range in which the amount of mouthing changes dramatically. In addition to providing developmental data about the changing functions of mouthing over age, the second study allowed us to validate the categories of mouthing along with categories of visual–manipulative activity by determining whether the categories designated as exploratory recovered when novel objects were presented.

Study 1

In our search for the best way to characterize and measure mouthing that might be exploratory, we started with a distinction between active mouthing and all other mouthing, a distinction which we had explored briefly in an earlier study (Ruff, 1984). Active mouthing is mouthing in which the mouth is moved over the object or the hands are used to move the object around in the mouth. It seemed to be a reasonable candidate for an information-acquiring activity, because it provides the infant with many changes and transformations in stimulation—a good basis for detecting the invariant structural properties of objects (J. J. Gibson, 1966). In addition, we recorded the frequency with which mouthing episodes were followed immediately by a look at the object. The observation of this behavior in infants certainly gives the impression that the infants are checking or confirming something that was detected by the mouthing that preceded the look, and we have scored the frequency of such looks in other studies (e.g., Ruff, 1984).

Method

In this study, 5-month-old infants were presented with three different objects for periods of free play. The observation of the infants’ activities with the objects served as the basis for exploring different types of mouthing and the extent to which each fulfilled the criteria for an exploratory activity. In this study, the major criterion was a decrease over time as the object became more familiar; that is, exploratory activity was expected to be higher in the beginning of a trial when the object was most novel than at the end.

Subjects. The sample of 32 full-term infants (14 girls and 18 boys) was drawn from a population born at the Albert Einstein College of Medicine. All infants were born within 38 and 42 weeks, had birth weights between 2,500 and 3,800 g, and had no perinatal complications. The infants were seen at a mean age of 22.2 weeks (range = 21.3 to 23.4 weeks). Two other infants were observed but were too fussy to be included.

Apparatus. For presentation of objects, we used a narrow table that could be adjusted to the infant’s height. A SONY Portapak video recorder and camera were used to record each infant’s behavior, and a stopwatch was used to time trials. When the videotapes were later scored for various behaviors, a Rustrak four-channel event recorder moving at 1/8 inch per second was used. The stimulus objects were a blue plastic rattle in the shape of a dumbbell, 10.2 cm in length; a red plastic ring, 10.7 cm in diameter; and a small, colorful rubber doll, 10.7 cm in length.

Procedure. The infant was seated on the mother’s lap in front of the table so that objects presented on its surface could be easily grasped and manipulated by the infant. The mother was asked to allow her infant to play freely with the object and to return it to within the infant’s reach if necessary. Any objects that dropped to the floor were retrieved by the mother or experimenter. The experimenter, who sat on the floor in front of the table, presented and removed each object. The objects were always presented in the same order for a single trial each. The trial durations varied depending on how long the experimenter judged the infant to be interested in interacting with the object, up to a maximum of 3 min. Trial durations ranged from 26 to 180 s; 70% of all trials were more than 150 s.

Dependent measures. From the videotapes we first recorded the frequency and duration of looking and mouthing. Looking was scored whenever the infant’s eyes were directed at the object. Mouthing was scored whenever the object was in contact with the mouth, lips, or tongue. Interobserver reliabilities for these general measures have always been higher than .90 (Ruff, 1984). Active mouthing was defined as occurring when the object touched either the inside or outside of the mouth and was moved around by the hand or held in place while the lips or tongue moved around the object. The interobserver reliability for this measure was calculated on the basis of two independent observers’ total durations of active mouthing for 15 of the infants (r = .97). The duration of other mouthing was obtained by subtracting the duration of active mouthing from total mouthing. Other mouthing included all other contact between the mouth and object, such as place-holding, gnawing, and sucking. Any one episode of mouthing could be composed of different proportions of active and other mouthing.

We also recorded the frequency with which the infants looked at the object immediately after mouthing. The immediacy of the look after is critical and means that there is no perceived time lapse between mouthing and looking; such looks probably occur because the infants are looking for the object as it is removed from the mouth. If the infant glanced in another direction after mouthing, however briefly, a look after was not scored. It was the immediacy of the look that counted here and not the duration of the look. Interobserver reliability based on the total number of looks after for 15 infants was very high, .98.
Results

The dependent measures in the analyses to follow are the durations of active and other mouthing transformed into percentages of trial time. Averaging over the three objects, the infants spent about 27% of trial time looking at the objects (9% to 58%) and another 24% mouthing the objects (0% to 55%). The rest of the time was spent mainly in manipulation without looking or not attending to the objects at all.

Decline over familiarization. Because the goal was to determine whether active mouthing met the major criterion for exploratory activity, we tested the expected differential effect of familiarization on the proposed exploratory and nonexploratory components of mouthing. The expectation was that active mouthing would decline over time, whereas other mouthing would not. For these analyses, the data were collapsed over the three trials. The mean durations of active mouthing and other mouthing for each half of trial were entered into a 2 X 2 (Halves X Type of Mouthing) analysis of variance (ANOVA). It might be argued that the two types of mouthing are not independent, because the data come from the same trials rather than from different conditions or sessions, but the proportion of trial time spent in mouthing, as presented earlier, suggests that about 76% of trial time was left in which the duration of either type could have varied. In addition, only an ANOVA provides a direct test of the hypothesized interaction between type of mouthing and half of trial and, in that sense, is preferable to separate analyses for the two types. However, there was no main effect of halves and no interaction between halves and type of mouthing (Fs < 1). As can be seen in Table 1, there was literally no change over time in active mouthing, which is not consistent with active mouthing serving an exploratory function.

Relationship of active mouthing and looks after. As another way of assessing the difference between active and other mouthing, we calculated, for each type of mouthing, the proportion of episodes that were followed immediately by a look. If active mouthing is exploratory and the infant's attention is focused on the object per se and not on its own activity, the look after could be used as a marker. If the look after is used to confirm information picked up during mouthing, then the data are consistent with the hypothesis that active mouthing is more exploratory than other mouthing. The immediacy of the look also suggests that the infant's attention is focused on the object per se and not on its own activity.

The look after as a marker. In a second analysis, we investigated the possibility that the look after could be used as a marker for exploratory mouthing. That is, we took the look as evidence that the mouthing preceding it involved attention to the object itself and the absence of a look as a lack of such focused attention. As in the earlier analysis, 21 infants provided data; after establishing which of their episodes of mouthing were followed immediately by a look, we calculated the duration of mouthing with looks after and the duration of mouthing without looks after.

The durations for the first and second halves of trial averaged over the three trials were entered into a 2 X 2 (Halves X Type of Mouthing) ANOVA. There was no main effect of halves, but there was a highly significant interaction between type of mouthing and time of mouthing, F(1, 20) = 14.2, p < .001. As can be seen in Table 1, mouthing with looks after showed a sharp decline, F(1, 20) = 12.8, p = .002, a pattern shown by 17 (or 81%) of the infants; mouthing without looks after tended to increase, F(1, 20) = 3.5, p = .07. These data suggest, therefore, that the infants were less likely to engage in mouthing with looks after as the object became more familiar; their use of mouthing without looks after did not vary with increasing familiarization (see Table 1).

A potential rival interpretation of these data is that the look after follows mouthing by chance, but, because looking declines over time, the probability of a look after declines; therefore, total duration of mouthing with looks after declines as well. If this were the case, the use of the look after as a marker for exploratory mouthing would be unjustified. There are several ways to test this alternative interpretation. One way is to consider the total number of "looks" at the object; the upper limit on the number of "looks after" that can occur in any time

<table>
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<tr>
<th>Measure</th>
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<tbody>
<tr>
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<td>Active mouthing</td>
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<tr>
<td>SD</td>
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<tr>
<td>Other mouthing</td>
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<tr>
<td>SD</td>
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Mouthing with and without looks after

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<tr>
<td>Proportion of available time (n = 21)</td>
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<td>Mouthing/look after</td>
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<tr>
<td>SD</td>
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<tr>
<td>Mouthing/without look after</td>
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<tr>
<td>SD</td>
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Mean duration per episode (n = 15)

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<tr>
<td>SD</td>
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<td>Mouthing/without look after</td>
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</tr>
<tr>
<td>SD</td>
<td>1.9</td>
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* Percentage of available time averaged over three trials.
segment is the number of mouthing episodes, but the higher the ratio of all looks to the number of mouthing episodes, the higher the probability that an episode of mouthing will be followed by a look. We therefore calculated the ratios of looks to mouthing episodes for the 19 infants who had at least one look after and who also looked at and mouthed the objects in both halves of the familiarization trial. The mean ratio for the first half was 1.70, and the mean for the second half was 1.51, a nonsignificant difference, t(18) < 1.

Another consideration is the duration of looking; that is, the more time the infant spends looking at the object when not mouthing it, the more likely it is that a look after will occur right after mouthing. The percentage of trial time spent mouthing and looking, however, is only about 50%, making this explanation unlikely. In addition, among the infants who exhibit looks after mouthing, the number of looks after is more highly correlated with the duration of mouthing (r = .53) than it is to the duration of looking (r = .04).

With an alternative explanation based on a chance relationship of the look after to either the frequency or duration of looking, there would be no reason to expect any systematic changes in the duration of mouthing episodes over time or any difference between episodes with and without looks after. Therefore, we examined the mean duration of episodes for both types of mouthing in each half of trial; that is, we divided total duration of each type of mouthing by the number of episodes of that type. For infants who had no episodes of mouthing, a mean duration per episode of 0 would not be meaningful; for that reason, comparison of the two types of mouthing could not usefully include infants who showed only one type of mouthing (n = 11) or demonstrated it in only one of the halves (n = 6). The 2 X 2 (Halves X Type of Mouthing) ANOVA was therefore done with 15 subjects and yielded a main effect of type of mouthing, \( F(1, 14) = 7.5, p = .015 \); the mean duration per episode of mouthing with looks after was longer than the mean duration of episodes without looks after. More important, there was a significant interaction between halves and type of mouthing, \( F(1, 14) = 6.4, p = .02 \), with the mean duration of mouthing with looks after decreasing over time, \( F(1, 14) = 4.3, p = .06 \), and the mean duration of mouthing without looks after showing no change, \( F(1, 14) < 1 \). These data suggest that there may be something important occurring within the episodes of mouthing with a look after (see Table 1).

All of these analyses provide evidence against the alternative hypothesis and further confirmation that mouthing with looks after is exploratory. Inspection of the data for individual children suggested that episodes of mouthing with looks after occurred in clusters and were not scattered over the trial. To confirm our observations statistically, we conducted Wald-Wolfowitz runs tests (Siegel, 1959) on the data from each of the 21 infants. Two-tailed tests were used because, in the data of any one infant, there could be more or fewer runs than the number expected by chance. Seven of the 21 tests revealed significantly fewer, and therefore longer, runs than expected, \( ps < .05 \) to \( < .001 \), whereas only one significant result would be expected by chance. In addition, only 4 of the 21 infants had more runs than expected, whereas 17 infants had fewer runs than expected (binomial probability = .008). These data suggest that 5-month-old infants' mouthing of objects may be characterized by periods of concentrated exploration and by a meaningful, not a chance, relationship to looking.

**Discussion**

The main purpose of this study was to elucidate the role of mouthing in object play of 5-month-old infants. We categorized mouthing in two different ways to see which system best fit our criteria for an exploratory activity. Our first comparison of active mouthing and other mouthing showed no decline over the familiarization periods in either type. On the other hand, active mouthing episodes were followed far more frequently by immediate looks, a behavior that we take to indicate that the child detected something interesting about the object during mouthing. We then divided mouthing into the duration of episodes followed by looks after and the duration of episodes not followed by such looks. Duration of mouthing with looks after declined sharply and significantly with increasing familiarization, whereas other mouthing did not change, a difference that suggests that mouthing with looks after is truly exploratory and may involve the intake of information about object characteristics. The alternative interpretation—that the total duration of mouthing with looks after is a function of the duration or frequency of looking—does not seem to be viable. In addition, the fact that the look after was more related to active mouthing than other mouthing is further suggestion that the look after is not related to mouthing by chance.

It might be argued that any goal-directed activity will decline when the child reaches the goal (Bruner, 1973) and, therefore, mouthing that serves functions other than exploration might also decline with time. For example, if mouthing is used by an overaroused infant for soothing, then that mouthing should decline along with the infant's arousal; if an individual infant were anxious or aroused by the unfamiliarity of the experimenter and the setting, that infant might suck on or mouth the objects presented to reduce the level of anxiety and arousal. However, there is no reason to expect that decrements occurring in such mouthing would be systematically related to the novelty of the object. The lack of a significant decline in mouthing without looks after suggests that such mouthing was not related to the

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1 Although there was no systematic variation of object characteristics, the three objects did vary on a number of dimensions. The most important of these was the complexity of the structure, which varied from the ring that was the same at all points, to the rattle whose dumbbell shape was different in the middle than at the ends and whose surface was slightly ridged, to the doll that had well-defined body parts including hands and feet. The constant order of presentation (rattle, ring, doll) was not the same as the ordering by complexity (ring, rattle, doll). We tested the effect of complexity, because exploratory activity should, in general, increase as object complexity increases. A 3 X 2 (Object X Type of Mouthing) analysis showed a marginal interaction between object and type of mouthing, \( F(2, 40) = 3.0, p < .06 \). As expected, mouthing with looks after was used differentially for the three objects, \( F(2, 40) = 8.7, p = .001 \), with the means ordered according to our judgment of increasing complexity (Ms = 4%, 11%, and 18% for the ring, rattle, and doll, respectively); mouthing without looks after was not used differentially (Ms = 19%, 20%, 21%, respectively), \( F(2, 40) < 1 \). The results are only suggestive but are consistent with our designation of mouthing with looks after as exploratory.
presumed decreasing novelty of the object over the trial. Unfortunately, the fixed order of object presentation made it impossible to conduct a direct test of the infants' responses to the presentation of a novel object.

In summary, the results suggested that mouthing with looks after may represent the exploratory, or information-gathering, aspect of mouthing objects. The look after, it should be noted, is used here as a marker or a sign that something exploratory is happening in the mouthing episodes that precede the look. On the other hand, the possibility that the infants are visually checking information obtained during mouthing also suggests a coordination between the two modes. We designed the second study to confirm the results with infants of different ages and to test specifically their responses to the presentation of experimentally novel objects.

**Study 2**

In the second study, we compared exploratory mouthing, as defined by the look after, with other mouthing in a developmental framework. The age range of 5 to 11 months was chosen to be representative of the period during which mouthing of objects peaks and then declines (Uzgiris, 1967) as well as to determine whether the role of mouthing in the exploration of objects changes as the amount of mouthing decreases. Secondary, we wished to compare visual-manipulative inspection or examining with other types of visual-manipulative activity; although examining has been studied extensively and seems to clearly meet the criteria for an exploratory activity, there has never been a comparison with other visual-manipulative activity involving the object. Including this measure of visual exploratory activity also allowed us to determine whether the relative balance of examining and exploratory mouthing changes with age. As noted before, the study was designed to test not only the expectation of a decline in exploratory activities with familiarization, but also the complementary expectation of an increase with the presentation of novel objects.

**Method**

Each infant was presented with four objects for periods of familiarization. The order in which the objects were presented was counterbalanced across infants, so that the change from one object to the next represented the presentation of something novel regardless of the nature of the particular objects. Each object was markedly different from the other three. After the initial period of familiarization, however, the same object was presented again before the novel object was presented. This acted as a control for the possibility that there would be some increase in arousal or responsiveness just because of the break in contact with the familiar object.

**Subjects**

The subjects for this study were recruited into four age groups of 5-, 7-, 9-, and 11-month-olds. There were 8 infants (4 boys and 4 girls) in each age group; the mean ages were 5 months and 10 days (SD = 9.2 days); 7 months and 16 days (SD = 10.0 days); 9 months and 9 days (SD = 5.8 days); and 11 months and 11 days (SD = 8.2 days). The data from 2 additional infants were not used because of experimenter error or because of the infant's complete lack of attention to the objects.

**Experimental objects**

There were four pairs of objects that differed from each other along several dimensions; within each pair the objects were very much alike, and each infant saw one object from each pair. The pairs were the following: (a) different wooden shapes, both painted with the same black and white design and both about 2.54 × 6.35 cm; (b) orange wooden cubes about 3.81 cm, one ridged and one with a lacy texture; (c) blue rubber bulbs about 4.57 cm in diameter with a wooden sphere or a wooden half-cylinder inside; and (d) green and black cylinders about 6.68 × 1.75 cm, one of which had small round depressions at one end and the other of which was smooth.

**Procedure.** Each infant was seen individually in the lab and sat on the mother's lap at a desk; the session was videotaped with a SONY portable video system. The assignment of each infant to a particular order of object presentation was determined before the infant arrived; 2 infants at each age were assigned to one of four orders (ABCD, BDAC, CDBA, or DCBA). For each familiarization period, the chosen object was presented until the infant met the criteria for ending a trial or until 180 s had elapsed. The criteria were (a) fussing for 5 s, (b) dropping the object three times with no other engagement with the object between the drops, and (c) turning away altogether from the test situation for 5 s. The familiarization trials varied from 50 to 180 s, with a mean of 152 s; 64% of the trials lasted the full 180 s. The length of the second familiarization trial was half as long as the original one. The timing of the trials was monitored by the experimenter with a stopwatch, and the interval between trials both within and between problems was only a few seconds. The mothers were asked not to interfere with their infants' activities in any way, although they sometimes helped retrieve dropped objects. The experimenter stood off to the side of the desk where the mother and infant were sitting; she presented the objects and timed the trials, but otherwise remained as unobtrusive as possible. All objects except the one the infant was given were out of sight.

**Dependent measures.** All measures were scored from the videotapes in real time using a computer programmed to serve as an event recorder. The coding was done by someone who was not aware of the hypotheses. Looking and the measure of mouthing with and without looks after were recorded in the way described in Study 1; however, duration of looking and the look after were coded at different times. In addition, we coded examining, which has been discussed elsewhere in detail (Ruff, 1986, 1989; Ruff & Lawson, 1990). Examining reflects the amount of time spent in focused visual inspection of an object; it usually occurs while the infant is also manipulating the object. Although any "deliberate" manual activity would be included in examining, the most likely are fingering, turning the object around, and transferring (Ruff & Lawson, 1990); these activities also have been implicated in the exploration of particular object characteristics, in contrast to more active, repetitive activities, such as banging (Ruff, 1984). A serious facial expression, frequently involving knit brows, is important and suggests that examining is a major way in which infants demonstrate focused attention during play with objects (Ruff, 1986; Ruff & Lawson, 1990). Reliability in scoring examining in infants 6 months and older has also been consistently above .90 in several studies with the same observers (Ruff, 1986). Using the videotapes of 9 infants in the previous study and two independent observers, we determined the reliability of coding examining in 5-month-olds; interobserver reliability for the total duration of examining was .87. The duration of examining was subtracted from the duration of total looking to obtain duration of other looking/manipulating; this category includes looking generally accompanied by holding, banging, waving, or dropping the object.

As before, durations of all activities were converted into percentages.

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2 These particular pairs of objects were chosen to study infants' responses to unidimensional changes, and originally there were 8 infants at each age who were presented with the other member of the pair after the original familiarization period. There was so little evidence, however, that the infants at any age responded to the discrepancies within pairs of objects that the data do not warrant further discussion; these infants are not part of this report.
of available time to correct for the different trial lengths between and within individuals.

Results

The percentage of trial time spent looking at the objects did not change with age (49%, 41%, 47%, and 47% for the 5- to 11-month-olds, respectively), whereas the percentage of time spent mouthing peaked at 7 months (11%, 28%, 18%, and 17% for the 5- to 11-month-olds, respectively). As in the last study, there was considerable trial time taken up by activities other than looking or mouthing (31% to 40%). The percentages for the 5-month-olds differ from those of Study 1, in which the infants mouthed more and looked less at the objects, probably because the objects in Study 1 were larger and easier to grasp.

Decline over familiarization. We first addressed the extent to which exploratory mouthing and examining declined over the period of familiarization. Figures 1 and 2 show that exploratory mouthing and examining declined systematically in each trial whereas other looking and mouthing showed no systematic change. For the statistical analysis, percentages of available time in first and second halves of each familiarization period were averaged over the four trials and entered into a 4 X 2 X 2 (Age X Halves X Type of Activity) ANOVA. The important interaction between type of mouthing and half was significant, F(1, 28) = 25.6, p < .001, with mouthing with looks after showing a highly significant decline, F(1, 28) = 20.7, p < .001, and mouthing without looks after showing a small increase, F(1, 28) = 6.6, p < .02. As can be seen in Table 2, 78% of the infants showed the expected decline in mouthing with looks after. Likewise, the interaction between type of looking and half was significant, F(1, 28) = 14.4, p < .001, with examining showing a systematic and significant decline, F(1, 28) = 46.1, p < .001,
Infants' Exploratory Activity

Decline in looking showed no change, \( F(1, 28) < 1 \). In this case, 84% of the infants showed the expected decline in examining. There was an interaction between age and type of looking, \( F(3, 28) = 3.9, \ p = .02 \), because examining increased with age and other looking declined.

Recovery to novelty. Figures 1 and 2 also show that there was no recovery of exploratory mouthing or examining to any representation of the same object and clear recovery of exploratory mouthing and examining to every presentation of a novel object. Very different patterns are seen for other looking/manipulating and other mouthing. For statistical purposes, the data from the re-presentation segments of the first, second, and third problems were averaged and compared with the average of the first half of familiarization in the second, third, and fourth problems. The percentages used in this analysis might have been affected by the systematic decline in trial length from the first to the last problem, \( F(3, 84) = 3.7, \ p < .001 \), but the mean length of the relevant re-presentation segments (74.5 s) and the mean length of the first halves of the relevant familiarization periods (76 s) were generally equivalent.

In a 4 \( \times \) 2 \( \times \) 2 (Age \( \times \) Trial: re-presentation vs. first half of next familiarization trial \( \times \) Type of Activity) ANOVA, we found a significant interaction between trial and type of mouthing, \( F(1, 28) = 9.9, \ p = .004 \), with a significant recovery for mouthing with looks after, \( F(1, 28) = 19.5, \ p < .001 \), but not for mouthing without looks after, \( F(1, 28) < 1 \) (see Table 2). Again, a solid majority of the infants (69%) showed the expected recovery in mouthing with looks after. The analysis of looking also showed a significant interaction between type of activity and trial, \( F(1, 28) = 6.2, \ p = .02 \), with a significant recovery in examining, \( F(1, 28) = 46.4, \ p < .001 \), but not in other looking/manipulating, \( F(1, 28) = 1.6 \) (see Table 2). As before, 84% showed the expected pattern in examining. There was an interaction between age and trial, \( F(3, 28) = 2.9, \ p = .05 \), which stemmed from a greater increase of examining with novelty in the two older groups than in the two younger groups.

Coordination of manual activities with looking and mouthing.

The data confirm the exploratory nature of some mouthing and some simultaneous looking and manipulating. Examining is, by definition, a combination of visual and manual activity. However, mouthing also occurs with simultaneous grasping of the object. This fact raises the possibility that our observed results for mouthing could have been the result of simultaneous manual and oral investigation of the objects. Therefore, it was im-

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**Table 2**

<table>
<thead>
<tr>
<th>Age</th>
<th>Mouthing with looks</th>
<th>Mouthing without looks</th>
</tr>
</thead>
<tbody>
<tr>
<td>5 months</td>
<td>F</td>
<td>F</td>
</tr>
<tr>
<td>6 months</td>
<td>F</td>
<td>F</td>
</tr>
<tr>
<td>7 months</td>
<td>F</td>
<td>F</td>
</tr>
</tbody>
</table>

*The means for the first half of familiarization trial and F(1, 28) from the second half of familiarization trial are the means for the first half of familiarization trial and F(1, 28) from the second half of familiarization trial.*
important to clarify whether the hands were holding and moving the object for the mouth to explore or were more directly involved in obtaining haptic information. The goal of these analyses was to assess the extent to which different manipulative activities occurred in the presence of looking and mouthing, which are mutually exclusive activities with the small objects we used.

The manual activities most likely to be seen during examination of an object are (a) fingering, (b) transferring the object from hand to hand, and (c) turning the object around or rotating it (Ruff, 1989). Because these manual actions can also occur during mouthing of the object, whereas other actions such as banging cannot, we limited our analyses to these three activities. To the category of fingering, we added squeezing, which was more likely to occur with the rubber bulbs (appropriately so, because these were the only objects made of an elastic substance). For the analyses in this section, we coded the manual activities during mouthing and looking from the videotapes and then compared the duration of fingering and squeezing, the duration of rotating, and the frequency of transferring the object from hand to hand under two conditions: when the infants were looking at the objects and when they were mouthing the objects. Our expectation was that the manual actions of fingering and transferring would be largely restricted to looking, during which they are likely to provide specific and global haptic information (Ruff, 1984, 1989), but that rotating might serve to enhance the pick up of oral as well as visual information.

Because the base durations of looking and mouthing were quite different within infants, the analyses were conducted with the percentages of time in the relevant condition spent fingering and rotating and the rate per second in the case of transferring. As two examples, we divided the total duration of fingering that occurred during looking by the total duration of looking in that trial and the total number of transfers during mouthing by the total duration of mouthing. We conducted a 4 × 2 (Age × Condition: looking or mouthing) ANOVA with repeated measures on the second factor for each of the three manipulative activities. Where appropriate, effects were followed up with analyses of simple main effects. Although, as before, the conditions are part of the same trial, given the amount of manipulation, the data in each condition were not constrained by the data in the other condition.

Means and standard deviations for both absolute amounts and percentages for each age group are presented in Table 3. For fingering/squeezing, there was a significant increase with age, F(3, 28) = 3.4, p = .03, and a significantly greater percentage of fingering/squeezing during looking (M = 5.7%) than during mouthing (M = 2.6%), F(1, 28) = 11.0, p < .003. The analysis on the rate of transferring yielded significant main effects of condition. There was a significantly higher rate of transferring during looking (M = 0.049 per second) than during mouthing (M = 0.013 per second), F(1, 28) = 23.6, p < .001. There was, however, only a marginally higher percentage of rotating during looking (M = 8.5%) than during mouthing (M = 6.1%), F(1, 28) = 3.2, p < .08. There were no significant interactions between age and condition for any of the three dependent variables.

Discussion

Both mouthing with looks after and examining meet the criteria of decline with familiarization and recovery to novelty, but their nonexploratory counterparts do not. As Figures 1 and 2 make clear, the recovery observed could not have been due only to the break between the test trial of one problem and the beginning of the next problem, because re-presentation of the same object never led to recovery. The differential patterns of change with increasing familiarization and presentation of novelty confirm and extend the findings of the first study.

The results of the supplementary analyses confirm the expectation that fingering and transferring are more likely to occur during looking than during mouthing. Rotating or turning the object around, however, occurs to a greater degree than the other two manipulations during mouthing, perhaps because it provides the mouth with changing information about the object.

General Discussion

The data from both studies support our contention that only some activity during manipulative play with objects can be considered exploratory. The major contribution of this project is the differentiation of mouthing into subtypes and the demonstration that only some types fit the criteria for exploratory activity. By using the immediate look after as a marker, we were able to show that duration of mouthing with looks after varies

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4 Although the three manipulative activities had previously been recorded from videotapes of infants in the same age range and by the same observers, we assessed interrater reliability of the total durations or frequencies of the activities under the two conditions. These reliabilities were based on the data from 2 infants at each age for a given manual activity in a given condition. The data represented the durations or frequencies in a given condition summed over all trials of an infant; the correlation between data sets from the two observers was calculated with the Pearson product-moment correlation (ns = 8). For the duration of fingering/squeezing, the reliability coefficients were .99 and .96 for looking and mouthing, respectively. For the number of transfers, the equivalent correlations were .98 and .93, respectively. For duration of rotation, the correlations were .96 and .88. The coefficients recalculated with age partialled out were all within .03 of the unadjusted correlations.

5 The possibility that the duration of mouthing with looks after could be an artifact of changes in looking was addressed in Study 1. We again calculated the ratios of looks to mouthing episodes for every infant who mouthed the objects in both halves of the familiarization trial; 1, 0, 2, and 2 infants were excluded from the four age groups, respectively, because of a lack of mouthing in one half. The ratios were then entered into a 4 × 2 (Age × Half) ANOVA. There were no main effects of age or half and no interaction between age and half. Although not significant, the mean ratio increased from the first to second half (3.0 vs. 3.7). The direction of change is contrary to the alternative explanation and therefore strongly suggests that the duration of mouthing with looks after is not a function of changes in looking over time. In addition, the number of looks after is related significantly more to duration of mouthing (83) than to duration of looking (50); the look after therefore does not seem to be related to the general tendency to look at the object.
with the novelty of an object; this is not the case for mouthing without the look after. Therefore, mouthing with looks after can reasonably be designated "exploratory mouthing." Using the same criteria, examining proved to be a better example of exploratory behavior than other types of visual–manipulative activity. Although examining has been studied extensively (Ruff, 1986, 1989), this study represents the first direct comparison to visual-manipulative activity that excludes examining (see also Oakes, Madole, & Cohen, 1991).

The differential decline of activities with exposure and differential recovery to novelty suggest that examining and exploratory mouthing are means of gathering information. For this purpose, exploratory activity may be linked to a more general system of attention; specifically, attention to the object during exploration may be more intense and require more effort than attention during other activities. This hypothesis is strengthened by a study showing that the exploratory activities are less vulnerable to distraction than are the nonexploratory activities (Saltarelli, Capozzoli, & Ruff, 1990). As another measure of variations in state, it might be of value to systematically code facial expression during both mouthing and visual–manipulative activity to determine whether the expression of interest (Izard, 1979) is associated with the exploratory but not the non-exploratory activities. Such an approach might be particularly helpful in extending our distinction to activities other than those emphasized in this report, for example, banging. The way in which the infant's activity is related to attention and learning clearly needs more investigation.

The results of Study 2 reveal developmental changes in exploratory behavior over the age range studied. Mouthing peaks at 7 months and then declines to 11 months. In contrast, the trend is for examining to increase from 5 to 11 months. If exploratory mouthing and examining are combined into a general exploratory score, then the proportion of exploration time devoted to exploratory mouthing decreases from .61 at 7 months to .35 at 11 months, whereas that devoted to examining increases from .39 to .65, respectively. These values demonstrate a shift away from mouthing as an exploratory tool and toward integrated visual and manual inspection. One possible reason for this shift is that new uses of the mouth, such as articulated communication, preclude or dominate its former functions. A more important reason, however, may be that the function of the mouth in haptic exploration is replaced by a more efficient manual system.

Because this gradual substitution of visual–manual inspection for mouthing would represent an important aspect of early development, we suggest a possible history of the two forms of exploratory activity and the developmental changes observed. Before infants can control their hands well enough to reach accurately and grasp, they are able to suck on and mouth objects that are put into their mouths or that get there through rudimentary hand–mouth coordination. The evidence (E. J. Gibson &

### Table 3
Manipulative Activity During Looking and Mouthing Over Age: Absolute Duration or Frequency of Activity and Percentage of Available Time Spent in Activity Per Trial

<table>
<thead>
<tr>
<th>Age</th>
<th>Absolute amount</th>
<th>Percentage available time</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Finger</td>
<td>Transfer</td>
</tr>
<tr>
<td>Looking</td>
<td></td>
<td></td>
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<tr>
<td>5 months</td>
<td></td>
<td></td>
</tr>
<tr>
<td>M</td>
<td>1.3</td>
<td>1.3</td>
</tr>
<tr>
<td>SD</td>
<td>1.1</td>
<td>2.0</td>
</tr>
<tr>
<td>7 months</td>
<td></td>
<td></td>
</tr>
<tr>
<td>M</td>
<td>3.9</td>
<td>4.1</td>
</tr>
<tr>
<td>SD</td>
<td>3.7</td>
<td>2.0</td>
</tr>
<tr>
<td>9 months</td>
<td></td>
<td></td>
</tr>
<tr>
<td>M</td>
<td>6.6</td>
<td>5.1</td>
</tr>
<tr>
<td>SD</td>
<td>6.3</td>
<td>4.7</td>
</tr>
<tr>
<td>11 months</td>
<td></td>
<td></td>
</tr>
<tr>
<td>M</td>
<td>7.4</td>
<td>3.5</td>
</tr>
<tr>
<td>SD</td>
<td>11.0</td>
<td>3.7</td>
</tr>
<tr>
<td>Mouthing</td>
<td></td>
<td></td>
</tr>
<tr>
<td>5 months</td>
<td></td>
<td></td>
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<tr>
<td>M</td>
<td>0.2</td>
<td>0.3</td>
</tr>
<tr>
<td>SD</td>
<td>0.3</td>
<td>0.7</td>
</tr>
<tr>
<td>7 months</td>
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<td></td>
</tr>
<tr>
<td>M</td>
<td>1.4</td>
<td>1.0</td>
</tr>
<tr>
<td>SD</td>
<td>1.3</td>
<td>1.13</td>
</tr>
<tr>
<td>9 months</td>
<td></td>
<td></td>
</tr>
<tr>
<td>M</td>
<td>1.0</td>
<td>0.8</td>
</tr>
<tr>
<td>SD</td>
<td>1.2</td>
<td>1.3</td>
</tr>
<tr>
<td>11 months</td>
<td></td>
<td></td>
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<tr>
<td>M</td>
<td>0.4</td>
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</tr>
<tr>
<td>SD</td>
<td>0.3</td>
<td>0.4</td>
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</tbody>
</table>

* For transfer, the transformation is rate per second.
Walker, 1984; Gottfried et al., 1977; Meltzoff & Borton, 1979) suggests that the substance and shape of objects can be detected during this early mouthing. Infants also spend a good portion of their early months looking around, and a multitude of studies attest to the kinds of information picked up from observed objects and events. The novelty of an object, whether it is first detected by the mouth or the eyes, may therefore arouse a desire to both look at and mouth the object, and the two actions may compete with one another, particularly as infants become more adept at taking objects in and out of their mouths. The induction of two actions by the same situation, however, may be an important mechanism in the development of integrated skills (Fischer, 1980) and might gradually lead the infant to look at the object after mouthing it in order to confirm or amplify the information that was picked up during mouthing. This implies an integration of two actions in the service of learning more about the object.

Mouthing, as a well-practiced haptic system, may dominate in exploratory activity at 5 and 7 months because the visual system is, at that point, more engaged than previously in controlling the emergent reaching, grasping, and manipulating of objects. As the infant becomes more practiced in visually guided grasping and manipulating, more attention could be devoted to the information provided by the hands; the hands could then begin to play a more extensive role in exploratory activity. Generally speaking, the hands can serve two functions (J. J. Gibson, 1966). Some manual actions are performatory and serve the eyes and possibly the mouth; as the infant turns the object around during looking and mouthing, the infant is provided with different perspectives of the object, an important process for highlighting the invariant characteristics of the object. Other manual actions, such as fingering and transferring, are directly exploratory in that they provide the infant with haptic information about the texture, shape, and substance of the objects being handled (Ruff, 1982, 1984, 1989). With development, these actions eventually are differentiated and become specialized for different object properties (Lederman & Klatsky, 1987).

Our analyses of manipulative activity during mouthing and looking show that infants are significantly more likely to finger and transfer objects when they are looking at them than when they are mouthing them. Rochat (1989) also found that fingering co-occurred with looking more than would be expected by chance, whereas fingering during mouthing was at or below chance levels. The tendency to manipulate objects while looking may be due to a need to visually control manual actions, at least when the actions are first emerging (Bushnell, 1985; Ruff, 1989). Or young infants may be more aroused by the sight of the object than the feel of it in the mouth, and the increased arousal leads to generally higher activity of the hands. In either case, the fact that looking occurs jointly with some activities that potentially provide haptic information again provides a basis for an emerging integration that we see in examining, an activity that dominates exploration by infants around 9 or 10 months. The fact that the infant does not seem to integrate the manual and oral methods of gathering haptic information may stem from an undesirable competition, because the mouth and hands would be exploring different parts of the same object simultaneously. One method — mouthing — drops out as the infant becomes a more efficient explorer of objects and the surviving method — manual activity associated with vision — provides the infant with a system in which there is useful redundancy from two modalities and a great deal of flexibility (Lederman & Klatsky, 1989).

These speculations make clear that there is still much to be learned about the development of the components of exploratory skills and their integration; about the growth of knowledge that comes from less and more skilled exploration; and about the relationship of exploratory activity to the processes of attention and learning. On the other hand, the other functions of infants’ play with inanimate objects, such as exercise of motor skills, should not be ignored, because nonexploratory activities may also play an important role in development. We hope that the distinctions explored and validated in these studies will allow us to refine further our observations and our understanding of infants as they interact with objects.

References


**Search Opens for Editor of New APA Journal**

The Publications and Communications Board has opened nominations for the editorship of a new journal, *Journal of Experimental Psychology: Applied*, for the years 1995-2000. Candidates must be members of APA and should be prepared to start receiving manuscripts early in 1994 to prepare for issues published in 1995. Please note that the P&C Board encourages more participation by members of underrepresented groups in the publication process and would particularly welcome such nominees. To nominate candidates, prepare a statement of one page or less in support of each candidate. Submit nominations to

Howard E. Egeth, PhD  
Chair, *JEP:Applied Search*  
Department of Psychology  
Johns Hopkins University  
Charles & 34th Streets  
Baltimore, MD 21218

The *Journal of Experimental Psychology: Applied* will publish original empirical investigations in experimental psychology that bridge practically oriented problems and psychological theory. The journal also will publish research aimed at developing and testing of models of cognitive processing or behavior in applied situations, including laboratory and field settings. Review articles will be considered for publication if they contribute significantly to important topics within applied experimental psychology.

Areas of interest include applications of perception, attention, decision making, reasoning, information processing, learning, and performance. Settings may be industrial (such as human-computer interface design), academic (such as intelligent computer-aided instruction), or consumer oriented (such as applications of text comprehension theory to the development or evaluation of product instructions).

First review of nominations will begin December 15, 1992.