INTEGRATION OF THE PROPERTY OF WEIGHT INTO INFANTS' MANIPULATION

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Abstract: This study examines the perception of the property of weight in infants' early manipulation. What is the baby's reaction when facing visually identical objects differentiable only by hand manipulation ? Will babies use the property of weight in a functional way ?
We presented to 8, 11 and 14 month-old infants four closed egg cups, three light (30g) and a heavy one (160g), during four minutes of free play. Total duration of looking at the objects, total time of manipulation, contact time with each object, exploratory actions and objects' arrangements in space were scored. Results indicated that the heavy object (called the 'trap object') was more watched, more manipulated and more lifted than the light ones as early as 8 months. Objects' arrangements in space revealed an evolution with age and are in favour of an integration of this tactilo-kineasthetic object property into free manipulation.

Keywords: Infant, Manipulation, Weight, Perception, Tactilo-kineasthetic

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INTRODUCTION

As they play an important role in the cognitive maturation of the young child, exploration of object properties and early manipulation in the infant have been the focus of interest for a number of developmental studies (Piaget, 1952 ; Bruner, 1972 ; Fenson, Kagan, Kearsley & Zelazo, 1976 ; Gibson, 1988). These exploratory behaviours have cognitive and adaptive functions as they allow the baby to extract important information from objects in the environment (Ruff, 1984).

Among object properties, texture and shape have been extensively studied (for a review see Bushnell & Boudreau, 1991), but very few experiments have been conducted on the property of weight. The early study of Mounoud and Bower (1974) investigated children's anticipation of an object's weight from its visual appearance, and showed that it is only around 9.5 months of age that infants expect visually identical objects to be of equal weight. Palmer (1989) demonstrated that 9 and 12 month old babies wave light objects more than heavy ones, which is not the case for 8 month olds; but Ruff (1984) found that neither 9 nor 12 month old babies reacted differently to a heavier or lighter object than the one they had been familiarised with, suggesting that discrimination of weight appears after 12 months. Combining motor development prerequisites and attentional factors, Bushnell and Boudreau (1991) developed a double-filter model of manual perception of object properties based on hand exploration. Exploratory movements associated with tactile sensation and feedback make this perception « haptic » (Gibson, 1962). They concluded that the perception of the hidden property of weight developed at the earliest around 9 months of age. The age at which weight is discriminated is therefore still controversial.

Furthermore, manipulation, starting around 6 months of age with the use of hands as a means of object prehension, becomes predominant and increases enormously between 9 and 12 months. This allows the baby to discover objects under different views and perspectives (Ruff, 1982), permitting a combination of visual, tactile and kinaesthetic information generated by movement. The baby thus develops different visual expectancies of objects, that vary with age and experience. Consistent with this hypothesis is the finding of Bushnell (1982) that objects are expected to have consistent visible and tangible properties for 11 month-olds. Nevertheless, even though some authors underline the importance of vision in tactile perception (Heller, 1982), numerous experiments carried out on the discovery of object properties by the young child have focused on discrimination using haptic manipulation of objects imposed on the baby. Although free play involves multimodal information and is more reflective of real life situations, few experiments have looked at infants' free play in order to assess how babies consider hidden object properties such as weight. Moreover, although we know approximately when infants discriminate certain properties, a question that has never been addressed as far as we know is whether children use them in their manipulation, and if so, what aspects are utilised.

In this experiment we studied the weight property and compared three age groups: 8, 11 and 14 months. Using visually identical objects, differentiable only by hand manipulation involving tactile and kinaesthetic information, we looked at babies' reaction in free play. The aim was to answer the following questions : how will infants use this property for which they don't have any expectancies? Will free play reflect any special use of weight? Will babies use this property in a functional way?

Method

Subjects

Thirty healthy babies from three Parisian day nurseries participated in this study and constituted three age groups as following: ten 8-month-old infants, 5 male and 5 female (m= 7 months 23 days, SD= 10 days); ten 11-month-old babies, 4 male and 6 female (m= 11 months 1 day, SD= 14 days), and ten 14-month-olds, 5 male and 5 female (m= 14 months 3 days, SD= 9 days). Seven additional infants were tested but not included in the final sample because of crying or fussing, or due to procedural reasons (see below).

Apparatus

The objects used were four closed wooden egg cups. Three of them were light and weighed 30g. The heavy object, filled with lead, weighed 160g and was called the «trap object». The weight difference between the heavy object and light ones was clear and non-ambiguous for adults. All of the objects were identical in shape, size, texture and substance. Colour varied between objects to minimise the baby's boredom and to enable the objects' recognition on video tapes: the trap object was green and the three light objects were yellow, red and blue respectively. For technical reasons, colour could not be counterbalanced across subjects. We assumed that tactile and kinaesthetic object properties such as weight would be more important and striking for the infant than colour, which should not constitute any experimental bias, partially as studies on colour preference (see Epinous 1988 for a review) have shown that in the order of preference, babies prefer red first, then blue, then green and last yellow. Therefore, if colour constituted a bias, it should be in favour of the red egg cup and not the green one. The absence of colour effects between the three light objects was verified statistically (see results).

Procedure

The infant, alone with the experimenter in an isolated room, was seated on a small chair in front of a small table. A video camera placed in front of the infant recorded the baby's looking and actions.
The experimenter displayed the objects in a diamond-shaped array on the table at a distance reachable by the baby's hands. The timer started when the objects were put on the table. The infant was allowed to play freely with the objects during four minutes (240s). The objects' order on the table was counter-balanced among subjects to avoid any place preference. The experimenter intervened only when the baby's attention shifted away too long from the objects, to start the game again, or when the infant gave him one of the toys. In this last case, the experimenter took the object and put it back on the table. To be accepted for analysis, the infant had to touch at least two objects including the trap object during a minimum period of 1 minute. This criterion excluded only one infant who did not touch any of the objects during the whole period of 4 minutes.

Dependent measures

Three main measures of infants' behaviours were scored: total duration of looking at each object, total duration of manipulation and contact duration on each object. Furthermore, duration of four different exploratory actions was differentiated from the videotapes for each object as follows:
- Time spent lifting each object with one or two hands.
- Time spent opposing each object against another one: this special action refers to putting one side of an egg cup against the side of another egg cup in a symmetrical position with one object in each hand. Opposition is then a grouping of 2 objects set apart from the other toys, which enables infants to directly compare objects two by two.
- Time spent banging each object on a surface (on another object or on the table). As well, the number of times babies banged the heavy object against a light object was compared to the number of times two light objects were banged together.
- Time spent mouthing each object, reflecting the amount of time the infant spent with the objects in his/her mouth.

Total duration of manipulation reflected the total time of contact with objects and thus included total time spent lifting, banging, opposing, mouthing and any other actions that we did not analyse separatly.
The number of piles built by infants were scored as measures of objects' arrangement in space. The piling up of 2 or more objects was considered a pile. Attention was focused on the number of piles containing or not containing the trap object and on its place within piles: at the bottom, on top or in the middle in the case of a big pile. We assumed that placing the heavy object systematically at the bottom of the pile would be a cue in favour of a functional use and integration of the property of weight into an infant's manipulation.
A 3 (age) x 4 (objects) ANOVA analysis was run for all actions studied and post hoc tests are reported when appropriate.

RESULTS

Time spent looking, lifting, opposing, banging and mouthing objects are shown in figure 1.
ANOVAs revealed a main effect of objects in the looking category ($F(3,81) = 8.05$, $p < .001$) which was due to the trap object being looked at more than any of the light objects ($F(1,27) = 22.29$, $p < .001$) across the three age groups of babies. No effect of age was found, no interactions were found.
A main effect of objects ($F(3,81) = 3.22$, $p < .05$) was found for the total duration of manipulation and was due to the heavy object being manipulated more than any of the light ones across age groups ($F(1,27) = 7.65$, $p < .025$). A main effect of age ($F(2,27) = 3.76$, $p < .05$) was due to 8 month-olds manipulating objects less than 11 month-olds ($F(1,18) = 7.64$, $p < .025$) and 14 month-olds ($F(1,18) = 4.68$, $p < .05$). No age x objects interaction was found.
For the lifting category, a main effect of age was found ($F(2,27) = 3.45$, $p < .05$) and was due to 14 month-olds lifting objects more than 8 month-olds ($F(1,18) = 5.11$, $p < .05$). A main effect of object was also found for this category ($F(3,81) = 3.69$, $p < .05$) and was due to the heavy object being lifted more than any of the light ones across age groups ($F(1,27) = 6.86$, $p < .025$). No age x objects interaction was found.

In the opposition category, there was no effect of objects, but a main effect of age was found ($F(2,27) = 3.52$, $p < .05$) : 14 month-old babies showed much more frequent direct opposition of objects than did the younger age groups.
A main effect of age was found in the banging category ($F(2,27) = 3.35$, $p < .05$) : the 11 month group banged objects more than the 14 month group ($F(1,18) = 5.77$, $p < .05$) and the 8 month group ($F(1,18) = 5.14$, $p < .05$). No effect of object was found. We also compared the number of times babies banged the heavy object against a light one to the number of times they banged two light objects against each other. We found a main effect of age ($F(2,27) = 3.62$, $p < .05$) which was due to 11 month olds banging objects more than the other babies as found previously. A main effect of objects was also found ($F(1,27) = 5.14$, $p < .05$) and was due to the number of times objects were banged against each other being significantly larger for the heavy object against a light one than for two light objects together. A significant age x object interaction ($F(2,27) = 3.67$, $p < .05$) was found and post-hoc tests revealed that 11-month-old babies banged the heavy object against a light one more than 8 and 14-month-old babies ($F(1,18) = 7.5$, $p < .01$).
As for the mouthing category, a main effect of age was found ($F(2,27) = 9.77$, $p < .001$). The 8-month-old babies mouthed the objects more than the 11-month-old babies ($F(1,18) = 4.54$, $p < .05$) and much more than the 14-month-old infants ($F(1,18) = 14.89$, $p < .005$). No difference among objects was seen for this category. No interaction was found.
There were no significant differences among the red, the yellow and the blue objects on any of the above measures (looking time and manipulations times) demonstrating that colour did not appear to be a bias in this study.

Concerning the total number of piles, a 3 (age) x 2 (type of pile: piles with or without the trap object) ANOVA analysis was run. A main effect of age ($F(2,27) = 6.5$, $p < .005$) was due to 14 month-olds making much more piles than 8 month-olds ($F(1,18) = 10.35$, $p < .005$) as shown in figure 2a. No difference was found between 11 and 14 months nor between 11 and 8 month-olds. No effect of type of piles (with or without the trap object) was foundThe location of the trap object within the pile was also examined (see figure 2b). A 3 (age) x 3 (place of the trap object in the pile: at the bottom, on top

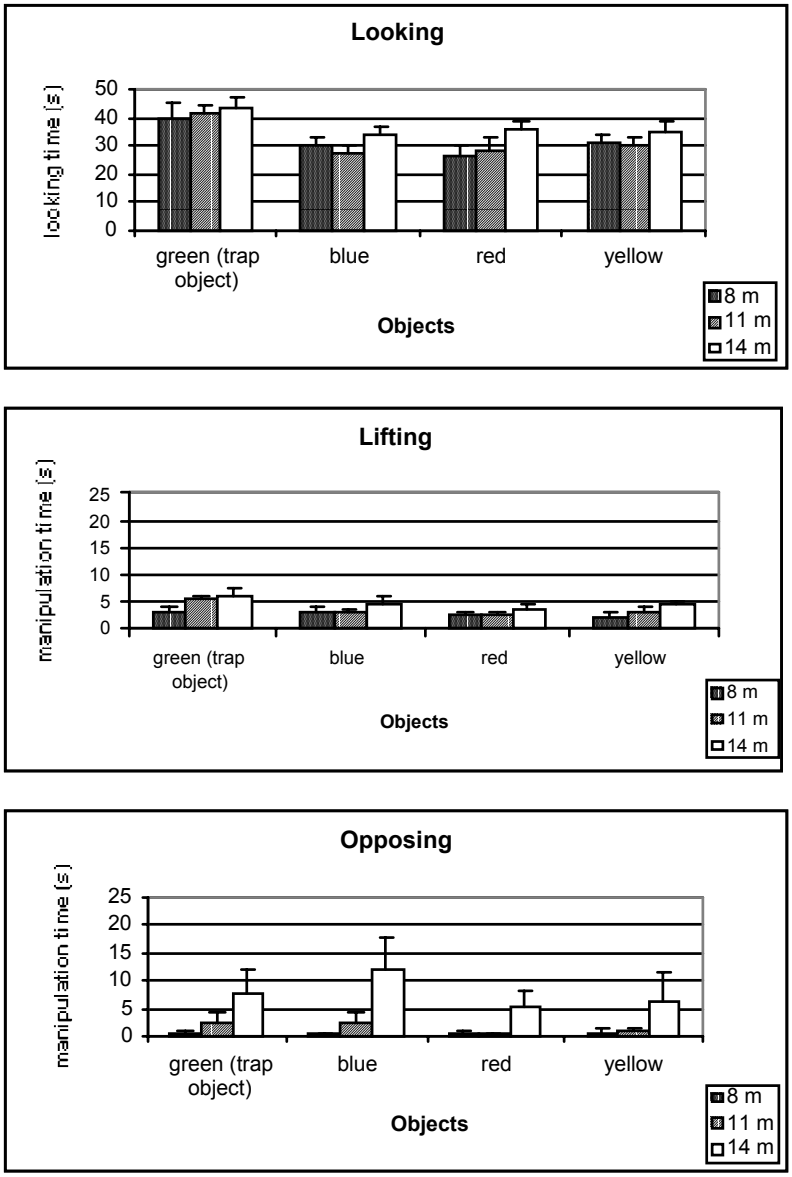

Figure 1

For the three age groups, mean time spent : a) looking, b) lifting, c) opposing, d) banging and e) mouthing the heavy and the three light objects.

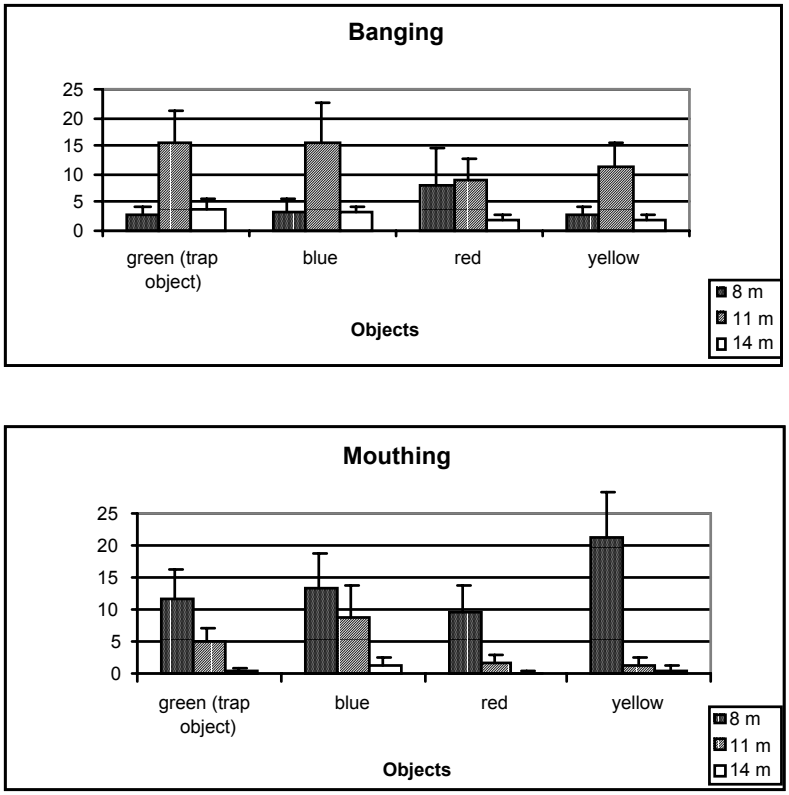

Figure 2
Total number of piles a) containing or not containing the trap object, b) containing the trap object at the bottom, in the middle or on the top of the pile.

Discussion

Our results showed that, across the three age groups of babies, the heavy object was looked at significantly more than the light objects. It was also manipulated more and specifically lifted more than the other egg cups. As well, the heavy object was banged against a light one more often than two light objects together. Within piles, the heavy object was put at the bottom more often than on top or in the middle of piles. This study showed that weight was discriminated among objects, as the heavy egg cup was looked at, lifted and manipulated more than the light egg cups across groups.

It is commonly accepted that looking constitutes an exploratory behaviour (Ruff, 1989) and that the time spent observing objects can reflect a discrimination among those objects (Pierault-Le-Bonniec, 1985). The fact that the heavy trap object was looked at more than the light ones is in favour of a weight discrimination since all the egg cups were visually identical except for their colour. However, colour was not considered a bias for two reasons. Firstly, since the colours used here were primary colours, it would be surprising if all the babies were more attracted by green than by red, yellow or blue, since red is the favourite colour of very young children (Epinoux, 1988). Secondly, the time spent manipulating the three light objects was not statistically different, so if colour had been a bias in any way, we should have found some differences in manipulation time for light objects. The only differences were between the heavy object (green) and the light objects and there is no reason why those differences should be attributed to the green colour instead of the property of weight. The longer time spent looking at the trap object is thus in favour of a weight discrimination.

No difference was found among age groups in the time spent looking at the trap object, suggesting that 8 month-olds looked as much as the other groups at the heavy object. Therefore, at all ages, the trap object is looked at more than the other egg cups. As well, no age by object interaction was found in the time spent manipulating or lifting, meaning that the heavy egg cup was treated differently than any of the light egg cups by all age groups, 8-month-old babies included. It is all the more interesting since Palmer (1989) reported that as early as 6 months, babies bang and wave objects and, despite their low frequency, those behaviours are related to the movements adapted to the detection of weight proposed by Lederman and Klatzky (1987). These authors reported stereotyped movement patterns directed at extracting particular object properties, what they called "exploratory procedures" (EP). They suggested that the unsupported holding of an object (i.e. lifting an object above a supporting surface) was the most adapted movement and the most used EP that adults employed to detect weight. Our lifting category is then the most closely related behaviour pertinent to weight discrimination, as it enables one to acquire information from muscles and tendons' tension and to adapt strength to gesture.

Therefore, the youngest babies also showed a preference in looking, manipulating and lifting the trap object. It thus seems with our behavioural measures, that they perceived the objects' weight difference, which is not consistent with the absence of weight discrimination prior to 9 months. Mounoud and Bower (1974) found that appropriate arm tension during manual retrieval of objects was seen from 9.5-months on, and Bushnell and Boudreau (1991) claimed that weight perception could not be seen before 9 months. In contrast, our results are in agreement with a perception of the property of weight as early as 8 months, in line with Palmer's (1989) results.
Nevertheless, the behaviours reflecting the perception of weight in free play seem to evolve with age. For example, at 11 months, weight was fully perceived as assessed by the greater number of times the heavy object was banged against a light one compared to two light objects being banged together. At 14 months, weight perception was reflected more by manipulation and lifting times which were significantly greater for the heavy object than for the light ones, as well as by the place of the trap object within piles. It seems that toddlers' perception of weight was no longer shown in actions such as banging but became evident in other behaviours such as making piles.

At 14 months, infants lifted objects and opposed them more than at 8 months. The fact that babies opposed objects more at 14 than at 8 and 11 months supports the idea of a direct comparison of two objects set apart from the others. This reflects an increased interest in two visually identical but haptically different objects (when heavy and light objects are opposed together), that differ only in their kinaesthetic property. The increasing opposition of objects can be related to the combinations obtained by Fenson et al. (1976) with 13 month old babies. Those groupings called "relational combinations" by the authors seem to represent an early expression of categorisation similar to, even if simpler than, groupings observed by Nelson (1973) with 19 month old infants. Our opposing category can also be compared to Bruner and Koslowski's study (1972) where infants from 12 months on were reported to be interested in objects taken two by two.

Because the egg cups used were very simple in shape and could not afford a great range of different actions, piles were interesting arrangements made by infants that could be analysed to see if the property of weight was used in any special way or in a functional manner. We found that the total number of piles was significantly higher at 14 months than at 8 months. Despite the fact that the number of piles containing the trap object was not significantly

different from the number of piles without it, the heavy object was put at the bottom of the pile more often than at any other location in the pile, when analysing piles with the heavy object, and the age by object interaction revealed that the trap object was put at the bottom significantly more at 14 than at 8 months. Given the very small number of piles made by 8 month-olds, this last result is not surprising. However, the main effect of the place of the trap object within piles across groups concerns 14 and 11 month-olds and is in favour of the use of the property of weight in a special manner in free play. Thus, the nature of the behavioural discrimination seemed to change over age, as shown by the piling position displayed in figure 2b. Gesell (1934) was the first to notice that numerous actions are typically seen only at a certain age. Such behaviours may begin to appear at an earlier age and their full expression reflects a degree of cognitive maturation specific to a given age. At the following age, they disappear or are integrated into more elaborated behaviours like those retained in infant behavioural scales (Josse, 1997). The lifting behaviour is slowly replaced by the piling action which is specific to 15 month-olds, as described in infants behaviour scales (Bayley, 1993; Josse, 1997). Thus, it seems that the piling position is a more elaborated behaviour where the place of the heavy object at the bottom of the pile reflects the perception of weight rather than exploratory actions such as lifting, manipulating, or banging objects. This is all the more interesting since, in an experiment on the property of substance using 3 hard and one soft visually identical cylinders, the same 14 month old group also made the most piles and tended to put the trap soft object on the top (Itier, unpublished report). Those two findings suggest that object properties are used during free manipulation. Older Infants seem to take into consideration that a soft object would be crushed under a pile of hard objects and that a heavy object could break light ones or is just too heavy to be put at the top of the pile.

Given Gibson and Walker's results (1984) that 12 month-olds bang hard objects more than soft ones, and that Lockman and Wright (1988) and Palmer (1989) reached the same conclusion with babies from 6 to 12 months old, we also analysed banging behaviour. This action could have provided a weight detection clue for infants, since banging objects of different weights produces different sounds. We did not find any difference among objects in the time spent banging them. However, when measuring the number of times objects were banged against each other, we found a greater number of banging of the heavy object against a light one than banging two light objects together, which also suggests a weight discrimination. The other noticeable effect was that the 11 month old group was the most active group in banging, confirming the huge increase in manipulation time, usually observed from 9 months on. Our results are in agreement with a more and more elaborated manual exploration, adapted to object properties (McCall, 1974 ; Zelazo, 1980 ; Belsky & Most, 1981), that replaces the use of mouth to explore objects. Indeed, even if all babies seemed to discriminate weight as shown by a difference in object manipulation, lifting and looking times, the most important action was mouthing at 8 months, whereas 11 month-olds spent most of their time banging. In contrast, 14-month-old babies tended to be more reflective, banging objects less but opposing them more and making many more piles. This is clear when comparing the amount of time devoted to the different behaviours as shown in figure 1.

Conclusion

Weight is a hidden object property that can only be detected haptically by the proprioceptive system. Weight was discriminated by all age groups as shown by increased looking, manipulating and lifting times for the heavy object, lifting being a movement well adapted to weight detection, and by the increased number of banging the heavy object against a light one

as compared to two light objects banged together. Our results are in desagreement with the 9 months age limit necessary for weight detection as eight month old infants seemed to perceive the property of weight among objects as assessed by our behavioural measures. Weight perception thus seems to be present as early as 8 months. However, in free play, weight perception is expressed differently depending on the age, being more obvious in the banging behaviour at 11 months and in the piling up action at 11 and 14 months. Infants tended to use the property of weight in a special manner as shown by putting the heavy object at the bottom more than at any other location in a pile. The nature of the behavioural discrimination of the property of weight seems to change over age as shown by different weight-related behaviours observed at different ages.

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