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ABSTRACT

As part of a study to determine whether visual and manual response systems are correlated, 26 children between 40 and 51 months of age took part in visual and manual reaction time (RT) tasks. Subjects, whose RTs had previously been tested at 3 months of age, were tested in 1 of 2 conditions. In the first condition, subjects viewed pictures only while eye movements were recorded. In the second condition, subjects pressed a left or right button depending on the location in which a picture appeared, and both eye movement RTs and manual RTs were recorded. All subjects received the RT measures first and then were administered part of the Wechsler Preschool Primary Scale of Intelligence to determine verbal, performance, and full-scale IQs. Children's RTs were compared with the RTs previously measured at 3 months to establish the stability of processing speed from infancy to early childhood. The study found a moderate correlation between manual and visual RT in early childhood, and stability in RT from infancy to early childhood. Negative correlations between manual and visual RTs and IQ, reflecting faster RTs with higher IQ, were found. Subjects were consistently slower to initiate eye movements when they were required to make a choice of which button to press than when they were not, but this effect was less striking for children with high IQ than low IQ. (AC)

Relations Among Manual RT, Visual RT and IQ

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FOUR QUESTIONS WERE ASKED FOR THIS STUDY:

1). Is "processing speed" a general property of individuals or does it vary across response systems?

2). Is "processing speed" stable from early infancy on?

3). Are there relations between infant and child "processing speed" and IQ?

4). Is the change in "processing speed" with cognitive load affected by IQ?

ABSTRACT

Children took part in visual and manual reaction time (RT) tasks at 46 months of age. One question was whether these two response systems (visual and manual) are correlated. This question was posed to test whether a bridge could be formed between infant RT work (based on eye-movement measures) and work on older children and adults (based on manual RT measures). In addition, RTs obtained in infancy to childhood RTs were obtained for comparison to establish stability of processing speed from infancy to early childhood. Also, RT measures were compared with IQ to examine the relations between infant and childhood processing speed and IQ. Finally, two visual RT measures were compared to determine whether IQ affects the response to task load.

We found that manual RT and visual RT correlate moderately in early childhood. In addition, there was stability in RT from 3 months of age to early childhood. As predicted, negative correlations were found between manual RT and visual RT with IQ, reflecting faster RTs with increasing IQ. Interestingly, subjects were consistently slower to initiate eye movements when choice-reaction, button-pressing was required (load effect) than when it was not. This "load effect" decreased with increasing IQ.

INTRODUCTION

Although Jensen and many others have found a relation between choice RT and IQ both with adults and school-age children, very few attempts have been made to examine this relation at younger ages or even to measure RT at these ages. Manual RT has been the predominant measure with the older subjects (See Figure 1). The few studies that have studied young children's RT have been mainly with infants and utilized visual eye-movement RT rather than manual, hand-movement RT. Haith developed this visual RT measure within the Visual Expectation Paradigm (VExP). Haith's VExP measure permits an assessment both of an infant's "raw" RT and how much RT is facilitated by an infant's expectation for a forthcoming visual event (See Figure 2).

Hence, there is a gap in research with children between 12 months and 6 years, and there is a gap in relating the infant measures to those that have been used with older subjects. A comparison of the two measures (manual RT and visual RT) was needed to determine whether they reflect a common process. We examined this issue in addition to questions about stability in RT, the relation of RT to IQ in infancy and childhood, and the effect of cognitive load.

METHOD

SUBJECTS: Thirty-four children (15 male, 19 female) between 40 and 51 months of age participated, with a mean age of 46 months. These children were chosen from a pool of children who were seen at 3-months of age at the Center for Infant Development. Of these children, data from twenty-six subjects were used for the analysis.

PROCEDURES: Subjects were tested in one of two conditions, counterbalanced for order.

In one condition, subjects viewed pictures only, while eye-movements were recorded. In the second condition, subjects pressed a left or a right button depending on the location in which a picture appeared and both eye-movement RTs and manual RTs were recorded. All 26 subjects received the RT measures first and then were administered part of the WPPSI-R IQ scale. The entire session lasted approximately one hour.

In the *VISUAL-ONLY* condition, there were no manual procedures used. Each stimulus appeared in a left, middle, or right location in either a fixed or random pattern for a total of three minute. The time that it took the subject to initiate an eye-movement toward a stimulus in the visual-only condition was referred to as visual initiation time (VIT). Each stimulus appeared for 750 ms, followed by a 1000 ms inter-stimulus-interval (ISI), during which the computer screen was dark. Sixty pictures were presented in the following order: 12 random presentations (no predicable sequence); a Left-Middle-Right sequence (four times); a Right-Middle-Left (R-M-L/R-M-L) sequence (four times); a L-M-R-R-M-L sequence (two times); and 12 random presentations.

In the *MANUAL* and *VISUAL* condition, a box with a home button and two target buttons, connected to a Zenith computer, was used to record manual RTs (See Figure 3). Subjects fixated a central stimulus and then responded to left or right picture appearances by releasing the home button and pressing the appropriate button (left or right). At the beginning of a trial, a colorful rotating image appeared in the center of the computer screen to serve as a central fixation stimulus. This stimulus stayed on for 500 ms to 3000 ms and was followed by the target stimulus on the left or the right. Each target stimulus appeared up to 5000 ms or until a button was pressed. After the first six alternating right-left (R-L) stimuli (practice trials), 36 more trials appeared in the following order: 12 random; 12

regular alternating (R-L); and 12 random presentations. A computer controlled the presentation and timing of all stimulus materials.

The Manual RT measures were divided into two categories: 1) manual initiation time (MIT)-releasing home button after stimulus onset, 2) (MMT)-movement from the home button to one of the corresponding buttons. The time it took for the subject to fixate each picture in the manual task was referred to as visual-manual initiation time (VMIT)-initiating time.

Eight subscales of the WPPSI-R were administered and three variables were derived: verbal IQ (VIQ), performance IQ (PIQ), and full scale IQ (FSIQ).

RECORDING AND DATA REDUCTION: A video camera mounted on the back of the testing chamber recorded the child's eye-movements, on videotape, using infrared corneal reflection procedures. A continuous time record and a digit-counter, which indicated the onset and offset of each stimulus event and the lifting and pressing of buttons, was also videotaped. These videotapes were later analyzed by an observer, who viewed the tapes on a VCR (Panasonic AG6300) in single-frame mode (30 frames each second) to determine the visual RT following the onset of the stimulus and the frequency of visual anticipation to the next stimulus location before its onset (Visual anticipation was possible only during the *VISUAL-ONLY* task). Reliability was obtained from five separate sessions. Reactive eye movements were judged to start on the same video frame for 86 % of the judgments and within +/- one frame (1/30 th sec) for 98 % of the judgments.

RESULTS

Pearson Product Moment correlations were computed to answer the five questions in this study.

GENERALIZING ACROSS RESPONSE SYSTEMS: Relation between visual and manual RT

Between-Subject Design: The median for each subject on the visual RT measures (VMIT and VIT) was compared with that for the manual RT initiation measure (MIT). We did not compare the visual measures with the manual movement (MT) measure because these measures were assessing different processes. Using the overall scores, a slight correlation was found between VMIT and MIT ($r = .28$; $p <= .10$) and between VIT and MIT ($r = .29$; $p <= .10$). These correlations may have been attenuated by the low variability for the visual RT measures (Table 1).

Within-Subject Design: Since the RTs for VMIT and MIT were recorded simultaneously, we were able to do a trial by trial analysis for the two response systems. The within-subject analysis showed that out of the 26 subjects the analysis were performed on, 22 subjects had a positive correlation between VMIT and MIT ($X^2 = 7.76$, $p <= .01$), as shown in Figure 4. That is, when one RT was fast, so was the other.

STABILITY OF PROCESSING SPEED: Relation between visual RT's in infancy and childhood

Significant correlations were found between infant overall median visual RTs and childhood overall median visual RTs (VMIT $r = .39$, $p <= .05$; VIT $r = .51$, $p <= .01$).

RELATION BETWEEN PROCESSING SPEED AND IQ: Correlations for infants and children

Infant Measures

As reported in Table 2, the overall median RTs were correlated reliably with all of the IQ measures (VIQ, $r = -.36$, $p <= .05$; PIQ $r = -.48$, $p <= .01$; FSIQ, $r = -.43$; $p <= .05$). Using the criterion set by Haith for % anticipation in infancy (RT < 200 ms), moderate correlations were found with IQ (VIQ $r = .37$, $p <= .05$; PIQ $r = .31$, $p <= .10$; FSIQ $r = .37$, $p <= .05$).

Childhood Measures

Processing Speed and IQ: Pearson correlations between IQ scores and MIT, MMT, VMIT, and VIT are reported in Table 3. MMT showed the largest correlations with PIQ, $r = -.39$, $p <= .05$, and FSIQ, $r = -.35$, $p <= .05$ for overall scores. MIT did not correlate with IQ significantly for overall scores, but the correlation was in the expected direction.

For the visual measures (VMIT and VIT), RTs and anticipations were separated for analysis. Anticipations were set at 130 ms to be consistent with Canfield's criterion, while RTs were greater than 130 ms. For VMIT, anticipations were unlikely due to the center fixation stimulus. As a result, RTs greater than 130 ms were used in the analysis, while RTs less than 130 ms were treated as outliers. The correlations for VMIT were low and not significant; however, the prediction was in the anticipated direction.

For VIT, anticipations were possible and were analyzed separately from RTs. No significant correlations were found between VIT and IQ. Percent anticipation was significantly correlated with performance IQ ($r = .50$, $p <= .01$) and fullscale IQ ($r = .40$, $p <= .05$), as shown in Table 4.

Variability and IQ: The variance was a better predictor than the median RT for most measures of reaction time and intelligence, as shown in Table 5. For MIT overall scores, we found significant negative correlations with all three IQ measures (VIQ, $r = -.35$, $p <= .05$; PIQ, $r = -.43$, $p <= .02$; and FSIQ, $r = -.44$, $p <= .02$). For MMT overall scores, significant negative correlations were found for PIQ ($r = -.39$, $p <= .05$) and FSIQ ($r = -$

.35, $p <= .05$). Also for VMIT overall scores, significant negative correlations were obtained for VIQ ($r = -.34$, $p <= .10$), PIQ ($r = -.37$, $p <= .05$) and FSIQ ($r = -.42$, $p <= .05$). The only overall measure we found no significant correlation for was the VIT.

COGNITIVE LOAD: As referred to above, the VMIT was the visual measure that was recorded with the manual task, and the VIT was the visual measure that was recorded alone, without button-pressing. Subjects were consistently slower to initiate eye movements for the *VISUAL-MANUAL* task than for the *VISUAL-ONLY* task (217 ms and 195 ms, respectively, for VMIT and VIT). We refer to this difference as a load effect (LD), when children had to make a choice manual reaction to press buttons.

There was a significant negative correlation between LD and IQ (VIQ, $r = -.37$, $p <= .10$; PIQ, $r = -.53$, $p <= .01$; FSIQ, $r = -.52$, $p <= .01$). The load effect was less striking for children with higher IQs than for children with lower IQs.

CONCLUSION

1. There was evidence from the within-S measures that visual and manual RTs were correlated, but the low between-S correlation between these measures was disappointing. The low between-S correlations probably reflected the small variance for the visual measures, a constraint that can be addressed in future studies by complicating the RT tasks.

2. This is the first examination of the stability of RT from infancy to childhood. In this study, we found that infant RTs predict childhood RTs as early as 3-months of age.

3. Both infant performance and childhood performance on the RT and anticipation measures predicted to childhood IQ. This is the first time that 3 month olds' RTs compared with their later IQ at 4 years. The size of the infant RT correlations with childhood IQ was quite

surprising.

Eye-movement anticipation provided a second avenue for examining infant to childhood stability. Anticipation refers to appropriate actions that are triggered in the absence of a current visual event. Our findings for the visual percent anticipation measure were encouraging, although somewhat weaker ($r = .37$) than for the RT measures.

The intercorrelations found among the childhood manual RT parameters with IQ, as assessed by the WPPSI-R, are consistent with the results of previous investigations. In addition to the RT-IQ correlations, analysis of variability provided new information that subject's intra-individual variability has about the same or greater relation with IQ than median RT. These findings demonstrated that it is not only the speed with which a child can execute mental operations that is associated with higher performance on tests of intellectual ability but also the consistency with which one can achieve at the same level over a period of time.

4. The findings for processing load were quite exciting. Apparently button-pressing to a stimulus involves more processing ability than only making a saccade to it. Higher IQ children were less impeded by this additional task. While this finding makes sense, it will be for future research to determine exactly what mechanisms mediate this effect.

* ($p <= .10$) ** ($p <= .05$) *** ($p <= .01$)

Table 1: Mean of Median & SDs for MIT, MMT, VMIT, VIT & INF

Measures	Mean of Median	SDs
MIT	717	182
MMT	490	152
VMIT	217	21
VIT	195	26
INF	542	136

Table 2: Correlations Between Infant RTs and % Anticipation to Later IQ

Measures	VIQ	PIQ	FSIQ
Infant RTs	-.36**	-.48***	-.43**
Infant % anticipation	.37**	.31*	.37**

Table 3: Correlations Between RTs and IQ

Measure	VIQ	PIQ	FSIQ
MIT	ns	ns	ns
MMT	ns	-.39**	-.35**
VMIT	ns	ns	ns
VIT	ns	ns	ns

Table 4: Correlations Between Childhood Visual % Anticipation and IQ

Measures	VIQ	PIQ	FSIQ
% anticipation	ns	.50***	.40**

Table 5: Correlations Between RT Variance and IQ

Measures	VIQ	PIQ	FSIQ
MIT	-.35**	-.43**	-.44***
MMT	ns	-.39**	-.35**
VMIT	-.34*	-.37**	-.42**
VIT	ns	ns	ns

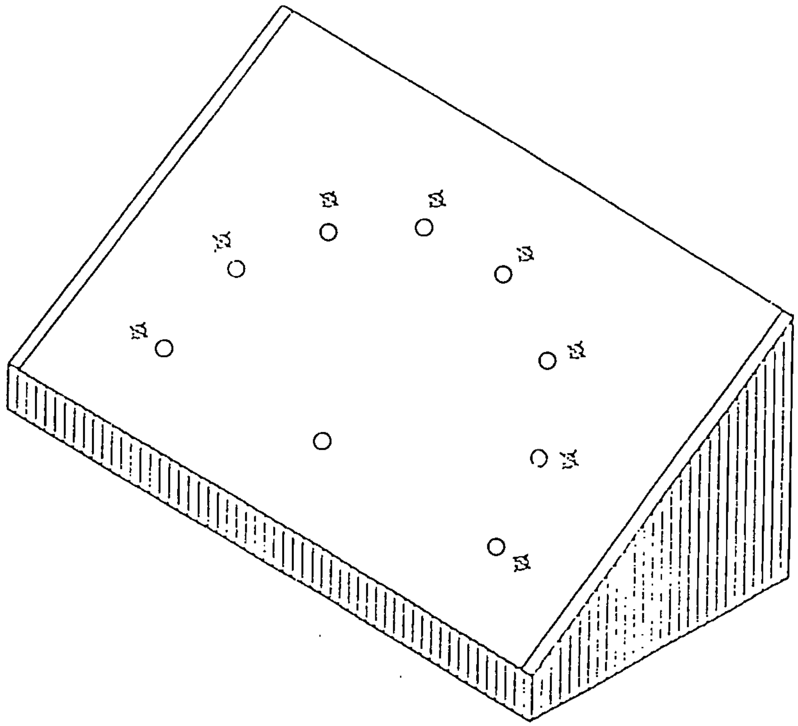

FIGURE 1. Subject's response console of the RT-MT apparatus. Pushbuttons indicated by circles, green jeweled lights by crossed circles. The "home" button is in the lower center, 6 in. from each response button.

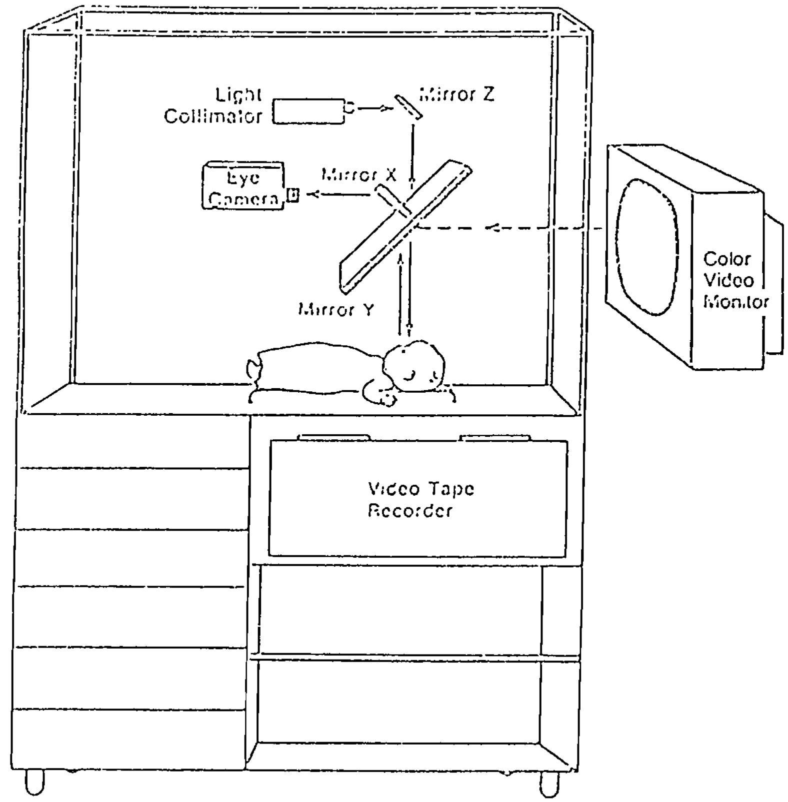

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FIGURE 3

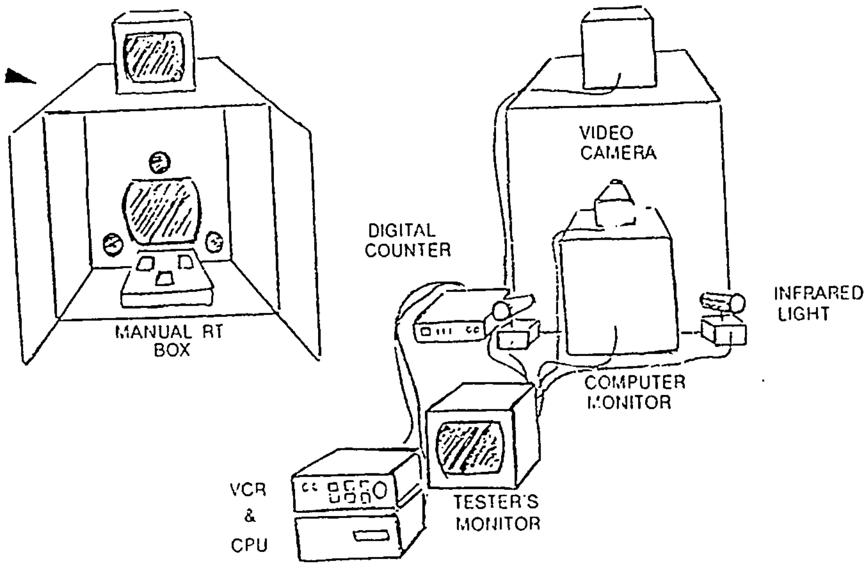

Figure 4