Archives de Psychologie, 1998, *66*, 85-103

WHICH BABIES ARE CLOSING THE AB GAP ? LEARNING EFFECTS IN OBJECT RETRIEVAL

Chris Lange-Küttner
University of Aberdeen

The present study is a behavioral investigation into the learning mechanism involved in the Piagetian AB search task in repeated trials. Individual differences in performance in repeated trials of the AB search task between infants who were either bottle- or breast-fed were analyzed to investigate whether the underlying learning mechanisms varied.

In the AB task, an object is, in a first search task component, hidden in location A, and then, in a second task component, hidden in location B. The developmentally earliest error in this task is to fail to search for the hidden object at all, i.e. missing the object in A. The second error pattern is to search successfully in A, but not in B, thus missing the object only in B. The AB error was commonly understood as the search in A instead of B. However, Cummings and Bjork showed repeatedly (Bjork & Cummings, 1984; Cummings & Bjork, 1981, 1983a, 1983b), when using a five-choice hiding site AB task instead of a two-choice hiding site AB task, that the AB error did not occur in the usual way as a return to A, but that the second search was distributed across places on the side of the correct place B. Infants' search increasingly centered on the targeted location within three practice trials. Thus Bjork and Cummings (1984) concluded that what hindered learning was not a response perseverance, or infants' centration on the actions of the own body. Further, Bjork and Cummings (1994) explained that the greater difficulty of the second location, in comparison to the first search site, occurred because of the additional information processing resources needed for spatial updating necessary for search in location B. However, distress control linked with spatial attention is a very salient issue in research on early cognitive development (Posner & Raichle, 1997). In the following review, research is discussed from the perspective of whether object retrieval processes in the AB task involve an emotional component.

Is there an emotional component in the AB task ?

Diamond found that performance in the AB task in the first year of life (1) was dependent on the delay that could be tolerated before the infant was

allowed to search for the object (Diamond, 1985); and (2) that the ability to solve the AB task was more dependent on brain processing of the prefrontal lobes responsible for linking and sequencing actions and perception (of cues), and inhibition of dysfunctional response tendencies, rather than on the parietal lobes responsible for shifts in spatial attention (Diamond, 1991). Time delayed response is also important in research on emotion processing and is called «behavioral inhibition» (Kagan, Reznick & Snidman, 1988).

To measure inhibition, Davidson (1994) devised a separation episode which involved infants to distance themselves from the mother, who was occupied filling out lengthy questionnaires, and to approach a talking robot, and a stranger with several attractive toys on a tray. Davidson selected infants from the two extreme ends of the mother separation/stranger approach scale, those who approached neither the robot nor the stranger within the set time of the experiment, compared to those who left the mother and approached the stranger at once, plus a group whose behavior was in between the extreme groups. Davidson found a function that the more inhibited exploration of novel stimuli and persons was, the less frontal brain activity in general. Asymmetrical frontal lobe processing occurred only in the extreme groups.

Dawson (1994, pp. 351) found the same frontal lobe asymmetry in infants of depressed mothers compared to normal children. In a developmental comparison of brain processing of normal 12 to 15 months and 21 months old infants in a separation episode, Dawson (1994) found that the younger infants showed generally more frontal lobe activation, while the older infants showed no marked change in frontal lobe processing, but a marked change in posterior parietal processing. The parietal area, however, is not known for emotional processing, but only for processing of a rather detached perception of the «where is it» portion, as opposed to «what is it» (Elman, Bates, Johnson, Karmiloff-Smith, Parisi & Plunkett, 1996, pp. 278; Mishkin, Ungerleider & Macko, 1983). From a developmental perspective, this result could be an interesting indicator that processes in the anterior brain are a marker for emotionally salient object retrieval in infants under one year of age, but posterior processes are more important in older children, probably because object retrieval becomes a less emotionally loaded process, and more of a perceptual attention regulation process, even when the mother is involved. In a longitudinal study, Bell and Fox (1992) showed that indeed at ten months infants with superior performance in the AB task (13 seconds delay tolerance at twelve months) also showed increased anterior-to-posterior EEG coherence.

The hypothesis that anterior brain processes are important in various cognitive tasks in the first year of life was investigated by Diamond, Werker and Lalonde (1994) by comparing a speech task, a classification task and the AB task. The speech task involved recognition of a familiar speech contrast, as opposed to a non-familiar non-native speech contrast. Infants passed this task

when they failed to recognize the non-native contrast (Diamond, 1994, pp. 394) because they became selectively responsive to the mother tongue. The classification task involved detection of a novel visual object from an array of previously habituated objects. Diamond *et al.* (1994) found that every single infant who passed the AB task had also passed the speech task. The predictive power of the speech task was borne out also in terms of likelihood. Infants solving the classification task (nine out of 22 = 40.9%) were more likely to pass the AB task than infants not solving the classification task (five out of 18 = 27.8%), while infants solving the speech task (14 out of 23 = 60.9%) were definitely more likely than infants not solving the speech task (none out of 17 = 0%) to pass the AB task. This result showed that – in logico-mathematical terms – the disappearance of sensitivity to contrasts of the less familiar non-native language was a necessary factor, while classification was a sufficient, but not a necessary ability.

An effect of familiarity is also prominent at this stage in socio-emotional development as children show increased stranger anxiety around nine months of age when they develop a conscious preference for their mother and reject approaches from a stranger, e.g. by refusing to being carried. Stranger anxiety is peaking between eight to ten months. The linked separation anxiety from the mother is peaking between 14 to 20 months, however, infants from African communities were found to show separation anxiety earlier because they stay in much more permanent and close contact with their mothers compared to typical Western infants (Shaffer, 1993, p. 424). In the longitudinal study by Bell and Fox (1994, p. 337) infants who cried more readily in a separation episode from their mother showed a first sudden emergence of increased frontal lobe activation exactly at nine months, i.e. at the same time when they develop a preference for the more familiar mother over a stranger.

Concluding, the review showed an intriguing picture of the confoundedness of emotional and cognitive object retrieval in the first year. The secure exploration of the environment while separating from the mother predicted more equilibrated brain processes in the frontal lobes. In more anxious infants, increased frontal lobe activation occurred at nine months when also the AB task is solved. More selective recognition of the mother tongue predicted more successful object retrieval in the AB task. Thus, a developmental coincidence of the emergence of selective sensitivity to familiarity and successful performance of the AB task was found in this review. Thus, so far one could conclude that in the first year of life object retrieval is an emotionally loaded process which becomes mediated and more successful with the sensitivity to stimulus familiarity.

Exploration of the breast and the bottle

The interesting question was now whether the degree of intimacy between mother and child could also be a factor in processes of object disap-

pearance and retrieval. Piaget (1955, p. 161) postulated that successful performance in the AB task would depend on an increasing exploration of objects for their own sake, i.e. recognition of all aspects of an object and not only those which can be exploited for the own needs and desires, as well as the independent relations of this object with other objects. Although Piaget was limited to use a bottle in his observations of his own children when they were infants, the breast was included *pari passu* in the world of spatial objects the infant encounters (Piaget, 1955, p. 107). Piaget (1981, p. 51) was opposed to make a difference between cognitive and affective structures. He claimed that feelings are constructed or reconstructed on every encounter with objects or with people, and both encounters would be affective and cognitive at the same time.

Piaget did not attribute the mother's breast a status as a special organ and breastfeeding the status as instinctual behavior, as for instance he did with sexual behavior: «Sexual behavior certainly involves instincts since it is a specialized behavior with its own goals and special organs» (Piaget, 1981, p.18). From this perspective, the relationship with the mother was not special in the first year of life, as this contradicted the capacity of the infant to desire objects such as the bottle, or the capacity of the infant to relate to the father. In fact, breast-feeding was not even listed under instinctual behavior, but instead «parental instincts» were mentioned: «People often speak of either a maternal or a paternal instinct. In either case, the legitimacy of the term instinct is doubtful. Perhaps in animals there is a connection between endocrine mechanisms and maternal behavior, but in humans the existence of such an instinct is questionable. [...] More generally, maternal and paternal behavior can be considered less as evidence of an instinct than as an extension of affectivity at every level». (Piaget, 1981, pp. 18/19).

However, from Piaget's point of view breast-feeding would fulfill his criteria for an instinct because it is a special organ which becomes functional after childbirth, regulated by endocrine and hormonal processes. There are mutual benefits for mother and child (Waterston, Platt & Helms, 1997): First, infants become protected against infection, infants can form their own feeding routines and do not have to conform to imposed expectations/schedules, and infants regulate the milk production in the mother's breast by demand. Second, most mothers experience lactational amenorrhoea which ensures wider spacing between consecutive children and more resources for the existing children, loose maternal fat build up during the pregnancy and do not have to attend to sterilize bottles, equipment and water. The World Health Organization recommends four months of unsupplemented breast-feeding (DaVanzo, Sine, Peterson & Haaga, 1994), and research showed that breast-fed infants' growth rates were increased between five to twelve months (Zeitlin & Ahmed, 1995).

In modern times, breast-feeding is often replaced with artificial «formula» feeding within the first days (Waterston *et al.,* 1997) for various reasons. Much research is carried out in developing countries, where formula feeding

in the absence of sterilized equipment lead to increased child death rates (Waterston *et al.*, 1997; Wilmoth & Elder, 1995). While breastfeeding makes demands on both women's time and body increasing the risk of economic insecurity of homes in developing countries (Baksh, Neumann, Paolisso, Trostle *et al.*, 1994), in developed countries the decision of middle-class married and insured women to breastfeed depended more on the father's level of education and his approval, or on recent or previous experience, e.g. whether the parents were breastfed as babies (Baisch, Fox, Whitten & Pajewski, 1989), rather than on the mother's work or social support (Littman, Medendorp & Goldfarb, 1994; Matich & Sims, 1992). However, it was found that large number of fathers held negative attitudes towards breastfeeding (Freed, Fraley & Schanler, 1993). Other factors that prevented women to cope with sore or infected breasts, anxieties about expanded and scarred breast tissue etc. were post-partum depression, low social class, youth and low educational attainment of the mother (Cooper, Murray & Stein, 1993).

However, Piaget (1951) claimed that close relationships would be neither special nor mysterious. In his work on the development of the object concept and the spatial field, Piaget (1955) analyzed infants' object attachment from a spatial perspective, analyzing part whole integration. In his observations, he described that infants explore various kinds of objects (e.g. paper knifes, rattles) with the hands, only with the aim to find which is the «good part» to insert into the mouth. Extensive observations were made on object rotation, using a bottle with a nipple (Piaget, 1955, p. 126). Piaget varied the sight of the nipple by showing the infant the bottle upside down, letting the infant see the rubber of the nipple, just two to three millimeters wide, or varied the distance of the object with both ends in the visual field of the infant. He found that initially, when presented with the bottle upside down, the infant either looked away at once and started to howl, or started to suck the glass (the bottom) and finding no food also started to howl. When only shown a glimpse of the rubber nipple, the infant managed to rotate the bottle. Piaget also described that the infant would visually explore both ends of the bottle at a distance, indicating intellectual interest, but when only the bottom end moved towards the infant, the same sucking of the bottom end of the bottle occurred. Piaget therefore concluded that although the infant was technically and motorically able to rotate the bottle, as well as perceptually interested in the bottle as such, the infant understood nothing as soon as the bottle was spatially close (Piaget, 1955, p. 127). However, at eight months the whole object was appreciated also when close to the body. The infant did no longer suck the wrong end, he did not abandon all retrieval attempts, cried or struggled, but immediately explored the whole object by displacing the wrong end, anticipating the nipple visually and leaning the body sideways to obtain the right end (Piaget, 1955, p. 163). It must be stated, however, that Piaget's conclusion from the observation of the successful appreciation of the whole object as an appreciation of the object in its own right was rather pathetic, as this did not give rise to more selfless behavior (see also Lieberman, 1993,

p. 152, for a discussion of more or less sophisticated methods to kill, exploit or comfort), only to a less immediate and more informed expression of desire (e.g. ceasing of crying or struggling). From the observations, it can be concluded that integration of the most desired «right» part into the whole object led to a more efficient realization of goal-directed behavior in proximal space.

The identification and integration of the breast within the body of the mother, however, is a different problem. The breast, of course, cannot be rotated in the same way as a bottle, and access to the nipple is not only a functional, but also an emotional negotiation between mother and child. However, previous research showed that retrieval of the person of the mother from two rooms functioned in a similar manner as object retrieval in a two-choice AB task. Corter, Zucker and Galligan (1980) showed that nine months old infants were likely to retrieve their mother from an another adjacent room A, but when she disappeared thereafter in an adjacent room B, infants were likely to search again in room A. Corter *et al.* (1980, p. 67) found that successful retrievers showed selective looking towards the mother's exit, i.e. they first localized where the mother had disappeared, and then looked more at her exit. Unsuccessful infants gave both doorways the same attention and were subsequently confused in their active search. Thus, it was found that a sustained preference for the pathway of a familiar object was leading spatial attention and object retrieval.

This account is compatible with the finding that infants increasingly centered their search on the actual hiding site (Bjork & Cummings, 1984), i.e. that a centration process occurred in repeated trials. When these results (Bjork & Cummings, 1984; Corter *et al.*, 1980) [illegible], it could be hypothesized that those infants who link the breast of the mother with the whole person who is mobile in her own right, will neither sit in distress and just cry without active search, nor lose the focused spatial attention on her pathway, but will use the time delay to center spatial attention on her exit location.

Learning processes in the AB task

Because repeated trials in the AB task were used but learning was not explicitly analyzed, data of two previous studies were re-analyzed (Bremner, 1978; Bremner & Bryant, 1977). From Bremner's data sets only those trials following the conventional design of a two-choice AB task, i.e. without experimental manipulation of spatial position (cues) of either infant or array, were selected and plotted. Trials were repeated five times. From Figure 1 it can be observed that while search in A was oscillating around ceiling level, search in location B was below chance level in trial 1 and 2; in trial 3 the gap between search in A and B was closed considerably, search in location B being above chance level, in both studies. In one of the samples (Bremner & Bryant, 1977), search in B deteriorated in the following trials four and five, while in

the other sample (Bremner, 1978) infants continued to close the AB gap by further improving search in location B.

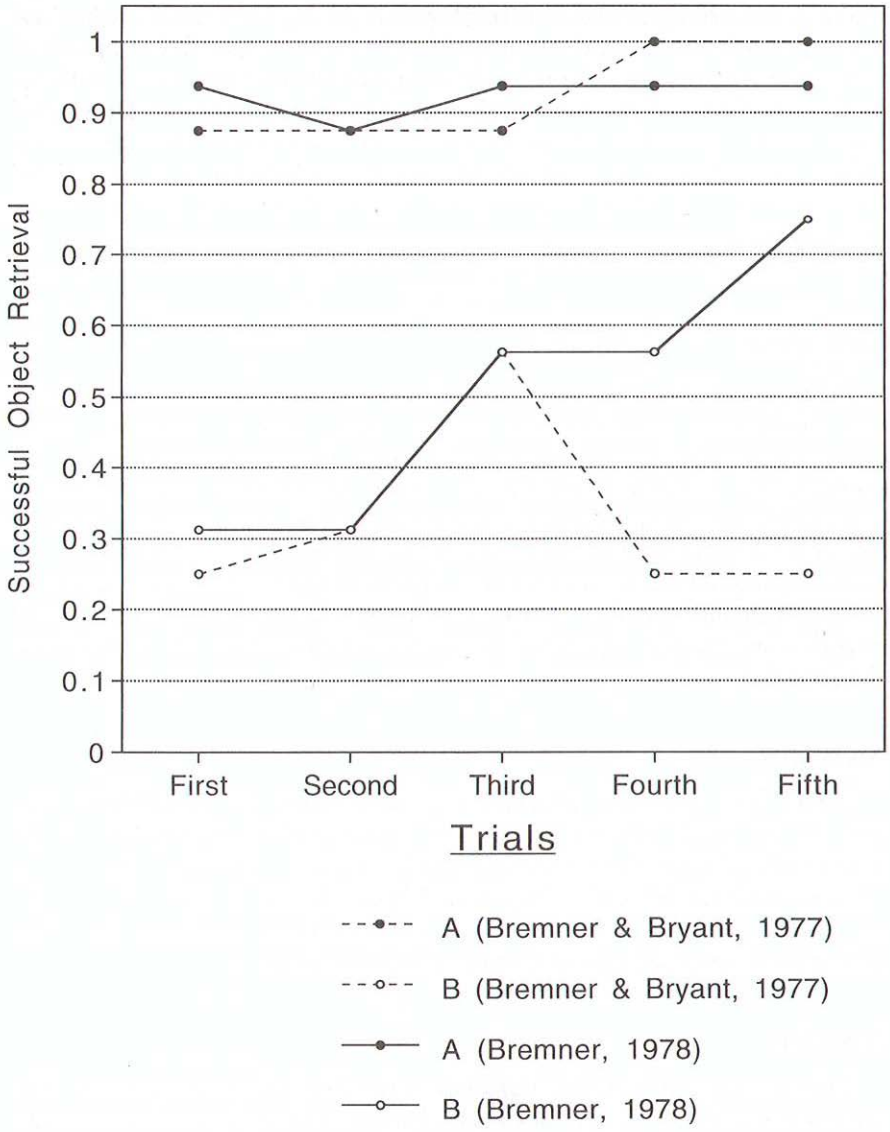


Figure 1: Closing the AB gap: Effects of practice on object search (reanalysed data of Bremner, 1978, and Bremner & Bryant, 1977).

In the present investigation, it was tested whether breast-fed infants would show better learning in the AB task. In previous research, breast-feeding predicted later intellectual achievement (Johnson, Swank & Howie,

1996; Rogan & Gladen, 1993), while bottle-fed infants and infants with feeding problems showed an intrinsic motivation deficit and a failure to thrive (Jenkins & Milla, 1988; Paul, Dittrichova & Papousek, 1996). In the present study, it was presumed that this combination of cognitive development and intrinsic motivation would be a promising factor for a specific hypothesis of performance in the AB task: It was investigated whether experience with the mother involving emotional as well as physiological regulation in proximal space enables breast-fed infants to center and focus spatial attention during object retrieval more successfully than bottle-fed infants, i.e. it was tested whether breast-fed infants improved more in object retrieval in location B in repeated trials.

Method

Participants

A sample of $N = 80$ infants were recruited by contact with health centres in a middle-sized Scottish town. Mothers were routinely asked in a short questionnaire whether and for how long they had breast-fed the infant. In Scotland and North England mothers often do not breastfeed (Waterston *et al.*, 1997), thus in this sample it was found that 33 infants were bottle-fed, and never breast-fed. The mean age of the bottle-fed infants was $M = 7;5$ months (range 22 weeks to 45 weeks). The mean age of the remaining $n = 47$ breast-fed infants was $M = 8;3$ months (range 23 weeks to 45 weeks). All infants were healthy and full-term babies without reported or suspected abnormalities.

Apparatus

Infants were seated on an infant-sized two-colored (blue-red) plastic seat, with the feet on the ground. The trial procedure was repeated three times on infant-sized, blue tables (surface 24 by 12 inch, height 12 inch). The toy was a yellow/pink rattle, a red cuddly hedgehog or a bunch of multicolored plastic keys. The toy was hidden beneath a cloth of the same color as the tables so that no color-coded spatial location cues were given.

Procedure

Infants were tested in the video lab of the Psychology department. The apparatus was the only item in the lab. Parents waited in an adjacent room, but could observe the experiment through a one-way screen. Video recording was controlled from a second adjacent room, also equipped with a one-way screen.

Because some infants in the present sample were younger than in the Bjork and Cummings study (1984), a delay of two seconds was used. The toy was hidden up to three times in location A until the infant responded, and

then hidden once in location B. The AB trials were repeated three times. Trials were made distinct insofar as infant-sized tables were taken away after each trial and built up again in front of the infant after some minutes, avoiding the impression of searches continuously alternating between A and B (Cummings & Bjork, 1984, p. 13). Presentation of the toy on the right and on the left side was counterbalanced. The infant's preferred toy was established before the experiment was started.

Scoring

Scored were object grasps, a score of 0 being awarded for unsuccessful search, i.e. the object was not retrieved, and a score of 1 was awarded as a pass for successful search, i.e. the object was retrieved. For scoring, the Video Tape Analysis (VTA) Observer System was used for frame by frame analysis. Interrater reliability between two independent raters was 95.5%. Disagreements were solved in a discussion.

Results

Presentation on the left versus on the right side had no significant effect on object retrieval and was thus omitted from further analyses. Analyses were carried out using analyses of variance, t-tests were carried out as contrasts (Difference) within the model. A 2 (breast versus bottle fed) by 2 (A versus B) by 3 (trials) analysis of variance (ANCOVA) with repeated measures on the second and third factor was performed, with age in weeks as covariate. Frequencies in percent are listed in Table I.

Table I: Breast- and bottle-fed infants passing on repeated trials of a two-choice AB task (Frequencies in %, Bottle-fed n = 33, Breast-fed n = 47).

	Pass A		Pass B	
First trial				
Breast-fed	72.3	(72.7)*	36.2	(24.2)
Bottle-fed	63.6		36.4	
Second trial				
Breast-fed	63.8	(69.7)	31.9	(27.3)
Bottle-fed	69.7		36.4	
Third trial				
Breast-fed	57.4	(57.6)	44.7	(42.4)
Bottle-fed	63.6		36.4	

*Frequencies of the matched breast-fed sample (N=33) are in brackets

It was shown that successful search increased with age ($F_{1, 80}$ = 17.41, p = .000) and that search was more successful in location A than in B ($F_{1, 80}$ = 34.05, p = .000). More important for the present investigation, breast-fed infants showed no better performance overall compared to bottle-fed infants ($F_{1, 80}$ = .03, ns). However, the third order interaction of feeding by trial by AB ($F_{2, 80}$ = 2.55, p = .081) indicated that breast-fed infants showed a large gap between successful search in location A and B which they gradually closed by improving search in location B, while bottle-fed infants' AB gap was smaller initially but widened in the repeated trials. Contrasts revealed that learning was significantly different between the two groups in the second to the third trial (first to second trial t = .59, ns; second to third trial t = 2.36, p = .021).

To increase statistical power, the considerably different samples sizes were equalized in number by randomly matching breast-fed infants to the number of bottle-fed infants, resulting in a sample size of n = 66. The mean age of the breast-fed infants did not change, nor did the age range. Again, it was shown that successful search increased with age ($F_{1, 66}$ = 12.40, p = .001), successful search occurred more often in location A than in B ($F_{1, 66}$ = 37.40, p = .000), and breast-fed infants showed no better performance overall compared to bottle-fed infants ($F_{1, 66}$ = .11, ns). With the random matched sample, the third order interaction of feeding by trial by AB was significant ($F_{2, 66}$ = 4.13, p = .018). Again, contrasts showed that learning differed significantly in the second to the third trial (first to second trial t = .72, ns; second to third trial t = 2.85, p = .006). Further analyses showed that duration of breastfeeding was not significant, of importance was only whether infants had been breast-fed at all.

The AB gap closure by improved search in location B in the second to the third trial in the breast-fed infants replicated the learning effects in the studies of Bremner (Bremner, 1978; Bremner & Bryant, 1977), however, when inspecting Table I it was found that infants in this study did not improve above chance in search in location B. It was suspected that this was due to the inclusion of younger infants, compared to the eight to ten months old infants in the Bremner studies. Thus, the random matched sample was split into two age groups of infants, one younger than eight months (bottle-fed n = 17, breast-fed n = 14), and one eight months and older (bottle-fed n = 16, breast-fed n = 19). A 2 (age) by 2 (breast versus bottle fed) by 2 (A versus B) by 3 (trials) analysis of variance (ANOVA) with repeated measures on the third and fourth factor showed that the older age group tended to search more successfully ($F_{1, 66}$ = 3.91, p = .053), successful search occurred more often in location A than in B ($F_{1, 66}$ = 36.18,p = .000), and breast-fed infants showed no better performance overall compared to bottle-fed infants ($F_{1, 66}$ = .04, ns). The only significant higher order interaction was again the three way interaction of feeding by trial by AB ($F_{2, 66.}$ = 4.03, p = .020). Also, contrasts of this interaction showed again that learning differed significantly in the second to the third trial (first to second trial t = .70, ns; second to third trial t = 2.80, p = .007)

Table II: Breast- and bottle-fed infants below and above eight months passing on repeated AB trials.

	Below 8 months		8 months and older	
	Pass A	**Pass B**	**Pass A**	**Pass B**
First trial				
Breast-fed	64.3	14.3	79.0	31.6
Bottle-fed	58.8	35.3	68.8	37.5
Second trial				
Breast-fed	64.3	21.4	73.7	31.6
Bottle-fed	64.7	17.7	75.0	56.2
Third trial				
Breast-fed	42.9	28.6	68.4	52.6
Bottle-fed	70.6	17.7	56.3	31.3

Results in Table II show that the older breast-fed infants improved search in location B above chance in the third trial. Annex I and II show that both younger and older breast fed infants closed the gap by improving search in location B with practice, the younger group showing a larger trade-off against search in location A. Interesting to note, though the fourth order interaction was not significant, was the difference of the two age groups of bottle-fed infants: While in the younger bottle-fed infants the AB gap widened, in older bottle-fed infants the ratio between successful location A and B searches stayed about the same across trials.

Discussion

The results of the present study were straightforward. In repeated trials breast-fed infants closed the AB gap by gradually improved search in location B in the second to the third trial, in accordance with previous data of Bremner (Bremner, 1978; Bremner & Bryant, 1977), while bottle-fed infants did not.

One should recall from the literature review that infants closer to the body of the mother showed separation anxiety earlier than infants who were more distant from the body of the mother. Thus, it is presumed that although breast-feeding as such could not have been a directly causal variable, even if it is a predictive variable for learning in the AB task. Instead, it is suggested, that the degree of intimacy with the mother must have had an influence on the degree of sensitivity to familiarity.

The individual differences in selective improvement in repeated trials in the AB task are particularly illuminating when one is interested in the underlying learning mechanism. From a logical perspective, when selectivity occurs in constrained cognitive systems, there is the implicit possibility that a trade-off occurs with the non-selected instance. However, when information processing capacity of the system increases, the trade-off is likely to be smaller or absent because of increased resources. Indeed, in the present study, it was found that the younger breast-fed infants could only selectively improve the «problem location» B against a large trade-off of successful search in location A, while the trade-off in the older breast-fed infants was much smaller. When inspecting Figure 1 with the plotted data of the Bremner studies, one can find that the sample of infants who managed to improve search in location B across five trials without a trade-off, were performing above 90% success in location A already in the first trial and thus had a more consolidated search pattern.

The learning mechanism of the bottle-fed infants was different from the Bremner samples and the breast-fed infants in the present study. Although no pattern was revealed that could be successfully tested statistically, it is possible to describe the difference. In younger bottle-fed infants, a trade-off in favor of search in location A occurred so that the AB gap widened. This occurred also in the sample of Bremner and Bryant (1977), infants whose search in location B deteriorated after the third trial, nevertheless improved to ceiling level in search in location A.

In older bottle-fed infants, performance between places A and B was linked, i.e. search in locations A and B was improving or decreasing at the same rate. A breakdown of selectivity in the treatment of the two places was also found in the study of Corter *et al.* (1980, p. 68): Infants making search errors had shown no selective attention in both visual and motor search to either of the rooms where the mother had disappeared. One could conclude that during the normal period of increased preference for the mother, those who do not have this preference retreat to an even distribution of resources across places, rather than to selectively sustain attention to a particular object pathway.

A tentative explanation of the varied learning mechanism in bottle-fed infants would be that following the complete pathway of the object from A to B got out of focus and, as a consequence, either a spatial primacy effect occurred (improvement in location A with deteriorating performance in location B), or places were regulated as if without an object, i.e. as if in the void (non-selective processing of locations A and B).

These results are both critical and supportive to Piaget's theory. Corter *et al.* (1980, p. 69) complained about Piaget's «amorphous» explanation of the AB search. In fact, Piaget offered more than one explanation. First, one explanation was «object permanence» which is commonly understood as a mental object representation so that the object can be held in memory when hidden. However, when it is presumed that emotional factors are important,

the term «object permanence» acquires a meaning that goes beyond a straightforward information processing or memory account. In the present study, the information processing capacity was more the general framework which determined the size of the trade-off effect of the selective improvement of search in location B in repeated trials. However, the information processing account did not explain why young infants were able to selectively improve search in location B at all.

Second, another explanation of Piaget was «egocentric space» which was understood as increasingly object-centered behavior in the spatial field, independently of the own body. But probably an emotional connotation of egocentrism is more justified than Piaget intended. Infants physiologically more distant to the mother showed some kind of «intellectual realism» insofar as they focused on spatial relations between locations A and B during a period when all their peers develop a preference for the mother, i.e. a familiar object. Thus, the intriguing question arises whether the anchor of spatial search are the objects themselves, the places themselves, or the link between objects and places. It was suggested that the normal learning mechanism in the AB task involves sustained attention for the object's pathway, i.e. an object linked with places. The span and the strength of this link between object and spatial pathway seems to be determined by the obviously not domain-specific concept of stimulus «familiarity».

Third, Piaget's explanation of sensori-motor intelligence (Piaget, 1941, pp. 228) was that infants can adjust and correct their behavior on a motor response level, but this would not constitute «l'équilibre permanent», i.e. a permanent state of equilibrium in the mind which would provide a functional anticipatory motor schema. The present analyses of the learning mechanism involved in the AB task showed that indeed infants can selectively improve performance in location B and close the AB gap. Whether this learning effect is durable was not tested, however, neural network studies indicate that an adaptive learning process account is an appropriate explanatory model (Munakata, McClelland, Johnson & Siegler, 1997). Thus, it is suggested that «adaptation permanence» may be a promising candidate for further research.

Piaget was a biologist who started his career on adaptation processes of snails in the lake Geneva and never dropped this concept. He became interested in children's cognitive development when he analyzed contingencies in normal as well as emotionally and behaviorally disturbed psychiatric children. We can be confident that Piaget's beginnings shaped the intelligence theory in a way that matches the recent interest of developmental psychologists in selective deficits, brain development and processing pathways (see also Bjorklund, 1997).

From the reanalyses of the Bremner data and the present result for the breast-fed infants it is concluded that default learning in the AB task works dependent on sensitivity to stimulus familiarity, enhancing selective improvement in sustained attention for the pathway of an object, the amount

of trade-off between selected and non-selected instance being determined by the constraints of the cognitive system.

SUMMARY

Bjork and Cummings (1984) showed that in the AB task infants aim for the correct place but search in adjacent places. In repeated trials, infants center and adjust their search to the correct hiding location. Re-analyses of previous research (Bremner, 1978; Bremner & Bryant, 1977) showed that infants close the gap between search in location A and B by selectively improving search in location B between the second and the third trial. In the present study, it was hypothesized that breast-fed infants would be better prepared to focus, i.e. center and improve selectively in the AB task. It was found that indeed breast-fed infants showed the same learning pattern, while bottle-fed infants did not. In addition, it could be observed that search in location A showed a trade-off with search in location B, which was the larger the more constrained the cognitive system, i.e. the younger the infants. It is suggested that sensitivity to familiarity enhances selective improvement of sustained attention for the pathway of an object in the AB task.

RÉSUMÉ

Bjork et Cummings (1984) ont montré qu'en résolvant la tâche AB les jeunes enfants envisagent de chercher à la position correcte, mais qu'ils cherchent dans les lieux voisins. En répétant leurs essais, les enfants centrent et ajustent leurs mouvements jusqu'à la position correcte. Dans les recherches de Bremner (1978, Bremner & Bryant, 1977) on peut observer que les enfants font le saut (passage de la position A à la position B) sélectivement entre le deuxième et le troisième essai. Dans la présente recherche, on a supposé que les enfants nourris au sein pourraient plus facilement centrer leur attention sur la cible et corriger sélectivement leurs mouvements de recherche. On trouve effectivement que les enfants allaités sont capables d'apprentissage, mais pas les bébés nourris au biberon. Par ailleurs, plus restreint est le système cognitif, c'est-à-dire, plus les enfants sont jeunes, plus le lieu A compromet la recherche en B. On suppose que la sensibilité à la familiarité facilite l'attention portée à la trajectoire spatiale de l'objet dans la tâche AB.

ZUSAMMENFASSUNG

Bjork and Cummings (1984) zeigten, dass Kleinkinder in der AB Versteckaufgabe Suche am korrekten Ort beabsichtigen, aber dann tatsächlich am benachbarten Ort suchen. Bei wiederholter Suche zentrierten und passten Kleinkinder erfolgreich ihre Suchbewegungen an den korrekten Ort an. Reanalyse früherer Forschung (Bremner, 1978; Bremner & Bryant, 1977) zeigte, dass Kleinkinder den

Erfolg der Suche am Ort B selektiv zwischen der zweiten und dritten Wiederholung verbesserten und auf diese Weise den Erfolgsunterschied zwischen Ort A und Ort B ausglichen. In der vorliegenden Studie wurde angenommen, dass gestillte Babies eher in der Lage sind zu fokussieren, d.h. selektiv ihre Suchbewegungen am Ort B zu verbessern. Die Gruppe der gestillten Kinder zeigte dieses Lernmuster, flaschengefütterte Kinder nicht. Die Verbesserung am Ort B führte zu einem trade-off mit der Suche am Ort A, der umso grösser war, je begrenzter die kognitive Kapazität des Kindes, d.h. je jünger das Baby. Es wird vorgeschlagen, dass Kinder, die sensibel für Vertrautheit sind, es wahrscheinlich leichter finden, die andauernde Aufmerksamkeit aufzubringen, die für die Verfolgung des Objekts von Ort A nach Ort B notwendig ist.

REFERENCES

BAISCH, M. J., FOX, R. A., WHITTEN, E., & PAJEWSKI, N. (1989). Comparison of breast-feeding attitudes and practices: Low-income adolescents and adult women. *Maternal Child Nursing Journal, 18,* 61-71.

BAKSH, M., NEUMANN, C. G., PAOLISSO, M., TROSTLE, R. M. *et al.* (1994). The influence of reproductive status on rural Kenyan women's time use. *Social Science and Medicine, 39,* 345-354.

BELL, M. A., & FOX, N. A. (1992). The relations between frontal brain electrical activity and cognitive development during infancy. *Child Development, 63,* 1142-1163.

BELL, M. A., & FOX, N. A. (1994). Brain development over the first year of life. In G. Dawson & K. W. Fischer (Eds.), *Human behavior and the developing brain* (pp. 314-345). New York: The Guildford Press.

BJORK, E. L., & CUMMINGS, E. M. (1984). Infant search errors: Stage of concept development or stage of memory development. *Memory and Cognition, 12,* 1-19.

BJORKLUND, D. F. (1997). In search of a metatheory for cognitive development (or, Piaget is dead and I don't feel so good myself). *Child Development, 68,* 144-148.

BREMNER, J. G. (1978). Spatial errors made by infants: Inadequate spatial cues or evidence of egocentrism. *British Journal of Psychology, 69,* 77-84.

BREMNER, J. G., & BRYANT, P. E. (1977). Place versus response as the basis of spatial errors made by young infants. *Journal of Experimental Child Psychology, 23,* 162-171.

COOPER, P. J., MURRAY, L., & STEIN, A. (1993). Psychosocial factors associated with early termination of breast-feeding. *Journal of Psychosomatic Research, 37,* 171-176.

CORTER, C. M., ZUCKER, K. J., & GALLIGAN, R. F. (1980). Patterns of infant's search for mother during brief separation. *Developmental Psychology, 16,* 62-69.

CUMMINGS, E. M., & BJORK, E. L. (1981). The search behavior of 12 to 14 month-old infants on a five-choice invisible displacement hiding task. *Infant Behavior and Development, 4,* 47-60.

CUMMINGS, E. M., & BJORK, E. L. (1983a). Perseveration and search on a five-choice visible displacement hiding task. *Journal of Genetic Psychology, 142,* 283-291.

CUMMINGS, E. M., & BJORK, E. L. (1983b). Search behavior on multi-choice hiding tasks: Evidence for an objective conception of space in infancy. *International Journal of Behavioral Development, 6,* 71-87.

DAVANZO, J., SINE, J., PETERSON, C., & HAAGA, J. (1994). Reversal of the decline in breast-feeding in peninsular Malaysia? Ethnic and educational differentials and data quality issues. *Social Biology, 41,* 61-77.

DAVIDSON, R. (1994). Temperament, affective style, and frontal lobe asymmetry. In G. Dawson & K. W. Fischer (Eds.), *Human behavior and the developing brain* (pp. 518-536). New York: The Guildford Press.

DAWSON, G. (1994). Development of emotional expression and emotion regulation in infancy. In G. Dawson & K. W. Fischer (Eds.), *Human behavior and the developing brain* (pp. 346-379). New York: The Guildford Press.

DIAMOND, A. (1985). Development of the ability to use recall to guide action as indicated by infants' performance on AB. *Child Development, 56,* 868-883.

DIAMOND, A. (1991). Neuropsychological insights into the meaning of object concept development. In S. Carey (Ed.), *The epigenesis of mind: Essays on biology and cognition* (pp. 67-110). Hillsdale NJ: Erlbaum.

DIAMOND, A., WERKER, J. F., & LALONDE, C. (1994). Towards understanding commonalities in the development of object search, detour navigation, categorization and speech perception. In G. Dawson & K. W. Fischer (Eds.), *Human behavior and the developing brain* (pp. 380-426). New York: The Guildford Press.

ELMAN, J. L., BATES, E. A., JOHNSON, M. H., KARMILOFF-SMITH, A., PARISI, D., & PLUNKETT, K. (1996). *Rethinking innateness.* Cambridge MA: The MIT Press.

FREED, G. L., FRALEY, J. K., & SCHANLER, R. J. (1993). Accuracy of expectant mothers' prediction of fathers' attitudes regarding breast-feeding. *Journal of Family Practice, 37,* 148-152.

JENKINS, J., & MILLA, P. (1988). Feeding problems and failure to thrive. In N. Richman & R. Lansdown (Eds.), *Problems of preschool children* (pp. 151-172). Chichester: Wiley.

JOHNSON, D. L., SWANK, P. R., & HOWIE, V. M. (1996). Breast-feeding and children's intelligence. *Psychological Reports, 79,* 1179-1185.

KAGAN, J., REZNICK, J. S., & SNIDMAN, N. (1988). Biological bases of childhood shyness. *Science, 140,* 167-171.

LIEBERMAN, P. (1993). *Uniquely human.* Cambridge MA: Harvard University Press.

LITTMAN, H., MEDENDORP, S., & GOLDFARB, J. (1994). The decision to breastfeed: The importance of father's approval. *Clinical Pediatrics, 33,* 214-219.

MATICH, J. R., & SIMS, L. S. (1992). A comparison of social support variables between women who intend to breast or bottle feed. *Social Science and Medicine, 34,* 919-927.

MISHKIN, M., UNGERLEIDER, L. G., & MACKO, K. A. (1983). Object vision and spatial vision: Two cortical pathways. *Trends in Neurosciences, 6,* 414-417.

MUNAKATA, Y., MCCLELLAND, J., JOHNSON, M. H., & SIEGLER, R. (1997). Rethinking infant knowledge: Toward an adaptive process account of successes and failures in object permanence tasks. *Psychological Review, 104,* 686-713.

PAUL, K., DITTRICHOVA, J., & PAPOUSEK, H. (1996). Infant feeding behavior: Development in patterns and motivation. *Developmental Psychobiology, 29,* 563-576.

PIAGET, J. (1941). Le mécanisme du développement mental et les lois du groupement des opérations. *Archives de Psychologie, 28,* 215-285.

PIAGET, J. (1951). *Play, dreams and imitation in childhood.* London: Routledge and Kegan Paul. (Original, 1946)

PIAGET, J. (1955). *The child's construction of reality.* London: Routledge and Kegan Paul.(Original, 1937)

PIAGET, J. (1981). *Intelligence and affectivity: Their relationship during development.* Palo Alto CA: Annual Review Inc.

POSNER, M. I., & RAICHLE, M. E. (1997). *Images of mind.* New York: Scientific American Library. (Original, 1994)

ROGAN, W. J., & GLADEN, B. C. (1993). Breast-feeding and cognitive development. *Early Human Development, 31,* 181-193.

SHAFFER, D. R. (1993). *Developmental psychology.* Pacific Grove CA: Brooks/Cole.

WATERSTON, T., PLATT, M. W., & HELMS, P. (1997). *Paediatrics.* Oxford: Oxford University Press.

WILMOTH, T. A., & ELDER, J. P. (1995). An assessment of breastfeeding promotion strategies in developing countries. *Social Science and Medicine, 41,* 579-594.

ZEITLIN, M., & AHMED, N. U. (1995). Nutritional correlates of frequency and length of breast-feeds in rural Bangladesh. *Early Human Development, 41,* 97-110.

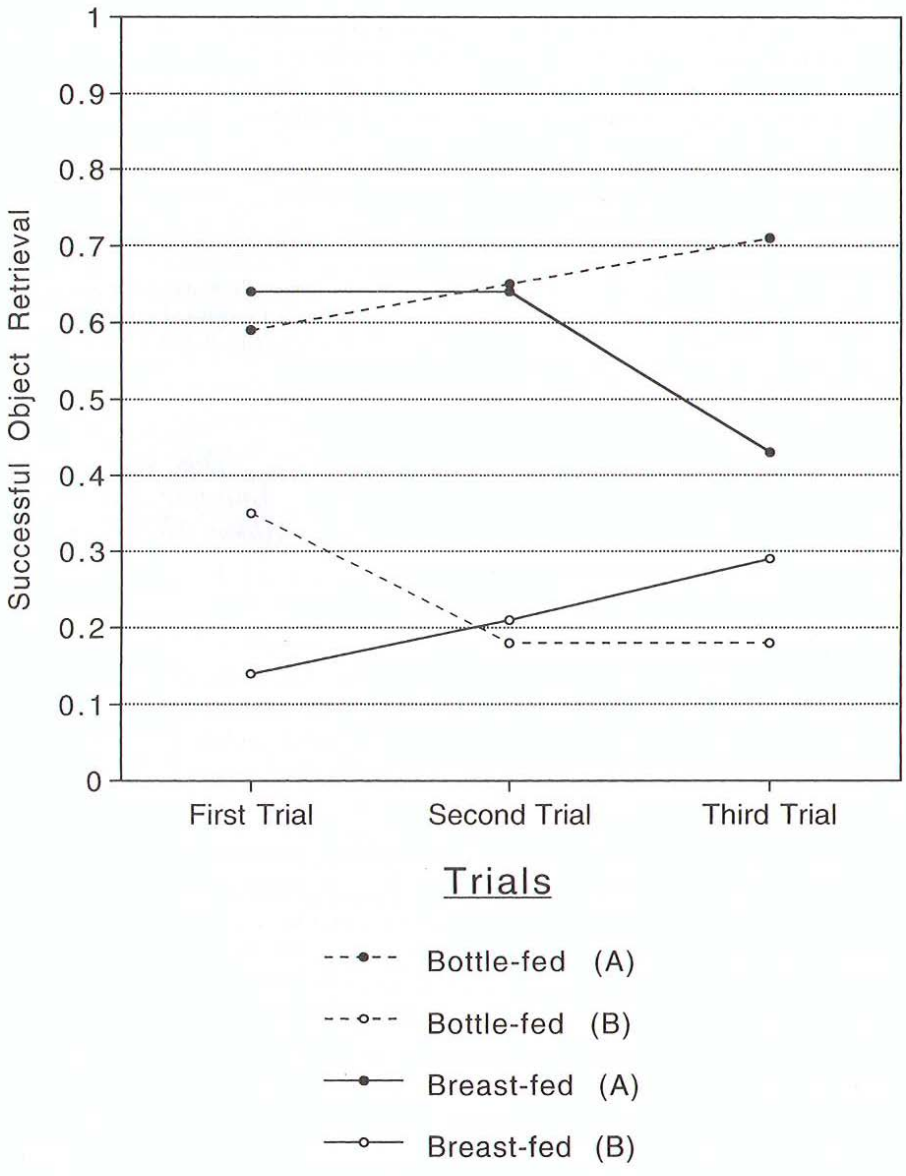
ACKNOWLEDGEMENT

The author would like to thank Margaret T. Crichton for her role in collecting data for this study. I am also grateful to the nurses and health visitors from the local Health Centres and parents for helpful co-operation and the children for participation in this research. I thank Robert Logie for comments on an earlier draft of this manuscript.

Author's Address
Dept. of Psychology
University of Aberdeen
Aberdeen AB24 2UB U.K.

ANNEX I

Annex I: Closing the AB gap: Effects of practice on object search in breast-fed and bottle-fed children below eight months.



ANNEX II

Annex II: Closing the AB gap: Effects of practice on object search in breast-fed and bottle-fed children of eight months and older.