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ABSTRACT

This study examined the development of smooth visual tracking in 11 infants 2 and 3 months of age, with particular attention given to the role of expectation in tracking complex visual motion. Data were gathered by recording the image of the infant's eye as he or she tracked a small computer-generated target as it moved in a sinusoidal trajectory across a video monitor. Tracking of this motion required coordination of horizontal and vertical eye movements. On 6 of 12 screen transits presented, the amplitude and period of the sinusoid were suddenly reduced and target velocity was decreased. Changes were expected to disrupt infants' tracking if infants were developing expectations for the base trajectory. Findings indicated that tracking amplitude, proportion of saccades, and phase lags improved with practice. Changes in the sinusoid disrupted tracking. Findings suggest that 2- and 3-month-old infants form expectations about a moving object's trajectory, and use expectations to facilitate tracking. (Author/RH)

REACTION AND ANTICIPATION IN INFANTS' TRACKING OF VISUAL MOVEMENT

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ABSTRACT

This study examined the development of smooth tracking in young infants, especially the role that expectation plays in tracking of complex visual motion. The image of the infant's eye was recorded as he or she tracked a small computer-generated target as it moved in a sinusoidal trajectory across a video monitor. Accurate tracking of this pattern of motion demands coordination of horizontal and vertical eye movements and is facilitated by expectation of changes in direction that occur at peaks and troughs. Hence, sinusoidal trajectories were chosen over the simpler horizontal motions typically used in tracking studies.

A 2.5 deg target appeared 16 deg to the right of visual center and moved to the left at 7 deg/sec, following a sinusoidal trajectory with amplitude of 12.25 deg and period of 19 deg. After traversing 32 deg, the target was replaced by a new one of approximately the same size, which moved at the same rate in the reverse direction, following the same trajectory. On six of the 12 screen transits presented, the amplitude and period of the sinusoid were suddenly reduced to 3 and 5 deg, respectively, while target velocity was decreased to 3.6 deg/sec. We expected the changes to produce disruption in tracking if infants were developing expectations for the base trajectory. Throughout the 3 min session, the infant's right eye was videotaped by infrared corneal reflection. Calibration data were obtained prior to the first screen transit.

Tracking amplitude, proportion of saccades and phase lags improved with practice. Changes in the sinusoid disrupted tracking. These findings suggest that 2-(n=3) and 3-(n=8) month olds form expectations about a moving object's trajectory, and utilize these expectations to facilitate tracking.

INTRODUCTION

Accurate tracking of complex visual motion is characterized by an intricate balance of reactive corrections and anticipatory adjustments. Thus, a charting of infants' progress toward more skillful tracking should provide a vehicle for gaining insight into the early development of these two underlying processes. This strategy guided the present study of 2- and 3-month olds' visual tracking of targets moving along sinusoidal trajectories. The tracking of sinusoidal trajectories requires fairly precise coordination of horizontal and vertical eye movements and is facilitated by expectation of the changes in direction occurring at peaks and troughs. For these reasons, sinusoidal trajectories were chosen for the present study rather than the simpler horizontal trajectories typically used in tracking studies.

GOALS OF THE STUDY:

- to achieve a better understanding of the development of smooth tracking in young infants
- to determine the role that expectation plays in young infants' tracking of complex visual motion

METHODS

SUBJECTS: Eight 3-month old and three 2-month old infants.

PROCEDURE: Infants viewed, by mirror reflection, brightly colored targets (e.g., checkerboards) traverse a computer monitor following a sinusoidal trajectory as shown in Figure 1. The tracking task began when a small target, subtending a 2.5 deg visual angle, appeared 16 deg to the right of the infant's visual center and began moving to the left at

7 deg/sec. The target followed a horizontally oriented sinusoidal trajectory with amplitude of 12.25 deg and period of 19 deg. After four cycles, the target, now 16 deg to the left of visual center, was replaced by a different target, of approximatelv the same size, which moved in the reverse direction, at the same rate, and along the same sinusoidal trajectory. On six of the 12 screen transits presented, the amplitude and period of the sinusoid were suddenly reduced to 3 and 5 deg amplitude and period, respectively, while target velocity was reduced to 3.6 deg/sec. Reduction in the size of the underlying sinusoid occurred after either one, two or three cycles of the larger sinusoid, producing transits with:

a) 1 cycle of the large and 5 cycles of the small sinusoid,
b) 2 cycles of the large and 3 cycles of the small sinusoid,
c) 3 cycles of the large and 1 cycle of the small sinusoid.

After tracing out the smaller sinusoid, the target was replaced by a new one which returned to the larger sinusoid for the start of a reverse transit.

Calibration data from four screen locations were collected immediately prior to the start of the tracking task. Throughout the session, which took place in a darkened room and lasted approximately 3 min, the infant's right eye was videotaped using standard techniques of infrared corneal reflection photography.

EYE MOVEMENT MEASURES: To assess the quality of tracking, the measures defined below, and depicted in Figure 2, were obtained:

a) Phase lag -- defined as the time lag between peaks and troughs in the infant's tracking record relative to peaks and troughs in the target's trajectory;

b) Amplitude error -- defined as the distance between the target and the infant's direction of gaze;

c) Proportion of saccades -- defined as the proportion of eye movements with velocities greater than 50 deg/sec;

d) Disruption in tracking -- defined as off-task behavior sustained for more than 500 msec, including blinking, looking away, excessive eye-head movement.

RESULTS

3-MONTH OLDS

Phase lag:

A significant linear relationship between phase lag and screen transit ($t = -2.709$; $p < .01$) indicated that tracking improved with practice. Within the session, there were several occasions on which one of the sinusoids was repeated for at least 70% of the cycles of two adjacent transits. In these cases, we defined the first cycle of the repeated sinusoid during the second transit as an "expected" cycle. Similarly, there were adjacent transits on which the sinusoid was suddenly changed after a majority of cycles of the other sinusoid had occurred. In these cases, we defined the first cycle of the changed sinusoid as a "non-expected" cycle. Phase lags were markedly reduced on expected cycles, compared to non-expected cycles, for the large ($t = 2.43$; $p < .05$) and small sinusoid ($t = 1.86$; $p = .11$). In addition, consistent marginally significant differences suggest that these facilitory and interfering effects tended to persist beyond the first cycle, throughout the entire remaining transit (t values from 3.3 to 1.5, with p values .02 to .18).

Amplitude error:

Amplitude error decreased with the number of transits presented ($t = -2.67$; $p < .05$), and was less on expected cycles, relative to non-expected cycles, of the large ($t = 2.95$; $p < .05$) and small ($t = 2.3$; $p = .06$) sinusoids. However, these facilitory and interfering effects tended not to persist on subsequent cycles. Amplitude error was greater during peak and trough regions, compared to ascent and descent regions for the large sinusoid (p values $< .05$). Similar differences, though not statistically significant, obtained for amplitude errors in tracking the peaks and troughs of the small sinusoid. Finally, amplitude error was less during tracking of the small sinusoid compared to the large (all p values $< .01$).

Saccades:

The proportion of saccades tended to decrease with increasing number of screen transits presented ($p = .20$) There were far fewer saccades on the second transit than the first ($p < .001$), and significantly more saccades during tracking of the small sinusoid when it was preceded by a majority of cycles of the large sinusoid ($t = 4.1$; $p < .01$). In addition, there were more saccades during peak and trough regions of both the large and small sinusoids relative to corresponding ascent and descent regions.

Disruptions in tracking:

Finally, the probability of failing to track the small sinusoid, which occurred less frequently overall than the large sinusoid, was greater than failing to track comparable portions of screen transits with the more frequent, large sinusoid ($z = 1.77$; $p = .07$).

2-MONTH OLDS

Inspection of the tracking records of the three 2-month olds suggests a number of differences from the older infants. Most notably, the 2-month olds characteristically had a greater proportion of saccades than the three month olds (Means of .25 and .15, respectively). Second, none of the 2-month olds showed disruptions in tracking the small sinusoid on its first appearance following a majority of repetitions of the large sinusoid. This is in sharp contrast to the 3-month olds, none of whom were able to complete tracking this first transit of the (non-expected) small sinusoid when it was preceded by a majority of cycles of the large sinusoid. These differences can be seen in Figure 3. Disruption in tracking one sinusoid after several repetitions of the other sinusoid generally did not occur until the 2-month olds had seen at least six screen transits. In contrast, for the 3-month old infants, substantial disruption in tracking occurred by the fourth transit, when the underlying sinusoid was first changed after several repetitions of the former sinusoid. Like the 3-month olds, the younger babies' tracking seemed to improve with practice, although facilitating effects tended to occur later for the younger infants. Tracking records from additional 2-month olds are required to test the reliability of these age comparisons.

CONCLUSIONS

1. Two- and 3-month old infants were able to form expectations about trajectories of visual movement, and to use these expectations to track more efficiently.

2. When non-expected trajectories occurred, infants' tracking tended to become less efficient, or totally disrupted.

3. Two-month olds tracked less efficiently than 3-month olds, and tended to take longer to develop expectations, which -- when appropriate -- facilitated tracking, or -- when violated -- interfered with tracking.

TABLE 1

SUMMARY OF FINDINGS FOR 3-MONTH OLDS

	PHASE LAG	AMPLITUDE ERROR	SACCADES	DISRUPTIONS IN TRACKING
1. Mean	358.6 msec	2.26 deg	.15	.26
2. Correlation with Transit #	- .25 **	- .31	.09	.40
3. On *Expected* Cycles of:				
a) Large Sinusoid	383.3 msec	1.72 deg	.16	.203
b) Small Sinusoid	229.3 msec	1.60 deg	.05	.375
4. On *Non*-*Expected* Cycles of:				
a) Large Sinusoid	476.6 msec	2.70 deg	.15	.215
b) Small Sinusoid	362.0 msec	2.06 deg	.17	.495
5. Comparisons	3a vs 4a * 3b vs 4b +	3a vs 4a * 3b vs 4b +	3a vs 4a ns 3b vs 4b **	3a vs 4a ns 3b vs 4b +

† *p* < .15
* *p* < .05
** *p* < .01

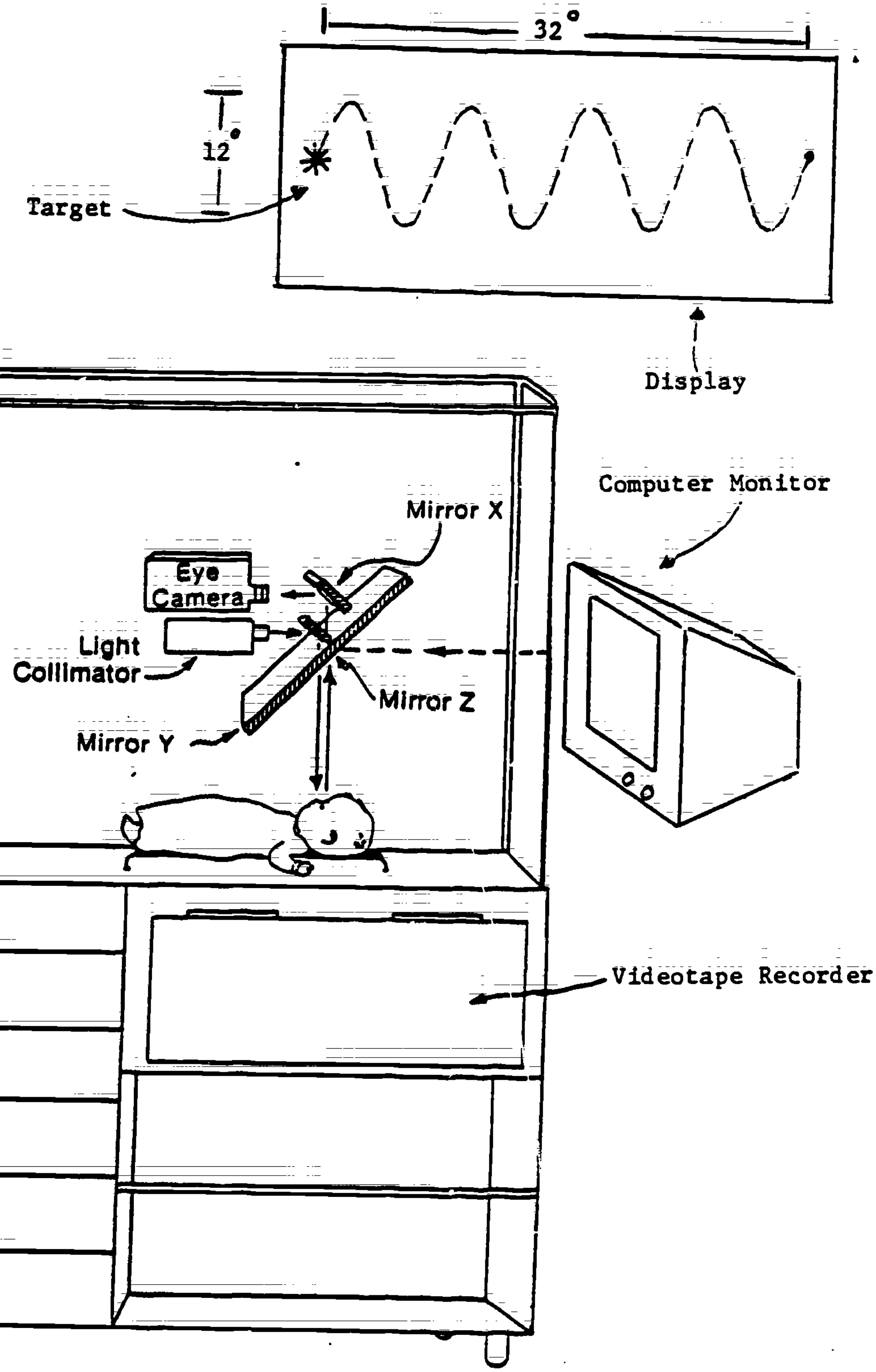

FIGURE 1

Apparatus and display for observing infants' tracking.

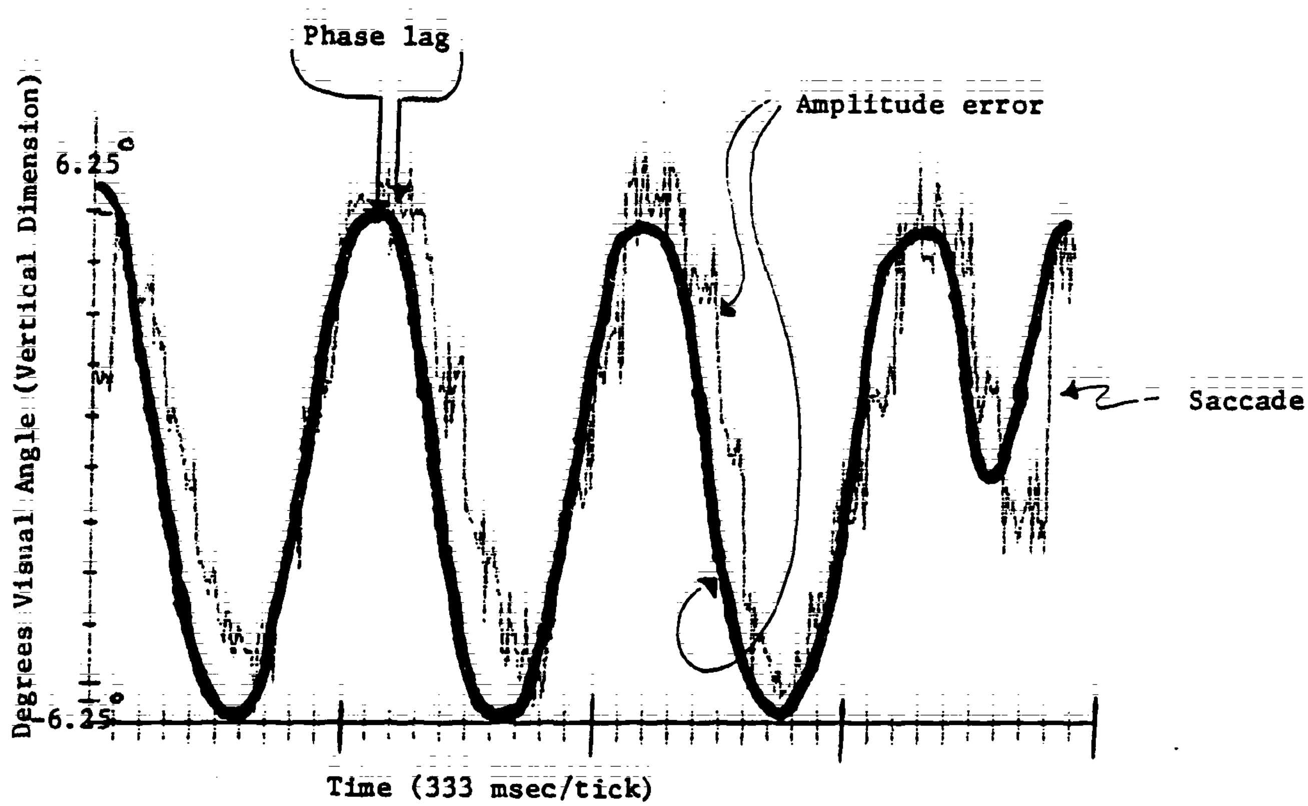

FIGURE 2

Infant's tracking record superimposed on target trajectory. Major tracking variables -- phase lag, amplitude error, and saccades -- are depicted.

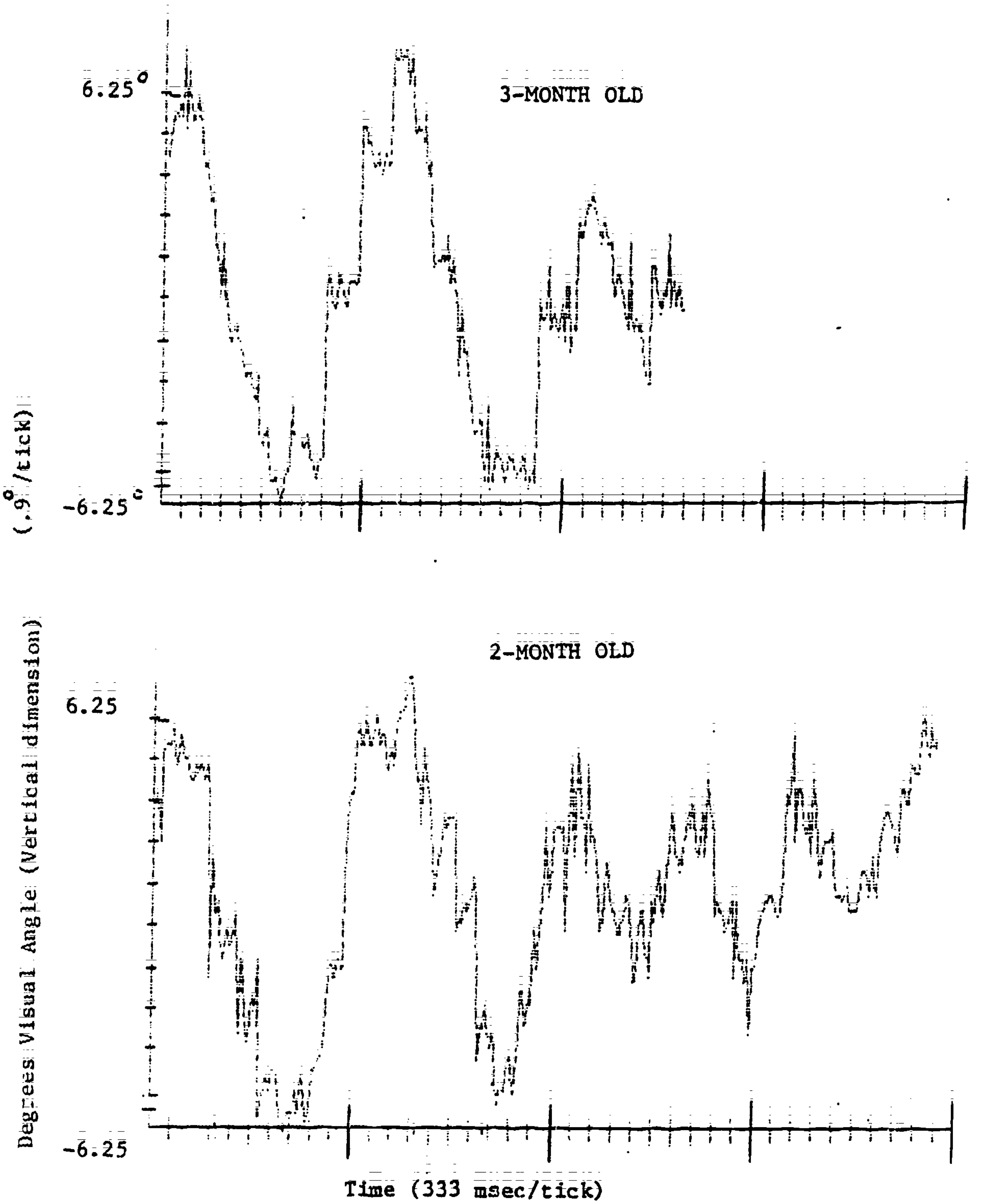

FIGURE 3

Comparison of 2- and 3-month olds' tracking records during the same screen transit.