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Affective, Behavioral, and Avoidance Responses on the Visual Cliff: Effects of Crawling Onset Age, Crawling Experience, and Testing Age

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ABSTRACT

Two visual cliff experiments with human infants are reported that were designed to determine relationships among cardiac responses, avoidance and other behavioral responses, and developmental factors. The developmental factors considered were age at crawling onset, age at testing, and amount of crawling experience. In Experiment 1, infants were given either 30 or 60 days of crawling experience following crawling onset. In Experiment 2, infants were tested at either 9 or 12 months of age and crawling onset age was recorded. Infants were tested using a crawling avoidance procedure and the placing procedure that has been established for heart rate responses. Crawling onset age was the best predictor of avoidance behavior. Heart rate response was also a significant predictor of visual cliff avoidance, and was found to be related to testing age, especially for late crawlers. Looking down behavior was also found to distinguish crawling avoidance and crossing of the deep side of the cliff apparatus. These results, it is argued, suggest that fear is not the primary determinant of avoidance behavior on the visual cliff, but does contribute to avoidance at later ages.

DESCRIPTORS: Infants, Visual cliff, Heart rate, Development.

The "visual cliff" has been an unique method for studying depth perception and emotional development in young infants. The visual cliff apparatus consists of a large table with a transparent surface approximately four feet from the floor. On one side, the "visual cliff," a cloth of checked pattern is laid on the floor, creating the illusion of a drop-off. On the other side, the "shallow" side, the checked pattern is flush with the surface. In early studies (Gibson & Walk, 1960; Walk & Gibson, 1961) it was shown that many species, including rats, chickens, sheep, cats, dogs, pigs, and goats would avoid the visual cliff at very young ages, but would readily cross the shallow side. Human infants, when called by their mothers, refused to crawl on the glass over the apparent drop-off, whereas they would cross the shallow side.

Some research studies have investigated the development of fearful responses to the visual cliff. Scarr and Salapatek (1970), using an observer's rating of the infant's fear, found a positive relationship between the fear of the drop-off and the age at which the child was tested. They did not, however, report how well fear predicts avoidance of the cliff, and, in fact, used avoidance as one index of fear. Several studies carried out in the laboratory of Joseph Campos (Campos & Langer, 1971; Campos, Langer, & Krowitz, 1970; Schwartz, Campos, & Baisel, 1973; Svedja & Schmid, Note 1) have used heart rate as an index of fear. These studies have found that infants at 2, 3.5, and 5 months of age show deceleration of heart rate to the deep side, whereas infants at 9 months of age show acceleration. In at least one of these studies (Schwartz et al., 1973), heart rate acceleration was positively correlated with the amount of distress, suggesting that in the visual cliff situation heart rate acceleration is an index of fearful responding (Campos, 1976; Campos, Hiatt, Ramsay, Henderson, & Svedja, 1978). Campos and his colleagues have interpreted these findings as indicating that the increase of fear with age is the result of greater crawling experience.

Fear in the visual cliff situation might be defined, or indexed, by any one of several parameters. Ratings of distress, such as crying, facial emotions, and lack of positive vocalizations, are evident during placing on the visual cliff (Hiatt, Campos, & Emde, 1979; Schwartz et al., 1973). The study of Schwartz et al. (1973) relates cardiac acceleration and these

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measures of distress, implying that they are both indexing fear in the visual cliff situation, as in other situations of distress for the infant (e.g., Campos, Emde, Gaensbauer, & Henderson, 1975; cf. Campos, 1976). Avoidance of the cliff may also be a result of fear in the visual cliff situation. If so, following the logic of Campos (1976) regarding the need for converging operations, it should be related to other measures of fear in the visual cliff situation, such as cardiac acceleration during the placing procedure and other ratings of distress.

Some recent research implies that fear of the cliff may not play a role in its avoidance by human infants. Rader, Bausano, and Richards (1980) found that infants who avoided the visual cliff when crawling readily crossed it when in a walker. If visual cliff avoidance results from fear of a cliff or an understanding of the cliff's consequences, the infant should avoid it both in the walker and while crawling. Further support that fear is independent of avoidance behavior on the visual cliff comes from the fact that different developmental factors seem to affect the two types of responses. Fear on the visual cliff has been shown to be related to testing age, and perhaps crawling experience. However, the age at which the child begins to crawl is the primary developmental factor determining avoidance (Rader et al., 1980; Richards & Rader, 1981). Infants who begin to crawl at early ages are more likely to cross the visual cliff than those infants beginning to crawl at later ages, even when crawling experience and testing age are controlled.

The present study was guided by two goals. First, a goal was to study the relationship between behavior in the crawling and placing paradigms of the visual cliff. To this end, the interrelationship between affective, behavioral, and developmental factors were examined in their ability to distinguish infants that crossed from those that avoided the visual cliff. In an initial report we examined the relationship between crawling onset age, testing age, and crawling experience, and crossing/avoiding the visual cliff (Richards & Rader, 1981). If it is the case that fear is a determinant of the avoidance behavior, it would be interesting to know how it compares with developmental and other behavioral responses in affecting avoidance of the visual cliff. The second goal was to assess how affective responses to the visual cliff, as measured by the heart rate response, were related to developmental factors. We were interested in determining if crawling experience and crawling onset age were as strongly related to the cardiac response as testing age has been shown to be.

Crawling onset age, crawling experience, and testing age are linearly dependent, so only two of these variables can be independently studied in a single experiment. Therefore, crawling experience and crawling onset age were studied in Experiment 1, and testing age and crawling onset age were studied in Experiment 2. In Experiment 1, infants were given either 30 or 60 days of crawling experience following crawling onset before being tested. These crawling experience levels correspond to the middle of the range of the experience levels in the Scarr and Salapatek (1970) and the Rader et al. (1980) studies. If there is a linear relationship between crawling experience and visual cliff responses in those two studies, the crawling experience levels chosen for this study should detect it. In Experiment 2, infants were tested at 9 or 12 months of age, and crawling onset age was determined by the mothers' reports. The testing ages were chosen so that our youngest age was similar to the older ages of the infants studied by Schwartz et al. (1973), and the older age was chosen to extend their findings to infants of 12 months. These testing ages partially overlap with the range of ages used by Scarr and Salapatek (1970), and by Rader et al. (1980). In both studies, crawling onset age has the status of a non-manipulated independent variable. In Experiments 1 and 2 we measured avoidance during the crawling procedure, heart rate responses during the placing procedure involving direct placement on the glass, and behavioral responses during the crawling and placing procedures.

EXPERIMENT 1

Methods

Subjects

Parents of 53 infants were contacted through birth notices when their infants were 4 to 6 months old. Parents were called monthly to determine the age at which the child first began to crawl. Crawling onset age was defined as the point at which the child was crawling on all fours, or the age at which the child had been creeping on its belly for two weeks. At the time of crawling onset, infants were randomly assigned to a crawling experience condition. At the end of 30 or 60 days they were tested on the visual cliff apparatus. Four subjects did not complete the testing procedure and were excluded from the study. Some initial results from these 49 subjects have been reported elsewhere (Richards & Rader, 1981). Three additional subjects were dropped from the study because of heart rate recording difficulties. A total of 46 infants completed the study.

Testing age ranged from 202–401 days, with a mean of 277 days (SD = 41.5). The mean crawling onset age was 229 days (SD = 42.2), and the range was from 141–353 days. Twenty-one infants were in the 30-day experience condition, having a mean crawling experience of 31.3 days (SD = 4.7) and a mean crawling onset age of 235 days (SD = 32.1). The 60-day experience condition had 25 subjects, with a mean crawling experience of 61.6 days (SD = 5.9), and a mean crawling onset age of 224 days (SD = 49.0).

Apparatus

The visual cliff apparatus was designed following Model III described by Walk and Gibson (1961), and was the same apparatus used by Rader et al. (1980). Video cameras were positioned at each end of the visual cliff apparatus in order to record the experimental sessions. Raters blind to the levels of crawling experience and crawling onset age assessed the videotapes for avoidance and behavioral observations. The behavioral observations included visual and tactile measures, such as looking down toward the glass surface, looking at the mother, and tactile testing of the glass surface. The behavioral observations also included measures of infant distress, including slight crying, active crying, and positive or neutral vocalization. The ratings were compared to those made by one of the authors (JER) for at least two infants for each rater, for a total of 19 infants. Perfect agreement for the sums over one trial of sec-by-sec ratings for behavioral variables were from 65 to 90 per cent; agreement for the presence or absence of a behavior on a trial was 95 percent; correlation coefficients between the ratings of the author and the others were above .87 for each of the different behaviors. Agreement for the avoidance response was 100 per cent. The behavioral data were converted to the number of responses per second, since behavioral data were obtained during trials with different times because of procedural differences, and differences due to the side of apparatus.

Heart rate was obtained by detection of the EKG signal from electrodes on the back of the infant approximately 5 to 10 cm below the shoulder blades, centered at midline, and 10 to 20 cm apart. The EKG was transmitted to a recording room next to the visual cliff room by a telemetry transmitter (EKEG Model K681) weighing 3 oz (84 g), strapped onto the infant by means of a small harness. An FM receiver (Kenwood Model KT-5300) was used to receive the signal, which was recorded on a Grass Model 5D polygraph. The R-wave of the EKG was detected by a level detector (Lafayette Model 76729), and a tape recorder (Sony Model TC158SD) recorded the occurrence of the R-wave. A Hewlett-Packard laboratory computer was used to measure the interbeat intervals, which were then transformed into sec-by-sec heart rate (Graham, 1978; Richards, 1980). Heart rate information on the polygraph and tape recorder were synchronized with videotape recordings using an event channel and a sec-by-sec marker.

Procedure

Infants were tested on the deep and shallow sides of the visual cliff apparatus using a crawling procedure (Gibson & Walk, 1960; Walk & Gibson, 1961) and a placing procedure (Campos et al., 1970). For the crawling procedure, infants were placed on the center platform headed toward the testing site. The mother stood at the center of the side selected for the testing site and called the infant to cross. The infant was first tested for 2 min without a toy presented. After this initial time, the mother was allowed to use a toy or other interesting object to coax the infant to cross. The mothers were instructed not to touch the glass nor to place the toy on the glass during the crawling procedure. Testing on one side of the cliff apparatus ended when the infant reached the mother or when 4 min elapsed without the infant reaching the mother. Avoidance was defined as the infant not crossing the cliff to the mother in the 4-min period.

For the placing procedure, infants were seated for 30 sec on the glass by the mother, approximately 18 inches (45 cm) from the side. At the end of 30 sec, the child was lifted by the mother from 18 to 24 inches (45 to 61 cm) above the surface facing downward, and was slowly lowered to the glass. The descent took from 3 to 5 sec. The child remained on the glass for 30 sec, at which time the trial ended.

Testing order of the 4 trials (shallow-deep and crawling-placing) was randomly determined for each subject. Analysis showed that each trial type occurred in the four ordinal positions nearly equally (± 4 maximum difference over the 46 possible outcomes). No apparent relationship occurred between the order of testing and the frequency of crossing or avoiding either the shallow or deep side of the apparatus.

Results

Heart Rate

Heart rate was analyzed sec-by-sec for the 5 sec while the infant was seated on the glass immediately prior to the placement, and for 15 sec beginning with the actual descent to the surface and including the placement on the glass. A multivariate analysis of repeated measures (McCall & Appelbaum, 1973; Richards, 1980, 1981) was used to analyze heart rate, since heart rate measured sec-by-sec is known to violate assumptions of repeated measures analysis of variance (Jennings & Wood, 1976; Keselman & Rogan, 1980; Richards, 1980; Wilson, 1974). The within-subjects effects that were tested with the multivariate method are contrasts which represent the side of the visual cliff apparatus, the pre 5 sec compared to the post 15 sec, a "descent" contrast between the pre 5 sec and the post 5 sec, and the first six polynomial trends. Crawling onset age and crawling experience were treated as between-subjects effects in a factorial design. Crawling onset age was tested as a continuous independent variable in the general linear models testing framework (Kerlinger & Pedhazur, 1973; Morrison, 1967).

There was a significant effect on heart rate level of the side of cliff apparatus (Hotelling $T^2 = 8.06$, $F(1/45) = 8.06$, $p = .007$). Heart rate was higher on the shallow side (mean = 147.1) than on the deep side (mean = 144.2), especially for the last 10 sec of the post 15 sec interval. There were other main effects on the within-subjects contrasts, but none of these effects interacted with the side of the cliff apparatus and so are not of interest. Similarly, crawling onset age interacted with several of the within-subject contrasts, but since none of these interacted with the side of the visual cliff they are not reported. Crawling experience had no significant effect or interaction on the sec-by-sec heart rate effects.

Discrimination of Avoidance Behavior

Discriminant function analysis was used to examine the interrelationships among heart rate responses, behavioral observations, and crawling onset age and crawling experience in the discrimination of crossing and avoiding infants. The results for crawling onset age and crawling experience for these subjects have been reported elsewhere (Richards & Rader, 1981). Of these two factors, crawling onset age was the only significant predictor. Infants who began to crawl at early ages were more likely to cross the cliff than those infants beginning to crawl at later ages (Table 1).

Heart rates for 5 sec prior to and 15 sec during the descent to the glass and following the placement on the glass of the deep side were used as predictors of the criterion groups. A minimum of three intervals significantly discriminated the groups, and five intervals provided the optimal discriminating ability (Figure 1). The raw heart rate data were transformed by a matrix representing a pre-post stimulus contrast, and the first three polynomial trends (Richards, 1981), and only the variable representing the quadratic trend significantly discriminated between the two groups. This suggests that the pattern of phasic acceleration in the first six intervals following the stimulus, presumably occurring during the descent to the glass, was the most important cardiac response for discriminating between avoiding and crossing groups.

Table 1

Means of variables that discriminate crossing and avoiding infants in Experiment 1

			Behavioral Responses (frequency per sec) On Deep Side For Crawling and Placing Procedures		
				Placing	
Infant Groups	N	Crawling Onset Age (days)	Crawling, Looking Down	Looking Down	Slight Crying
Avoiding	25	247	.167	.437	.193
Crossing	21	207	.240	.268	.036

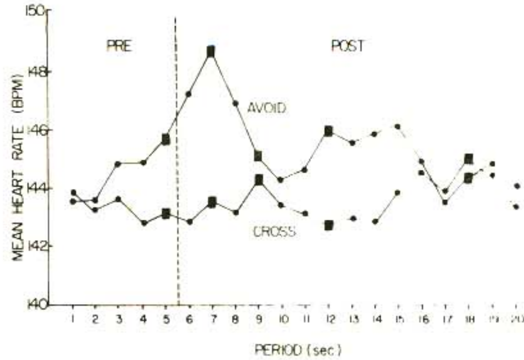

Figure 1. Mean heart rate during deep placing for avoiding and crossing subjects in Experiment 1. The PRE intervals include the last 5 sec while the infant was seated on the glass, and the POST intervals begin with the descent to the surface. Intervals marked with square boxes are those that significantly discriminated crossing and avoiding groups.

Behavioral observations obtained from videotape recordings were tested as predictors of avoidance and non-avoidance. The only behaviors that discriminated between these groups were looking down toward the glass on the deep side during the crawling procedure and looking down toward the glass during the placing procedure, and slight crying during the prone position on the deep side (Table 1). Infants who crossed the deep side spent more time looking down during the deep side crawling procedure than those who avoided the deep side. For the other two behaviors, the infants who avoided the visual cliff spent more time engaged in the behavior than those infants who crossed the visual cliff.

Significant discriminators from the three sets of variables were entered into a discriminant function in different orders to determine whether the predictive ability of each set was independent. Crawling onset age was the best predictor of the three sets, and retained its predictive significance regardless of the order in which it was entered. The heart rate responses retained their discriminative significance if entered after crawling onset age. Heart rate discriminated less well but still significantly if entered following the behavioral variables. Of the behavioral measures, looking down on the deep side during placement and crawling procedures retained their significant discriminative power if entered after crawling onset age or heart rate.

Order Effects

Although we attempted to control order effects by random assignment of testing order, the possibility that the order of testing may have affected the responding was examined since some effects of multiple testing on the visual cliff have been reported (Campos et al., 1978). We separated groups into those infants receiving the crawling procedure on the deep side before being tested with the placement procedure on that side, and those infants tested with the crawling procedure following the placement procedure, to determine if the previous exposure (or lack of exposure) had an effect on the behavioral and cardiac responses during the placement procedure. A stepwise discriminant analysis with these two orders as the criterion groups and the behavioral and cardiac variables as discriminating variables did not have significant discriminating power, indicating that the pattern of cardiac and behavioral responding was similar in the two groups. To test further for possible order effects, discriminant functions with the crossing-avoiding criterion groups (as described in the prior section) were done separately for the two orders. These analyses produced results for the two orders nearly identical to those reported in the previous section when order was not considered.

EXPERIMENT 2

Methods

Subjects

Parents of 43 infants were contacted through newspaper birth notices when their infant was 9 or 12 months of age. Crawling onset age was determined by questioning the parents during the first phone contact and reconfirmed before testing at UCLA. Three infants did not complete the procedures and were excluded from the study. Of the 40 infants tested, 20 were in the 9 month old group and 20 in the 12 month old group. Some initial results from these 40 subjects have been previously reported (Richards & Rader, 1981). We encountered difficulties in recording heart rate for three infants in the 12 month old group and one infant in the 9 month old group. These infants, as well as two infants randomly selected from the 9 month old group were excluded from all analyses.

The 17 infants in the 9 month old group had a mean testing age of 273 days (SD = 13.2), with a range from 245–290 days. This group had a mean crawling onset age of 213 days (SD = 25.7). The 12 month old subjects had a mean testing age of 364 days (SD = 21.6), ranging from 350–393 days. The mean crawling onset age for this group was 220 days (SD = 74.8). The mean crawling onset age in days for both groups combined was 217 (SD = 55.0). The standard deviation of the crawling onset age differs for the two testing age groups since the 9 month old infants had a maximum crawling onset age of 9 months, whereas the 12 month old testing age group had a crawling onset age maximum of 12 months.

Apparatus and Procedure

The apparatus and procedure for testing the infants were identical to those described in Experiment 1. The four trial types were distributed approximately equally among the four ordinal positions. As in Experiment 1, there was no apparent relationship between the order of testing and the crossing or avoiding of the deep or the shallow side of the visual cliff apparatus.

Results

Heart Rate

As in Experiment 1, heart rate during the placing procedure on the visual cliff apparatus was analyzed on a sec-by-sec basis using the multivariate method of analyzing repeated measures. Testing age and crawling onset age were treated as between-subjects factors in a factorial design, and the within-subjects effects listed in Experiment 1 were used in this experiment. The effect of the side of the apparatus on heart rate levels approached statistical significance (Hotelling $T^2 = 3.38$, $F(1/33) = 3.38$, $p = .075$). The mean heart rate on the shallow (mean = 145.7) was higher than it was on the deep side (mean = 143.4). Heart rate on the shallow side showed an increase in the first 2 sec of the poststimulus interval, presumably occurring during the descent to the glass. A large deceleration in the 10 poststimulus sec was evident on the side of the visual cliff apparatus. There were no other main effects of the within-subjects effects, and no significant interactions of these effects with the side of the apparatus.

Of the possible interactions between crawling onset age, testing age, and the within-subjects factors, only the interaction between crawling onset age and testing age with the side by polynomial trends contrast was significantly related to heart rate (Wilks *Lambda* = .5615, $F(6/25) = 3.25$, $p = .0156$). The individual *beta* weights relating crawling onset age and the transformed variables showed that the side by quartic and the side by quintic effects were significantly affected by the crawling onset age for the 9 month old infants. The side by sextic effect was significantly affected by crawling onset age for the 12 month old infants. Figure 2 shows the heart rate responses for the 9 and the 12 month old infants on the deep and shallow sides, unadjusted for crawling onset age. The 12 month old infants showed an accelerative response in the first few poststimulus seconds on the deep side, whereas the 9 month old subjects showed a large cardiac deceleration from the seventh through the tenth poststimulus seconds. This effect was further investigated by looking at the pattern of significant *beta* effects relating crawling onset age to the within

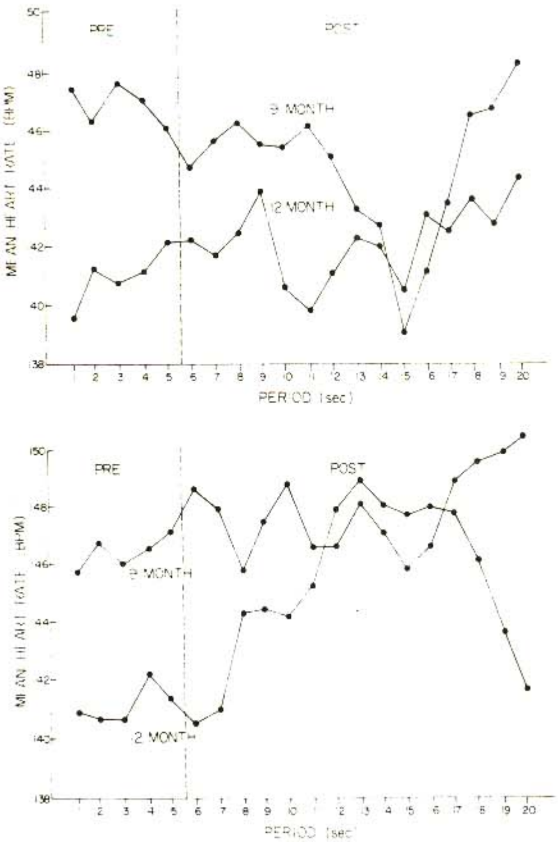

Figure 2. Mean heart rate during shallow (bottom figure) and deep (top figure) placing for 9 and 12 month old subjects in Experiment 2. The PRE intervals include the last 5 sec while the infant was seated on the glass, and the POST intervals begin with the descent to the surface.

subjects effects. The *beta* weights showed that this effect was stronger for the later crawlers. On the shallow side, the 9 month old infants showed little heart rate response, but the 12 month old infants showed a large acceleration of heart rate following placement on the glass. The shallow side response was more characteristic of the infants who began to crawl at the early ages.

Discrimination of Avoidance Behavior

A discriminant function analysis was used, as in Experiment 1, to explore relationships among heart rate responses, crawling onset age and testing age, and behavioral responses for infants who avoided and those that crossed the deep side. The discriminant analysis results for crawling onset age and testing age for these subjects have been reported previously (Richards & Rader, 1981). Crawling onset age was a significant predictor of the criterion groups, and testing age had some discriminating power but it did not significantly discriminate between the two groups. Infants who began to crawl at early ages were more likely to cross the deep side of the visual cliff apparatus than those who began to crawl at later ages (Table 2).

The results for the discriminant analysis using heart rate levels during the placing procedure on the deep side were similar to those for Experiment 1. Several intervals used in combination discriminated significantly between the crossing and avoiding subjects (Figure 3). The heart rate levels were transformed by a matrix representing a pre-post stimulus contrast and the first three polynomial trends (Richards, 1981). As in Experiment 1, the quadratic trend significantly discriminated between the two groups. The phasic accelerative response in the first few seconds following placement on the surface again was characteristic of the avoiding infants (cf., Figure 1, Figure 3).

The behavioral variables which significantly discriminated avoidance behavior included looking down on the deep side during the crawling procedure and while being placed in the prone position (Table 2). Other discriminating behaviors on the deep side included testing behavior during placing, looking at the mother during placing, and positive or neutral vocalization during placing. Slight crying during placement on the shallow side was also a significant discriminator.

The three sets of variables, heart rate, crawling onset age, and behavioral responses, were used in a discriminant analysis entered in different orders

Table 2

Means of variables that discriminate crossing and avoiding infants in Experiment 2

			Behavioral Responses (frequency per sec)					
			Deep Crawling,	Deep Placing Procedure				Shallow Placing,
Infant Groups	N	Crawling Onset Age (days)	Looking Down	Looking Down	Look at Mother	Surface Testing	Positive Vocalize	Slight Crying
Avoiding	18	238	.104	.275	.233	.045	.068	.228
Crossing	16	192	.143	.237	.295	.023	.086	.166

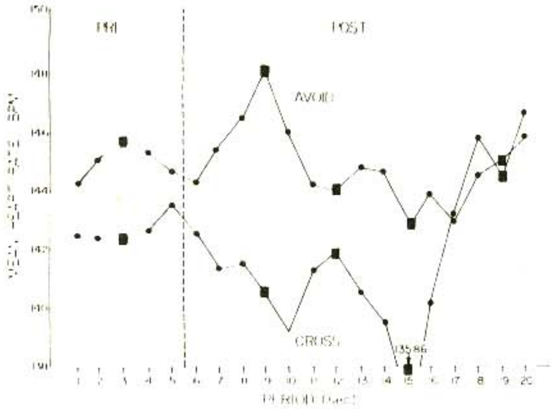

Figure 3. Mean heart rate during deep placing for avoiding and crossing subjects in Experiment 2. The PRE intervals include the last 5 sec while the infant was seated on the glass, and the POST intervals begin with the descent to the surface. Intervals marked with square boxes are those that significantly discriminated crossing and avoiding groups.

to assess the relative independence of each set. Crawling onset age retained its predictive significance if heart rate levels were entered first, and retained its predictive power but to a lesser degree if the six behavioral variables were entered first. Heart rate levels retained their significance if entered following crawling onset age, and retained their power but to a lesser degree if the behavioral variables were entered first. Looking at the mother during the placing procedure on the deep side lost its discriminative significance if crawling onset age was entered prior to the behavioral variables, but the other five variables retained their discriminating power. Looking down on the deep side during the placement procedure and during the crawling procedure retained their predictive significance after heart rate was entered, as did testing behavior during the deep side placing procedure.

In Experiments 1 and 2, looking down during the crawling procedure and looking down during the placing procedure on the deep side were the only consistent behavioral predictors which were independent of heart rate and crawling onset age. In separate discriminant functions for each experiment, these two behavioral variables, heart rate, and crawling onset age retained their significant predictive power regardless of the order in which they were entered into the discriminant function. In both studies crawling onset age was the best discriminator of the three sets.

Order Effects

As in Experiment 1, we tested the heart rate data for order effects. There were some order effects that emerged from these analyses, primarily affecting the longer latency heart rate responses. The group tested first in the crawling procedure had higher heart rates during the placement procedure in periods 3 and 18, and a lower heart rate in period 20, than the group tested in the placing procedure first (Figure 3). When the crawling-avoiding distinction was used as the criterion group, it was found that the group receiving the crawling procedure prior to the placing procedure showed the difference in heart rate on poststimulus second 10 (Figure 3, period 15) as was found with the total group, and did not show differences between the crossing and avoiding groups on the last 5 poststimulus seconds. For the subjects receiving the placing procedure prior to the crawling procedure, the opposite pattern of results was true. Thus, any effects of the order of testing are primarily confined to the long latency heart rate responses.

DISCUSSION

In this study, crawling experience had no appreciable effect on infants' cardiac responses to placement on the deep side of the visual cliff. The effect involving testing age, especially for older crawling onset age infants, suggests that the accelerative trend which discriminated between the crossing and avoiding infants occurred more frequently in the 12 month old subjects. Nine month old infants showed cardiac deceleration to visual cliff placement on the deep side. Crawling onset age was the best discriminator of avoidance behavior, when compared to heart rate responses to placement, and with behavioral responses during both crawling and placing procedures. However, the heart rate response to being placed on the deep side was a significant discriminator of avoidance behavior independent of crawling onset age. Looking down behavior on the deep side during crawling and placing procedures also provided independent discrimination of avoiding and crossing groups. The replication in the two experiments of the interrelationship among crawling onset age, heart rate, and behavioral responses in the discrimination of avoidance behavior strengthens the empirical validity of this finding. Certain fear-related behaviors which significantly discriminated crossing and avoiding groups, such as crying, had shared variance with heart rate responses in the discrimination of avoidance behavior.

It is clear from this research, supporting research by Campos et al. (1970), Schwartz et al. (1973), and Scarr and Salapatek (1970), that fear of the visual cliff is positively related to age of testing. Scarr and Salapatek showed that there is a positive relationship between the age at which the child is tested and an observer's rating of the child's fear. The research by Campos and his coworkers has shown a clear trend from cardiac deceleration at ages below 6 months to acceleration at 9 months when the child is placed on the glass over the visual cliff. Experiment 2 reported here showed cardiac deceleration to the placement at 9 months of age, and acceleration in infants at 12 months of age, especially for infants who began to crawl at later ages. Although the exact ages for the shift from cardiac deceleration to acceleration are different from those reported by Campos, the trend is identical. The age differences may have resulted from laboratory or procedural differences. For example, it has been shown that the cardiac accelerative response to a stranger is partially contingent on the presence or absence of the mother (Campos et al., 1975). Thus, using the mother to do the placement in the present study may have produced the age differences between the studies (cf. Campos et al., 1978). The fact that the heart rate responses had shared variance with the negative affective responses in the discrimination of avoidance behavior implies that both were indexing a distressful response to the cliff, replicating the relationship between fearful behavioral responses and cardiac responses reported by Schwartz et al. (1973). These results support the conclusion that cardiac acceleration is an index of fear of the visual cliff situation (Campos, 1976).

The cardiac accelerative response on the shallow side by 12 month old infants in Experiment 2 and the increase in heart rate on the shallow side in Experiment 1 limit an unequivocal interpretation of heart rate acceleration as fear in the visual cliff situations. This type of result has been reported before (Schwartz et al., 1973; Svedja & Schmid, Note 1). For example, an inspection of Figure 1 of Schwartz et al. (1973) suggests that the 9 month olds' cardiac response to the shallow side involves a longer latency cardiac acceleration than their response to the deep side, whereas the younger group in that study have virtually no change over that period. It is possible that this response on the shallow side represents cardiac changes due to motor activity. Informally, we have observed that there was more crawling on the shallow side than on the deep side following placement, and it is possible that the 12 month old infants did this more frequently. The possibility that this represents a response to "collision" with the shallow side is not likely, since it occurs after the actual descent to the cliff is finished. Similarly, the difference between the latency of the 9 month olds' decelerative response on the deep side and the 12 month olds' accelerative response on that same side (Figure 2) implies that a strict attention-fear dichotomy interpretation of the deceleration-acceleration responses is not unambiguous for the visual cliff situation. Indeed, the order effects reported in Experiment 2 suggest caution in the interpretation of these longer latency response patterns. However, since the cardiac accelerative trend during the descent to the cliff was common to the discrimination of avoidance in both experiments (Figure 1, Figure 3), it may be safe to assume that this differentially measures fear in avoiders and non-avoiders.

Crawling onset age was the single best predictor of avoidance behavior in this study (cf. Rader et al., 1980; Richards & Rader, 1981). Infants who began to crawl at early ages tended to cross the visual cliff, whereas infants crawling at later ages avoided it. The effect of crawling onset age on avoidance behavior does not operate through differences in fear of the visual cliff in early and late crawlers. The independence between the crawling onset age effect and the negative affective response is shown by the observation that infants beginning to crawl at later ages and tested at 9 months of age show cardiac deceleration to placement even though they tend not to cross the cliff. On the other hand, infants with the same later crawling onset ages when tested at 12 months of age also tended not to cross the cliff but showed acceleration rather than deceleration during placement procedures. Stated otherwise, there is not a necessary relationship between later crawling onset age and the direction of cardiac responding. This independence between crawling onset age and negative affective responding was also illustrated in the discriminant function analyses, in which heart rate responses and crawling onset age independently and significantly discriminated crossing and avoiding subjects.

No effect of 30 or 60 days of crawling experience on cardiac responses to the visual cliff was found in this study. Crawling experience did not affect the cardiac response to placement in Experiment 1 in which days of crawling experience was controlled by testing groups either 1 or 2 months following crawling onset. This finding with discrete levels of days of crawling is consistent with the lack of an effect of crawling experience of similar levels but when crawling experience levels varied randomly (Rader et al., 1980; Scarr & Salapatek, 1970). It is possible that a complex non-linear relationship exists between crawling experience and responses on the visual cliff, such as an all-or-none effect, or a relationship based on experience within the first month of crawling. Mothers of infants almost uniformly report an initial period during which infants will crawl off beds, couches, and chairs. These same infants then come to avoid "natural" cliffs, and also will not cross the visual cliff (Campos et al., 1978). Some latency differences in the crawling response on the deep side have been reported for infants with 0 to 30 days of experience (Campos et al., 1978). Svedja and Schmid (Note 1) reported that infants with a mean crawling experience of 30 days, tested at 7 months of age, showed more accelerative responding while being placed on the visual cliff than did non-crawling infants tested at the same age. The relationship between crawling experience and *avoidance* behavior, however, would be limited to the infants that begin to crawl at older ages, since it is only those infants that begin to crawl at older ages who consistently avoid the visual cliff (Rader et al., 1980; Richards & Rader, 1981). Research with infants of crawling experience of less than one month, controlling also for testing age and crawling onset age, is needed to answer this question definitively.

The results of this study, in conjunction with other research, provides an interesting picture of the relationship between negative affective responses to the visual cliff and its behavioral avoidance. Infants beginning to crawl at very early ages do not avoid the visual cliff even when tested as old as one year of age, and seem to show no fear of the cliff, as indexed by cardiac acceleration and behavioral distress. Infants beginning to crawl at later ages, perhaps 6.5 to 7 months of age, avoid the visual cliff at 9 and at 12 months of age. Generally, however, these infants do not show affective fear of the visual cliff as measured by the cardiac response until 12 months of age. Thus, the negative affective response to the visual cliff is increasing with age, but it is not necessary for the infant to avoid the cliff. Rather, it may merely accompany avoidance in the later crawling infants who are tested at older ages. The fact that the heart rate accelerative response discriminated between crossing and avoiding infants in both experiments of this study implies that fear does make a substantive contribution to the avoidance response, especially at the later ages. It is not, however, a necessary determinant of avoidance.

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