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ABSTRACT

The purpose of the present study was to determine whether infants categorized as demonstrating good or poor neuromuscular integrity (voluntary motor abilities reflecting movement coordination) would show differences in use of sensory motor schemas. Subjects were 26 full-term (10 males, 16 females) and 10 premature infants (6 males, 4 females) between 31 and 37 weeks of age, who were not neurologically impaired. Infants were classified for evidence of good or poor neurological integrity on the basis of their interaction with a single red cube. A total of 11 operationally defined behaviors involved in the infant's initial approach and manipulation of the cube were coded as being a good or poor response using criteria based on clinical judgment, developmental norms, and Halverson's study of grasping. The results of this study indicate that the quality of fine motor behavior influences the way normal 8-month-old infants use objects. The evidence suggests that infants with good neuromuscular integrity tend toward greater use of manipulative schemas, while infants with poor neuromuscular integrity tend toward greater use of visual schemas. (CS)

Neuromuscular Integrity and Use of Sensory Motor Schemas

Claire B. Kopp

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Neuromuscular Integrity and Use of Sensory Motor Schemes

Claire B. Kopp

Neuromuscular integrity refers to voluntary motor abilities that reflect coordination and smooth regulation of movement. In regard to infants the term has been used clinically to describe fine motor behaviors involved in reaching and grasping. Although the developmental sequence of these motor abilities has been documented by Halverson (1932), Gesell and Amatruda (1947), White, Castle and Held (1964), Bruner (1968, 1970), and Twitchell (1970) there has been little research on differences in neuromuscular integrity and its effect on infant behavior and subsequent development. The purpose of the present study was to determine whether infants categorized as demonstrating good or poor neuromuscular integrity would show differences in use of sensory motor schemes.

During the latter part of the first year of life reach and grasp patterns of normal infants generally are well developed. Most 8 month infants react to a presented object with great interest and reach for it with accuracy (Baruk, Leroy, Launay, Vallancien, 1953), using a grasp that involves the radial side of the palm being placed on the object along with thumb and first two fingers (Halverson, 1932). Nonetheless, qualitative differences are observed in reach and grasp actions. Movements of some infants are described, clinically, as showing lack of integration and incoordination. Although infants with central nervous system dysfunction may manifest this type of incoordination, a small group of infants with no known neurological deficit also have difficulty executing anticipatory motor adjustments of arm and hand prior to making contact with an object. Furthermore, extraneous movements may be exhibited while reaching and grasping.

Provence and Lipton (1962) reported incoordinated reach and grasp movements of institutionalized infants although the developmental sequence of these behaviors was similar to that of home reared infants. The authors found lack of modulation of movement, slower approaches to objects, extraneous actions, and frequent dropping of objects. Provence and Lipton attributed these distortions to deprivation of experiences and suggested that fine motor behaviors might be more dependent on the "organizing influence" of external stimulation. However, similar motoric behaviors are observed in some infants who were premature at birth and even a small group of full term infants who are home reared. Although the nature of the antecedents of poor neuromuscular integrity is unknown, it is highly probable that some aspect of development will be affected.

The infant who evidences good neuromuscular integrity may interact with objects in a different manner than infants who have poorly integrated movements, even though both groups of infants evidence the same level of grasp patterns. For example, infants who manipulate objects with ease may master the component acts associated with manipulation of a specific object and then go on to explore and utilize other sensory motor schemes. Bruner (1970) suggested that when an action became organized it was then incorporated into new action patterns. But, as Bruner points out, more complex behaviors appear when attention does not have to be directed to the act itself but to the object of interest and this in turn leads to further knowledge and skill. If, however, the clumsy infant has to be more attentive to his motor behavior in order to execute an action or if his motor control is not well regulated he may evidence different types of schemas than the well integrated infant.

The purpose of this study was to differentiate infants, who evidenced no neurological impairment, solely on the basis of demonstration of good or poor neuromuscular integrity to determine whether the groups differed in the use of sensory motor schemes. Since neuromuscular integrity was to be the only criterion used to classify infants the subject pool consisted of available full terms and prematures.

METHOD

Subjects.

The subjects were 26 full term (10 males, 16 females) and 10 prematures (6 males, 4 females) without neurologic deficit who were with three exceptions, between 32 and 36 weeks of age from their expected date of delivery. One infant was 31 weeks and two were 37 weeks of age. The full terms were recruited from interested parents in the local community, whereas many of the prematures constituted a portion of a sample of infants involved in a longitudinal study.[1] All of the infants used for this analysis had to demonstrate ability to pick up the test objects utilizing thumb and fingers on the radial side of the hand which is a characteristic of the 32 week old infant (Halverson, 1932). Four infants were excluded because they did not meet this criterion. Data from six additional infants could not be analyzed due to equipment difficulties.

Procedure

All of the subjects were tested in the same laboratory room. The infants were seated in a crib before a 26in.X 34in.grey wooden table top that was adjusted to be at the subject's waist level. A Javelin video camera with a zoom lens was placed approximately 5 ft. to the left and 3 ft. above the crib and recorded the infant's behaviors with all the test objects. The infant's mother stood at the foot of the crib in full view of the subject while E_2 or E_3 was behind the crib, out of range of the infant's view, watching a television monitor. A brief adaptation period in the crib was allowed the infants before the formal test procedure was initiated. The mother presented and removed test objects at a signal from the examiner. During the test proper, the mother was instructed not to initiate conversation with her infant but to verbally soothe him if he started to fret.

Stimulus objects

The first object given to the infant was a single 1 in. red wooden cube (ST 1) placed directly in front of the infant 4 in. from the edge of the table top closest to his chest. The infant was allowed to manipulate the cube for 60 sec. and his initial interactions with this cube was used only to code neuromuscular integrity which will be discussed below.

Two additional objects were presented to the infants to elicit sensory-motor schemas. The first of these for Trial 1 was a single 1 in. red wooden cube that had a $\frac{1}{4}$ in. white dot painted on each side (ST 2). The other stimulus object,for Trial 2, was made of three similar cubes tied together with ¼ in. white plastic cord. Two small black faucet washers were placed between each cube (ST 3). These are shown in Figure 1. Each of these stimuli were separately presented to the infant for 60 sec.

Place Figure 1 about here

These stimuli were placed in the same position as the single red cube. Sometimes the infant dropped the stimulus object on the floor, when this happened, the examiner lengthened the stimulus time so that the infant would have a total of 60 sec. to interact with each object.

Classification of Subjects: Neuromuscular Integrity

The infants were classified for evidence of good or poor neuromuscular integrity on the basis of their interaction with the single red cube (ST 1). E_1 using regular speed, and slow motion and stop frame features of a Javelin video tape system, coded eleven items involved in the infant's initial approach and manipulation of the object. Each of the behaviors was operationally defined and was individually coded as being a good or poor response using criteria based on clinical judgement, developmental norms, and Halverson's (1932) study of grasping. The number of good responses were summed and those infants who had 7 or more good responses were considered to have overall good neuromuscular integrity (GNl) while infants with scores of 6 or less were considered to have poor neuromuscular integrity (PNl).[2]

On the basis of this assessment 24 infants (21 full terms, 3 prematures) demonstrated good neuromuscular integrity (GNl) and had a mean age of 34 weeks (1.6) and 12 infants (5 full terms, 7 prematures) showed poor neuromuscular integrity (PNl) with a mean age of 34.3 weeks (1.5).

Sensory Motor Schemas: Coding

The frequency and duration of the infant's individual schemas with stimulus objects, ST2 and ST3, were independently coded by E_2 or E_3. Duration was coded in the following way. The slow motion feature of the videodeck was turned on, and using an eight channel Rustrak event recorder the examiner pressed one or more Rustrak buttons to code on paper tape the particular schema being emitted. Slow motion on the video tape is seven times slower than that of real time, therefore, the coded behavior on the paper tape was seven times longer than actual time. The examiners then decoded the paper tape and divided each schema by 7 to obtain the real time duration of each schema.

The totals for each emitted schema over the two 60 sec. periods were summed for duration. Frequency counts were made by adding the number of times each schema was repeated in the entire behavioral sequence.

Operational definitions were written for more than twenty potential behaviors that included looking, holding, examining, mouthing, transferring, hitting, shaking, etc.[3] Periodic inter-observer reliability studies of many of the schemas indicated observer coding agreement, for duration of specific behaviors, averaged better than 0.9.

RESULTS

Many similarities were noted in the infants' use of schemas although idiosyncratic behaviors also were noted occasionally. Commonly observed behaviors were grouped together in schema categories. Some schemas were mainly manipulative but included visual components. These were 1) exploration which consisted of examining the object (looking at the object while turning it around in the hands[4]), mouthing the object, transferring, and purposeful releasing; 2) large action behaviors which consisted of waving and banging the object against the table top; and 3) simple action such as sliding the object along the top of the table top. Other schemas were mainly visual but could include manipulative components. These were 4) looking at the stimulus object without touching it; 5) looking around the room while holding the object; and 6) looking around the room without the object in hand. These major categories were used as the basis of several group comparisons that are discussed below. No overall sex differences were obtained in any analysis so the male-female data were pooled.

Duration of Schemas: Combined and Seperate Trials

The mean duration responses for the group of six behaviors were compared for the good neuromuscular integrity group (GNI) and the poor neuromuscular integrity group

(PNI) using univariate t tests. Since the groups were unequal in size every t statistic that is reported in this paper has been computed using separate rather than pooled variances and adjusted degrees of freedom to obtain a more conservative estimate of t.

The mean scores and standard deviations for duration (seconds) for the combined trials are presented in Table 1. Of the six behavi~~s, differences were found in

Insert Table 1 about here

exploring behaviors with the GNI group demonstrating a significantly greater amount: t(26,7)=3.03, p .007. No other behaviors showed significant group differences although a weak trend was noted for the PNI group to demonstrate more large action behavior.

Since exploring incorporated mouthing, examining, releasing, and transferring schemas, an analysis was made to determine if some of these schemes were more predominant than others. Examining and mouthing were exhibited most often by both groups although the GNI group consistently demonstrated a higher mean duration than the PNI group. However, duration of mouthing contributed most to the exploring score and was done for a significantly longer period of time by the GNI group: t(26,7)=2.30; p.02.

Use of a number of univariate t tests may give misleading results as significance may be a chance occurrence. Furthermore, univariate tests use less information about possible relationships among variables and may not indicate overall group differences (Winer, 1971). Therefore, a multivariate analysis of the six behaviors was made using Hotelling T^2 which is transformed into an F statistic. A trend was obtained for overall group differences on the amount of time spent on the six behaviors F(6,29)= 2.04, p.09.

In order to determine if the differences that were noted on the univariate t tests were more a function of Trial 1 or of Trial 2, separate trial analyses were made. On each trial, exploring showed significant group differences with a greater amount consistently demonstrated by the GNI infants: (Trial 1: t(23,4)=2.78, p.01); Trial 2: t(17,4)=2.46, p.02). In addition, on Trial 1 the duration of large action behavior exhibited by the PNI group showed a trend towards significance.

Of interest is the change in duration of some of the behaviors shown by the infants from Trial 1 to Trial 2. Figure 2 shows these differences for all the exploring

Insert Figure 2 about here

behaviors together, then mouthing and examining separately, and the three commonly observed visual behaviors. The amount of mouthing remained relatively stable for both groups, however, the GNI infants demonstrated considerably more mouthing and maintained this over both trials. Examining increased for both groups on the second trial, which was to be expected as the second object was novel, however, examining increased somewhat more for the GNI infants. The patterns of response of visual behaviors also were markedly similar in trend. Again, the novelty of the second object was reflected in more time spent looking at the object while holding it and a decrease in visually scanning the surroundings. On two of the three visual behaviors the PNI infants demonstrated a greater duration of visual schemas and maintained this across the two trials.

Frequency of Schemas: Combined and Separate Trials

The mean scores and standard deviations for frequency of response of the six behaviors were compared for the GNI and PNI infants (Table 2). The GNI group demon-

Insert Table 2 about here

strated significantly greater frequency of exploring: t(32,1)=3.10, p.004, while the PNI group showed a weak trend toward greater amount of large action and simple behaviors. As with duration the frequency of mouthing was the behavior in the exploring category that showed significant group differences: t(32,9)=2.88, p.007. A multivariate analysis of the six behaviors indicated significant overall group differences in the frequency of exhibited behaviors : F(6,29)=2.41,p.05.

Separate trial analyses of group performance indicated that GNI infants tended to explore with a greater frequency on Trial 1: $t(33,5)=1.84$; p.07 and did significantly more on Trial 2: $t(22,7)=2.93$; p.008. In addition, a trend was noted for the PNI group to demonstrate more large action behavior on Trial 2: $t(15,8)=1.99$; p.06. A multivariate analysis for overall group differences on frequency of exhibition of the six behaviors showed no significant differences for Trial 1 but significant group differences on Trial 2: $F(6,29)=2.76$; p.03.

Figure 3 shows the changes in frequency of some of the behaviors from Trial 1 to

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Insert Figure 3 about here

Trial 2. As with the duration data, there was similarity in response trends for both groups. The slope of change for frequency of exploring was greater for the GNI infants. The PNI infants reflected a greater frequency of holding the object and looking at it on Trial 2. As with duration, both groups of infants did less visual scanning of the environment on Trial 2.

Correlational Analyses: Duration and Frequency

Correlational analyses were made to determine how the six behaviors related to one another. These data, using both trials combined, are given in Table 3. For

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Insert Table 3 about here

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duration of schemas, exploration was negatively correlated with holds object and looks at it, holds object and looks around room, and large action behavior. An unexpected negative correlation was obtained for holds object and looks around room with looks at object with no contact. The correlational analyses for frequency were less consistent with a significant positive correlation obtained for large action behavior with holds object and looks at it, and a significant negative correlation for looks at object without contact with holds object and looks around the room. The fact that this latter correlation was found for both duration and frequency suggested that some types of visual behaviors may be more mature developmentally than others. Assuming that novel surroundings promote visual scanning, in eight months olds, and that a novel object stimulates immediate manipulative and visual exploration, then just looking at an object, without reaching for it, might be an immature behavior. If this is so then looks at object without contact should be negatively correlated with a mature manipulative behavior such as examining, and positively correlated with large action or simple behaviors. The data show that for both frequency and duration of examining there were significant negative correlations with looks at object without contact ($r=-.38$, p.02, $r=-.38$, p.02, respectively). There were, however, no significant positive correlations of looks at object without contact with less mature manipulative behaviors. Therefore, the assumption that looks at object without contact is an immature behavior for 8 months olds could be only partially supported.

Premature vs. Full Term: Schema Comparisons

The purpose of this research was to investigate neuromuscular integrity as it was reflected by infants use of schemas and not a comparison of full terms versus prematures. However, since the group categorized as having good neuromuscular integrity was composed mainly of full term infants and the poor neuromuscular integrity group did have many prematures, it was decided to do a full term versus premature analysis. The expectation was that the results from this analysis would be weaker than the comparison based on neuromuscular integrity but that some similar trends would be found. The results did confirm the expectation. For duration of the six behaviors two approached significance. These were simple and looks at object while holds, and were done for a longer period of time by the prematures. A multivariate analysis for duration of schemas showed overall significant group differences: $F(6, 29)=2.51$; p.04. For schema frequency there were no significant findings in the univariate or multivariate analyses, however trends were noted for the prematures to show a greater frequency of the simple schema.

DISCUSSION

The results of this study indicate that quality of fine motor behavior influences the way normal eight month old infants use objects. Those infants who were labeled as having good neuromuscular integrity evidenced greater manipulative and oral exploration of objects. Furthermore, although both well integrated and poorly integrated infants demonstrated use of the major schemas expected at eight months of age, overall group differences in schema performance were found.

The nature of the group differences becomes clearer when the predominant style of object interaction of each group is contrasted, although within group variability was found for both PNI and GNI infants. In general, PNI infants spent almost half of their total trial time engaged in one or more of the three types of visual explorations. The percentage of time they spent in all of the measured manipulative behaviors combined was less than the time spent in visual explorations. Examining was their predominant manipulative behavior followed by mouthing, which was used as often as large action and simple schemas combined. In contrast, GNI infants evidenced greater use of manipulative schemas than visual behaviors. Of course visual exploration was also important for these infants but it accounted for one third of their trial time whereas the manipulative schemas accounted for more than half. Furthermore, the predominant behavior of these infants was mouthing which was followed closely by examining. Large action and simple behaviors combined accounted for a small fraction of their trial time. Therefore, it is evident that infants with good neuromuscular integrity tended toward greater use of manipulative schemas while infants with poor neuromuscular integrity tended toward greater use of visual schemas.

An intriguing characteristic of the PNI group related to their incidence of mouthing. This is a predominant behavior at eight months of age (Gesell and Amatruda, 1947; Uzgiris, 1967) and yet sixty percent of PNI infants did little or no mouthing compared to less than fifteen percent of GNI infants who evidenced minimal mouthing. The PNI infants were not developmentally retarded as every infant had to demonstrate a grasp pattern consonent with that expected at 32 weeks of age. Furthermore, all except one of the PNI infants had the ability to do the complex motor behavior, examining, even though their actions were considered to be clumsy. It is possible that use of more complex motor behaviors along with the infrequent use of other normal behaviors such as mouthing is characteristic of the type of uneven development occasionally observed with some infants. The PNI group was comprised mainly of prematures who may demonstrate greater variability in performance than full term infants (Parmelee, 1973). Certainly unevenness is found also with a few fullterm infants. However, during childhood there is a greater incidence of impairment among the premature population than among the full term population (Caputo and Mandell, 1970; Lubchenco, Papadopoulos, Searls, 1972). Whether unevenness in use of schemas coupled with poor neuromuscular integrity is a precursor of later developmental difficulties or is a temporary manifestation of development is unknown.

There is no question that manipulative activities have attentional or informational value for infants (Piaget, 1952; Gibson, 1967; Kagan, 1971; White, 1971). It has also been suggested that it is modulated motor behaviors that free the organism to focus attention on the object of interest with consequent additional information input (Bruner, 1973). Furthermore, in relation to six month olds, McCall (1972) proposed that certain fine motor behaviors produce perceptual contingencies that may have relationships to developing social and cognitive abilities. Therefore, neuromuscular integration in the operation of fine motor behaviors would seem to be a requisite for optimal development. Furthermore, Gibsón(1967) noted that once hands were under control the natural model of exploring is to use simultaneous visual and manipulative exploration. In this study, infants who demonstrated poor neuromuscular integrity evidenced more visual than manipulative exploration. But, visual exploration might prove to be beneficial for some PNI infants as it may limit distracting stimuli that might arise from manipulative explorations that are clumsy. It is obvious that information processing does go on during infancy using visual modes (Kagan, 1971; Bruner and Koslowski, 1972; Jeffrey and Cohen, 1973; Kopp and Shaperman, 1973). Perhaps the most important developmental issue is not what style of interaction is used by infants but rather that the preferred style does not distract the infant from attending to the salient and relevant events that occur in his milieu. This thesis merits further study.

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Footnotes

1. All of the infants were being reared in the home by their natural mothers with the exception of one infant who was cared for, during the day, by a caretaker. Complete data were not available to determine social class but it appeared that most of the full terms were from middle class families whereas about half of the prematures could be considered from the middle class.

2. The items used to code neuromuscular integrity are as follows:

1) First cube approach: good (g) - looks at object; poor (p) - looks at hand or closes eyes.

2) Form of approach: g - plane of approach is in direct line from hand to object; p - circuitous approach to object.

3) Speed of approach: g - approaches object in 2 sec. or less after first glance at object; p - approaches in 3 sec. or more.

4) Hand position as initially approaches object: g - evidence of hand in some aspect of midposition; p - hand completely pronated.

5) Accuracy of approach: g - grasps top and side of cube; p - precarious grasp on cube, drops or aims at and misses cube.

6) First hand portion on cube: g - evidence of hand in some aspect of midposition; p - hand completely pronated.

7) First finger position on cube: g - fingers and thumb simultaneously touch cube; p - two or more fingers touch cube then thumb brought to cube, or thumb touches cube then fingers brought to cube.

8) Finger spread: g - hand on cube, fingers are not spread apart more than 0-$\frac{1}{4}$ inch; p - fingers are spread apart more than $\frac{1}{4}$ inch.

9) Type of grasp: g - use of fingers and thumb; p - thumb is not involved in grasp, i.e. palmar.

10) Parallel or extraneous movements of secondary arm/hand while primary hand manipulating test object: g - none observed or demonstrated one time; p - observed two or more separate times.

11) Tremor, coarse or fine, during total manipulation period: g - none observed; p - tremor noted.

The items that most differentiated the infants were items 3 through 7.

3. The definitions are available upon request.

4. Described by Uzgiris (1967).

TABLE 1

Duration of Schemas

Combined Trials

Behavior	Group: GNI Mean Duration (Seconds)		Group: PNI Mean Duration (Seconds)	
Exploration[a]	57.12	(16.54)	35.26	(22.03)
Large action[b]	7.90	(7.17)	11.90	(8.29)
Simple (sliding object)	1.62	(3.07)	2.55	(3.39)
Looks at object - no contact	6.72	(6.82)	8.15	(10.61)
Looks at object while holding it	15.94	(8.00)	20.17	(11.90)
Holds object and looks around room	18.06	(14.01)	23.20	(19.49)

a Consists of examining, mouthing, transferring, purposeful release

b Consists of waving and banging

TABLE 2

Frequency of Schemas

Combined Trials

Behavior	Group GNI Mean Frequency		Group PNI Mean Frequency	
Exploration[a]	28.20	(10.90)	19.00	(6.79)
Large action[b]	15.97	(17.68)	28.66	(24.34)
Simple (sliding object)	1.79	(1.91)	3.41	(3.60)
Looks at object - no contact	8.08	(8.97)	8.58	(12.33)
Looks at object while holding it	24.16	(18.41)	30.33	(21.05)
Holds object and looks around room	16.79	(11.45)	21.75	(16.11)

a Consists of examining, mouthing, transferring, purposeful release

b Consists of waving and banging

TABLE 3

Correlations for six behaviors for combined Trials: Duration

Combined Trials

	Exploration	Large Action	Simple	Looks: No Contact	Looks Around Room	Holds Object and Looks at it
Exploration	—	-.36*	-.26	-.29	-.46**	-.43*
Large Action		—	.06	-.22	.13	.29
Simple			—	-.07	.11	.10
Looks: No Contact				—	-.36*	-.12
Looks Around Room					—	-.04
Holds Object and Looks at it						—

* $p < .05$ $r = .34$

** $p < .01$ $r = .44$

TABLE 4

Correlations for six behaviors for combined Trials: Frequency

Combined Trials

	Exploration	Large Action	Simple	Looks: No Contact	Looks Around Room	Holds Object and Looks at it
Exploration	—	-.03	.00	-.01	-.13	.24
Large Action		—	.18	-.22	.21	.61**
Simple			—	-.11	.21	.22
Looks: No Contact				—	-.34*	-.21
Looks Around Room					—	.21
Holds Object and Looks at it						—

* $p<.05$ $r=.34$

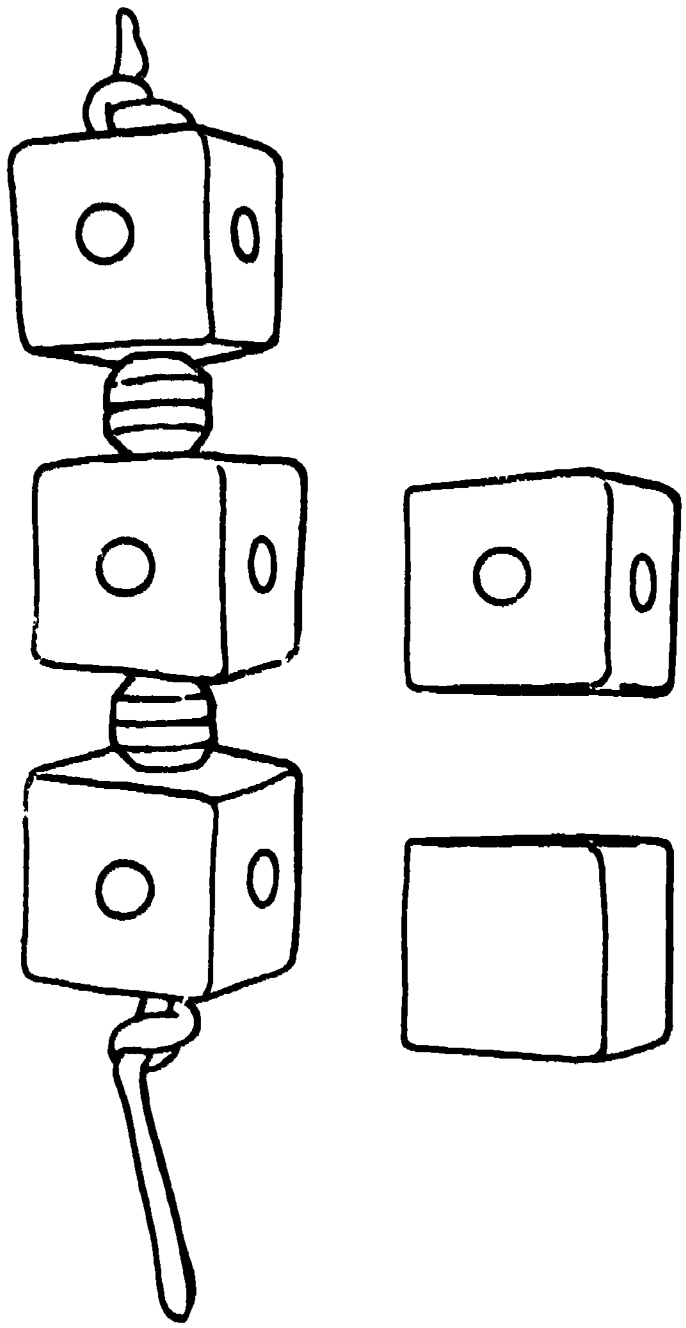
** $p<.01$ $r=.44$

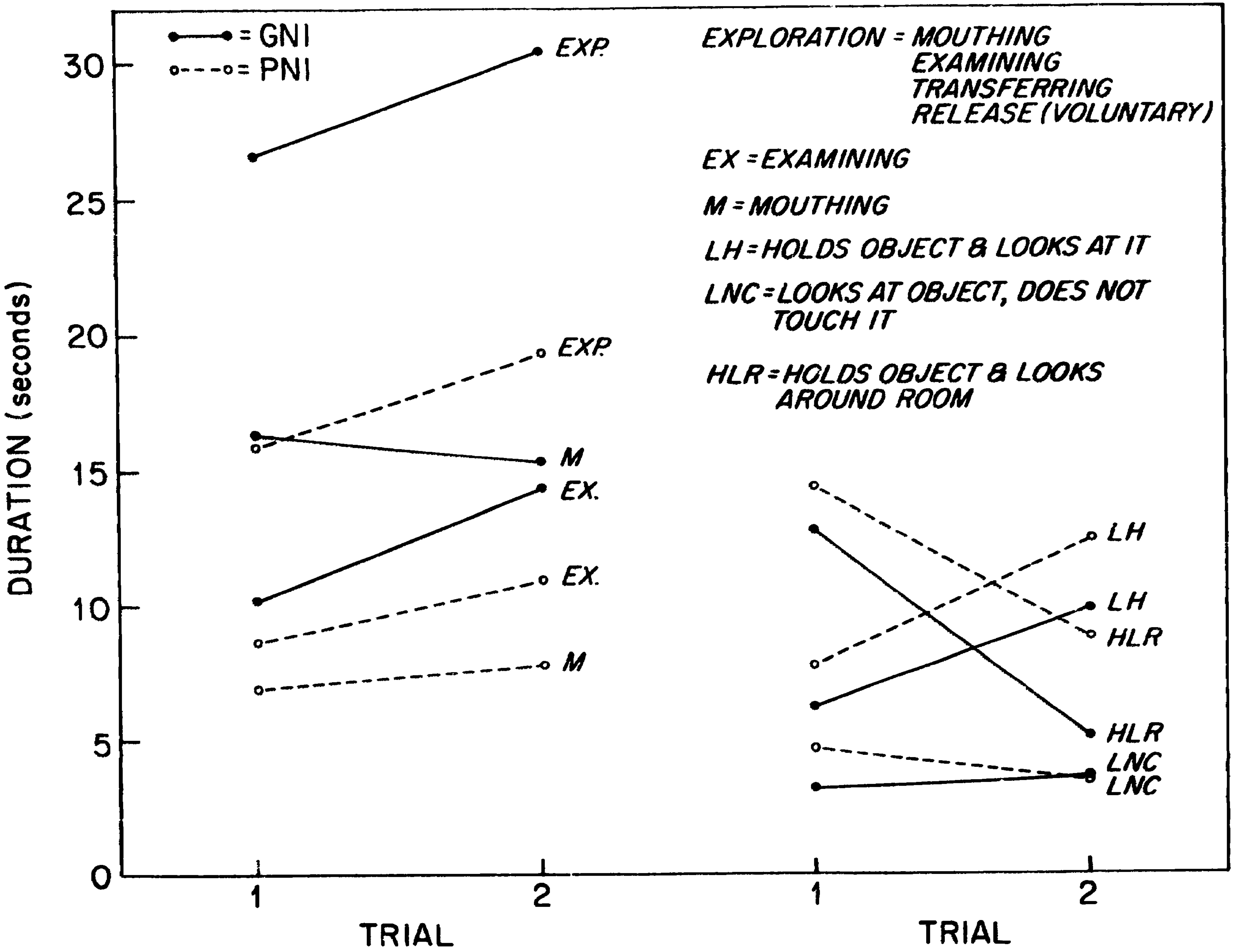
Figure Captions

Fig. 1 Stimuli

Fig. 2 Mean duration of selected behaviors on Trial 1 and Trial 2

Fig. 3 Mean frequency of selected behaviors on Trial 1 and Trial 2

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EXP.
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M
EXPLORATION = MOUTHING
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TRANSFERRING
RELEASE (VOLUNTARY)
EX = EXAMINING
M = MOUTHING
LH = HOLDS OBJECT & LOOKS AT IT
LNC = LOOKS AT OBJECT, DOES NOT TOUCH IT
HLR = HOLDS OBJECT & LOOKS AROUND ROOM
LH
LH
HLR
HLR
LNC
LNC
DURATION (seconds)
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5
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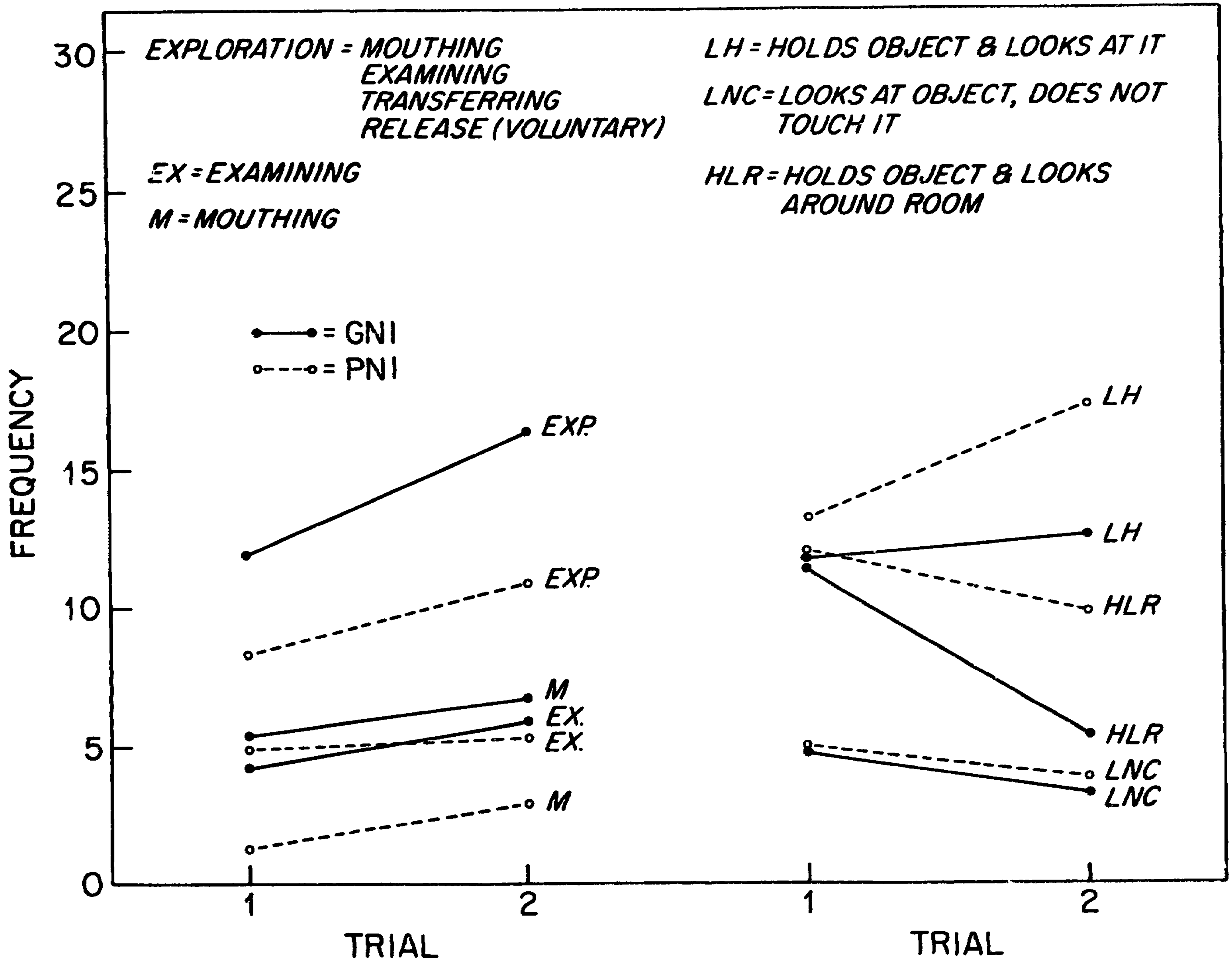
EXPLORATION = MOUTHING
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EX = EXAMINING
M = MOUTHING
= GNI
= PNI
LH = HOLDS OBJECT & LOOKS AT IT
LNC = LOOKS AT OBJECT, DOES NOT TOUCH IT
HLR = HOLDS OBJECT & LOOKS AROUND ROOM
FREQUENCY
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