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Mouthing and Grasping of Objects by Young Infants

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Mouthing and grasping objects are two common behaviors observed in young infants, although little is known about the relations between these activities. Data from two previously published experiments on 4- to 8-month-old infants (N = 133) are further analyzed to investigate if: (a) variation in object size and shape influences whether objects are mouthed after being picked up, and (b) infants modify their grip configurations in order to mouth objects as opposed to performing other prehensile actions. The results showed that larger objects increased the propensity of young infants to mouth objects; object size also contributed to differentiating the grip configuration according to the intent of the action. The findings suggest that infants as young as 4 months perceive that object properties afford different actions and differentiate grip configurations to realize specific task goals.

Exploratory behavior is one way in which infants learn about themselves and their environments (E. J. Gibson, 1988). This exploratory behavior can be oriented toward detecting what objects in the environment afford for various actions (E. J. Gibson, 1982; J. J. Gibson, 1979/1986). One prevalent exploratory behavior observed in infants is the tendency for them to transport objects to their mouths after these objects have been grasped. Indeed, Palmer (1989)

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observed that approximately 30% of objects grasped by 6-month-old infants were brought to their mouths. It is assumed that infants mouth and manipulate objects to gather information about the various dimensions of the objects (Palmer, 1989; Rochat, 1987, 1993; Ruff, 1984).

For an infant to mouth an object, a coordinated sequence of movements is often necessary. The act of mouthing could also include the movement dynamics associated with reaching for an object, grasping the object, and transporting the object. Indeed, grasping is nearly always performed in the service of some other activity, such as exploring, mouthing, throwing, manipulating, and transporting. Movement dynamics are an emergent property of the constraints to action (Kugler, Kelso, & Turvey, 1980, 1982). The constraints to action include not only those of the organism and environment but also those that arise from the task itself (Newell, 1986).

Acting to realize a particular goal will specify a particular set of constraints on the individual in action. For example, the perception of the *mouth*ability of an object as opposed to its *move*ability on a surface of support might lead to different actions and grip configurations. Action differentiation presumes perceptual differentiation of the affordances, but the former is not a sufficient test of the latter, only an outcome consistent with it. In this article, we present data from experiments that examined whether the object properties of size and shape influence the perception of the affordance of the *mouth*ability of a given object and whether infants differentiated grip configurations to the same object according to the task constraints arising from the action goals.

There have been a few studies of the relation between mouthing and grasping in infants. Rochat (1987, 1989, 1993) examined the grasping–mouthing link in neonates and 2- to 6-month-old infants. He proposed that different mechanisms appeared to be driving the mouthing actions of these infant age groups. In the first 2 months of life, the grasping and mouthing link was related to feeding, whereas by 5 months of age the mechanism for grasping and mouthing had become an information gathering system. In addition, Rochat demonstrated that when infants were constrained from using their hands to grasp an object, they leaned forward in an attempt to mouth the object. These observations suggest that young infants perceive the affordance of the *mouth*ability of objects and have a knowledge of the constraints on grasping when mouthing is the goal of the action.

Ruff (1984, Study 1) presented infants age 6, 9, and 12 months with two series of objects. In one series, the shape of the object varied while the surface pattern remained constant, and in the other series, the color of the objects varied while the texture remained constant. Ruff noted that the infants mouthed and transferred objects more in the patterned series, in which shape varied. On the other hand, the infants fingered objects in the textured series more often. Palmer (1989) found that mouthing was used by infants as a means to detect the object properties of weight, texture, and sound. With the latter two properties,

however, the infants supplemented their mouthing actions with waving of the object and adapted their actions to the type of support surface used. Palmer noted that infants who were presented with a foam table surface mouthed objects longer than those presented with a hard table surface; more banging and switching of objects grasped also occurred in the hard-surface condition. These findings suggest that young infants perceive what the environment affords for prehensile action in that object-texture and surface-support variations induce differentiation of prehensile action.

Newell, Scully, McDonald, and Baillargeon (1989) showed that infants as young as 4 months differentiated grip configurations as a function of the object properties of shape and size. The data revealed that the number of fingers used to grasp the object increased as the object size increased. It was also found that the presentation mode influenced the grip configuration infants used to grasp large objects. When a large cup was inverted so that the open end contacted the surface of support, infants predominately used two hands to successfully grasp the cup. In contrast, when the cup was presented with the open end to the infant a one-hand grip was primarily used even when the cup size was increased. These findings show that young infants are able to discriminate objects in meaningful ways in relation to the perceived task demands (Newell, 1986), but no analysis was made of the prevalence of mouthing activity and its relation to the grip configuration.

In this article, we provide some initial data on infants' perception of affordances with objects by drawing inferences from the mouthing of objects as a function of object properties and age. The following questions guided the analyses presented here: (a) Do the object properties of size and shape influence the prevalence of mouthing? (b) Is the nature of the prehensile goal—for example, mouthing versus some other movement activity—an influence on the grip configuration used to grasp the same object? To address these questions, data from the infant prehension studies of Newell et al. (1989) and Newell, McDonald, and Baillargeon (1993) were further analyzed with respect to the relation between the grasping and mouthing of objects.

EXPERIMENT 1: NEW ANALYSIS OF NEWELL ET AL. (1989)

Method

Subjects. One hundred two infants between the ages of 119 and 289 days participated. The infants were divided into five age groups approximately 1 month apart. These groups were labeled as the 4-, 5-, 6-, 7-, and 8-month groups, and there were 21, 22, 21, 22, and 16 infants in each respective age bracket.

Apparatus. Four objects were utilized for this experiment. Three objects were lightweight plastic toy cups with diameters (heights) of 1.2 (1.9), 2.6 (2.8), and 9.0 (9.5) cm, respectively. The fourth object was 2.54 cm (1 in.) wooden cube identical in size to that used in the Halverson (1931) experiment.

Procedure. The infants were tested individually in a soundproof room. Each infant sat on the lap of a first experimenter who sat on a hard-back chair at normal table height. Each infant was positioned with his or her back to the first experimenter to form a common sagittal plane of motion. The first experimenter provided postural support to the infant, without interfering with the infant's arm and hand movements. The experimenter supported the infant by holding the sides of the torso under the arms. The infant was required to support his or her own body and was not allowed to rest against the chest of the experimenter. The grasping routine was videotaped allowing full view of the infant, the infant's grip configuration, and the activity the infant engaged in after grasping the object.

The object for each trial was presented by a second experimenter from the right-hand side of the infant. The object was placed in the middle of the open and flat hand of the second experimenter. The cups were presented in an open mode with the cup opening face up and in a closed mode with the cup face down. The object was centered in the midline of the infant's torso and within a comfortable reaching distance. A 10-s presentation period was permitted to allow the infant to make contact with the object. The four objects provided seven unique modes of object presentation to the infant. Three rounds of the seven presentation modes produced a total of 21 grasping trials for each infant. The order of presentation mode within each round was randomly determined for each subject. On most trials the object was grasped by the infant and used as part of an activity.

The videotapes of the grasping trials were coded as described in Newell et al. (1989). For the purpose of this article, however, the following aspects of prehension were analyzed: (a) number of times each object was grasped, (b) number of hands used to grasp the object, and (c) the activity the infant engaged in after grasping the object. The prehensile activity was classified according to whether the object was brought to the mouth or moved from the experimenter's hand but not lifted to the mouth. *Mouthing* was defined as the object making contact with the mouth and included trials on which the object was stopped by the experimenter from making contact with the mouth, just prior to contact. The contact with the mouth was prevented on trials with the smaller objects to prevent the infants from swallowing the objects.

All measures were scored in terms of frequency of occurrence as a function of age group and object. This group-frequency plotting technique has been used previously by Gesell and Halverson (1936) and Newell et al. (1989). The group

data were analyzed using logistic regression and the likelihood-ratio chi-square statistic (L^2; Haberman, 1978–1979).

Results and Discussion

The first analysis calculated the number of times each object was grasped. A *grasp* was defined as the infant's hand(s) making contact with the object and lifting it from the experimenter's hand. The open and closed cup data were plotted separately to enable the results of the closed presentations to be contrasted with the results found in the Newell et al. (1993) study, to be reported subsequently. The frequency of grasps was influenced by size of object and mode of presentation. On average, objects were grasped approximately 90% over all the object presentations. Only the trials in which the object was grasped are used in the subsequent analyses.

Figure 1 illustrates the percentage of times each object made contact with the infants' mouth as a function of object presentation mode. The data from this

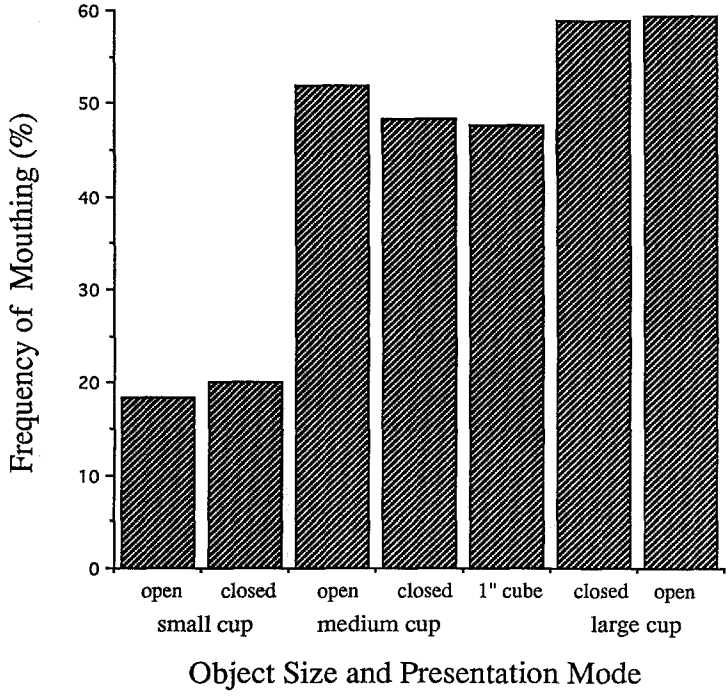

FIGURE 1 Frequency of object mouthing as a function of object size and presentation mode (Experiment 1).

analysis revealed that, on average, 44% of all objects grasped were transported to the infants' mouths, with the largest cup mouthed 57% of the time compared to the smallest cup being mouthed only 18%. These data were modeled using logistic regression analysis and the likelihood-ratio chi-square statistic (L^2) used to determine the goodness of fit for each model (Haberman, 1978–1979). The net effect of object size on mouthing frequency was found to be significant, $L^2(2) = 199.2$, $p < .001$. A post hoc Helmert contrast revealed that the small object produced significantly less mouthing than did the medium and large objects ($z = 12.08$, $p < .001$). However, presentation mode of the cup had no significant effect on mouthing frequency, $L^2(1) = 2.18$, $p > .05$. These findings illustrate that object size systematically influenced the prevalence of mouthing in infants aged 4 to 8 months irrespective of the mode of object presentation.

Figure 2 shows the percentage of mouthing (given that an object was grasped) as a function of infant age. Mouthing frequency was clearly lower at 4 months of age, whereas the frequency fluctuated around 45% to 50% for the other age groups. Logistic regression revealed age to be a significant factor in determining the percentage of objects mouthed, $L^2(4) = 24.8$, $p < .001$. A post hoc Helmert contrast revealed that the difference between the 4-month-old group and the mean of all the other age groups accounted for this main age effect ($z = 4.12$, p

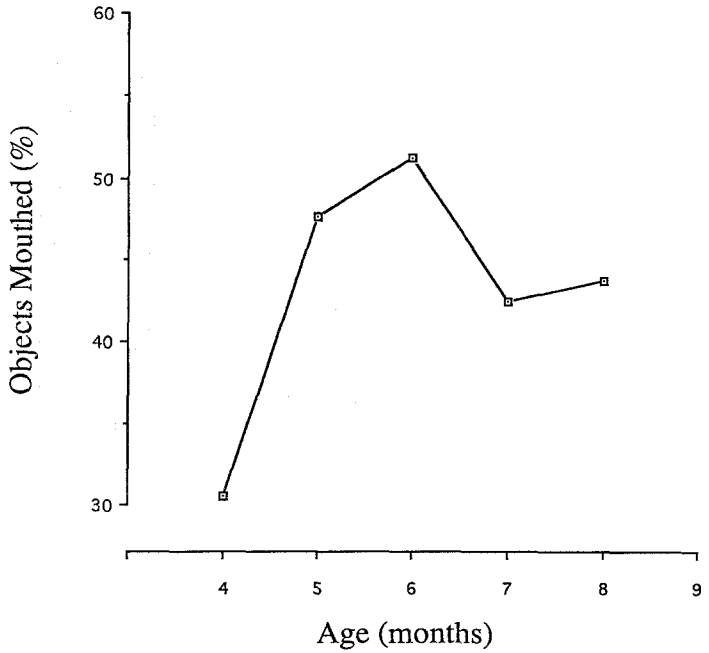

FIGURE 2 Frequency of object mouthing as a function of infant age (Experiment 1).

$< .001$). These data suggest that there is a significant change from 4 to 5 months of age relative to mouthing frequency, but over the ages of 5 to 8 months mouthing frequency is relatively stable.

Our second question was whether there would be a difference in the grip configurations used when infants mouthed objects as compared to when they just moved them away from the experimenter's hand. For this analysis the absolute frequency of hand use (one vs. two hands) for each object size and mode of presentation was contrasted according to the goal identified (i.e., mouthing or moving). Figure 3 illustrates that when the largest cup was presented in the closed mode, a two-handed grip configuration was used 87% of the time when the object was mouthed, as compared to 75% when only moved. However, Figure 4 illustrates that two hands were used less frequently in the open mode (38% for mouthing and 28% for moving) compared to the closed mode (cf. Figure 3) for the largest cup. Modeling these data with logistic regression revealed that the actions performed (mouthing or moving) were each done with different frequencies of one- and two-hand grips, with the moving action having a significantly higher proportion of one-handed grips, $L^2(1) = 8.7$, $p < .05$.

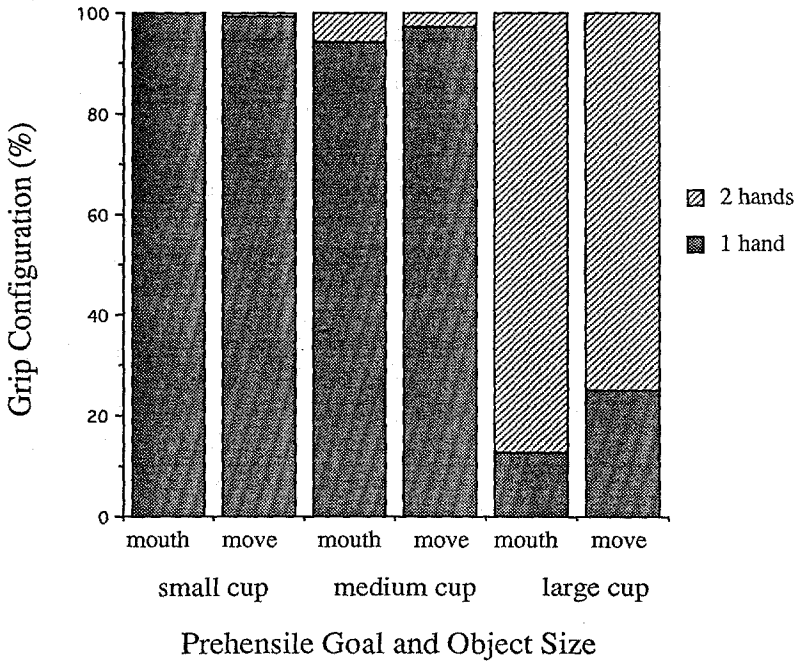

FIGURE 3 Frequency of using one or two hands as a function of the prehensile goal (mouthing vs. moving), object size, and presentation mode for the closed-mode cups (Experiment 1).

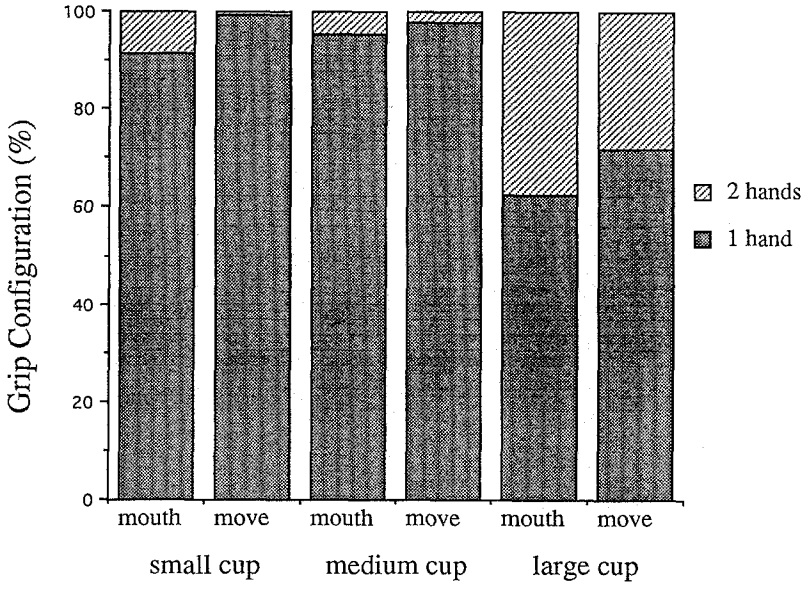

FIGURE 4 Frequency of using one or two hands as a function of the prehensile goal (mouthing vs. moving), object size, and presentation mode for the open-mode cups (Experiment 1).

Age did not interact with these hand-frequency trends for moving and mouthing, a finding that is consistent with the grip configuration data reported in Newell et al. (1989). There were not enough degrees of freedom in the design to examine the triple interaction of age, object properties, and action on hand frequency, but the frequency totals suggested that there was no interaction.

There was, however, a significant interaction of mode of presentation and object size, $L^2(2) = 27.3, p < .001$, which reflected the increased proportion of two-handed grips when handling the large cup presented in the closed mode. This difference in grip configuration relative to the mode of presentation is the most dominant difference and presumably arises because the open mode affords single-hand grasping, whereas the closed mode requires two hands to lift the object.

EXPERIMENT 2: NEW ANALYSIS OF NEWELL ET AL. (1993)

Methods

Subjects. Thirty-one healthy infants between the ages of 5 months, 14 days and 8 months, 14 days (M = 7 months, 2 days) participated.

Apparatus. Seven lightweight, brightly colored cups were used in this experiment. The cup diameters were 1.2, 2.6, 3.9, 5.1, 6.5, 7.5, and 9.0 cm, and their heights were 1.9, 2.8, 3.8, 4.7, 5.6, 6.0, and 9.5 cm, respectively. In this experiment, the objects were always presented so that the open end was face down on the experimenter's hand (i.e., same as the closed mode in Experiment 1).

Procedure. The presentation and filming procedures were identical to those described in Experiment 1 with the exception that all objects were presented in the closed mode. The seven objects were presented over three rounds with each subject completing a maximum of 21 trials. The order of presenting the objects within each round was randomized for each of the subjects. Each trial was coded as previously described in Experiment 1.

Results and Discussion

The number of times the infants grasped each object is illustrated in Figure 5. These data indicate a trend for decreased grasping frequency with increasing object size which logistic regression revealed to be significant, $L^2(6) = 44.3, p <$

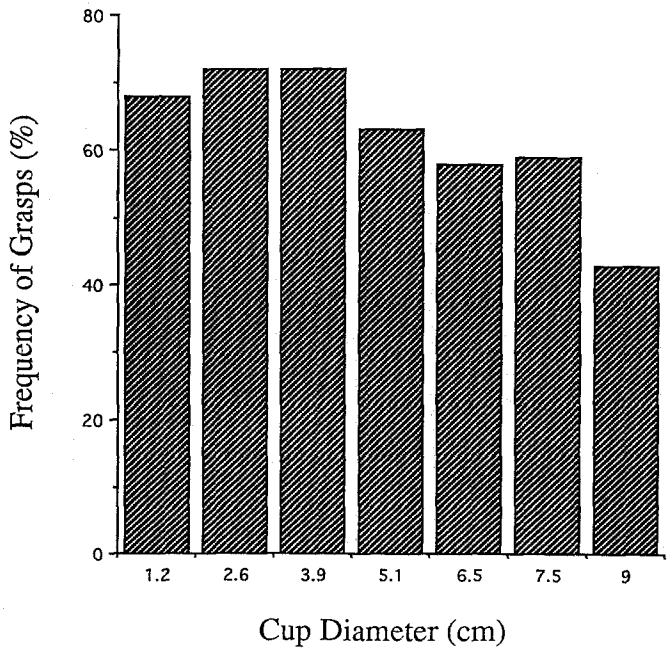

FIGURE 5 Frequency of object grasping as a function of object size (Experiment 2).

.001. This finding is consistent with the findings of Palmer's (1989) study. However, examining the number of times the object was transported to the mouth reveals a trend similar to that found in the Newell et al. (1989) study. On average, the objects that were grasped were transported to the mouth on 49% of the trials. Figure 6 illustrates that the largest cup (9.0 cm) was mouthed 67% compared to the smallest object (1.2 cm) being mouthed 30%. Again, logistic regression analysis identified mouthing frequency to be significantly influenced by object size, $L^2(6) = 22.1, p < .001$. This finding confirms that larger objects appear to afford more mouthing activity to the infants.

In the Newell et al. (1989) study a small but statistically reliable relation was observed between the goal of the activity and the grip configuration used to grasp the object. In this experiment (Newell et al., 1993), a larger cup selection was used which resulted in a more noticeable systematic trend between the goal identified and the grip configuration used by the infants. As Figure 7 illustrates, infants used a two-handed grip configuration more frequently when the objects were mouthed compared to when they were moved. This trend was revealed to be significant using logistic regression analysis, $L^2(1) = 23.4, p < .001$.

As one might expect, there was also a significant trend for object size to influence the grip configuration, $L^2(6) = 189.3, p < .001$, with the larger objects more frequently gripped with two hands. Post hoc contrasts showed that the

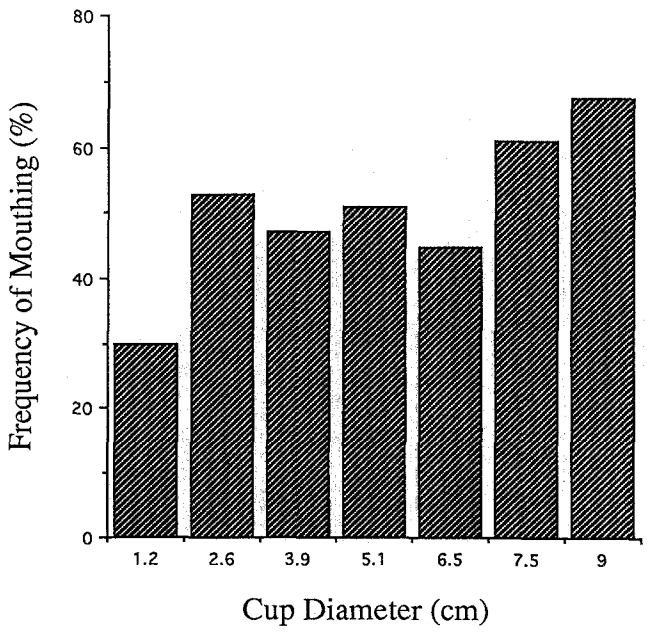

FIGURE 6 Frequency of object mouthing as a function of object size (Experiment 2).

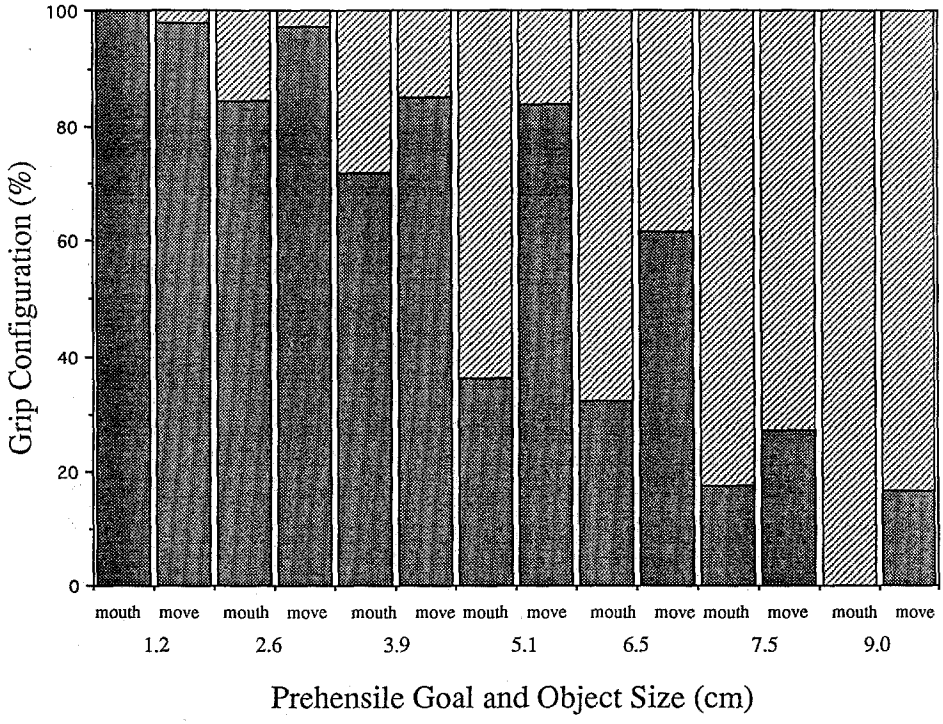

FIGURE 7 Frequency of using one (dense shading) or two (diagonal lines) hands as a function of the prehensile goal (mouthing vs. moving) and object size (Experiment 2).

9-cm cup produced significantly less grasping than did the other cup sizes. This object-size effect is consistent with the observations reported from the previous study. These results suggest that infants do adapt their grip configuration to mouth objects successfully.

GENERAL DISCUSSION

The findings from both experiments confirmed the common observation that young infants have a tendency to transport objects to their mouths once grasped. On average, the objects were mouthed 44% and 49% of the total trials where a grasp took place for each of the experiments that we examined. Previously, Palmer (1989) found a lower overall mouthing frequency of 30% in infants aged 6 months with a range of objects that varied in size and texture.

The data from the first experiment (Newell et al., 1989) showed a systematic change in mouthing frequency as a function of infant age, especially between the

4-month age group and the older infants. These findings are consistent with those of McCall (1974) and Ruff (1984) who reported that mouthing frequency in infants decreases with increasing age for infants in the age range of 6 through 12 months of age. Rochat (1989) has shown that the duration of object contact with the mouth during mouthing increases similarly over the same age range. The findings reported here confirm that infant age influences the frequency of mouthing, although further experimental work with an extended age range is required to determine the more precise influence of age. The texture of the objects may also interact with age and object size in determining infant mouthing (Palmer, 1989).

This article focused on trends in the frequency of mouthing due to the object properties of size and shape, as well as on the grip configuration used to grasp objects. In both experiments, the larger objects were mouthed significantly more frequently than the smaller ones. This trend appeared most clearly in Experiment 2 which used a more gradual increase in cup size. The presentation mode of the objects (in effect, object shape) did not influence the frequency at which objects were mouthed, even though presentation mode did significantly interact with size in determining how the object was grasped.

Why would infants mouth larger objects more frequently than smaller objects? One hypothesis is that infants bring larger objects to the mouth more often than smaller objects because they need the mouth to provide the additional support to sustain the stability of the object in the hand, while they are exploring the object. With this hypothesis, mouthing per se would not be the goal of the activity but, rather, the goal of the task would be maintaining the grasp of the object by using the mouth as a third hand. McCall (1974) found evidence for this hypothesis in his study of 12-month-old infants' grasping. A second hypothesis is that infants find mouthing easier with the larger object because they can manipulate the object position in or at the mouth without invoking a precision grip, a grip architecture that has been documented to occur later in age than a power grip in prehensile development (Halverson, 1931; Napier, 1956). Additional studies examining in detail the nature of the mouthing action would be required to distinguish the relative contribution of these hypotheses to the interpretation of the grasping–mouthing data.

The second question we examined was whether infants adapt their grip configurations to the same object geometries when engaged in different actions. In other words, do different task goals, which presumably involve different intentions, engender different grip configurations for the same object geometry? In both experiments, a systematic trend was noted: A two-handed grip was predominately used, regardless of the mode of presentation, when objects were mouthed. This trend was consistent across the infant age groups in Experiment 1 but was more salient in Experiment 2, presumably because a more gradual range of cup sizes was used. These findings are consistent with those of Rochat (1989) who found that infants tended to support objects with two hands during

oral manipulation. Moving the cup to the mouth requires fine-motor coordination and we postulate that young infants use two hands to guide and improve their control of the object while transporting it to their mouths.

However, in Experiment 2, there was also a trend for object size to mediate the grip configuration as a function of whether the object was mouthed or merely moved from the original base of support. Specifically, for the intermediate object sizes, there was a clear trend for grip configuration to vary as a function of action within the same object geometry. Thus, the influence of object size on the affordance of differential actions was consistent across the two experiments, although this effect could not be modeled formally in the logistic regression analysis due to the limited number of degrees of freedom. These findings are consistent with the notion that action is an emergent property of the interaction of three sources of constraint—namely, the environment, the organism, and the task (Newell, 1986).

In summary, these data demonstrate that the infants' intentions and the constraints of the environment in the form of object properties lead to systematic tendencies in mouthing and grasping. Increasing object size increased mouthing frequency, whereas presentation mode appeared to have no influence on mouthing frequency. A steadier two-handed grip configuration was employed when infants intended to mouth objects and object size mediated the grip configuration in relation to the goal of the action. The findings suggest that (a) object size affords different activities for young infants and (b) grip configurations are differentiated according to the intent of the action.

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