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Age, Handedness, and Sex Contribute to Fine Motor Behavior in Children

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Abstract

The original rotor pursuit test requires that the subject attempts to keep a metal stylus in contact with a small metal disk that was placed in the surface of a turntable that rotated at a constant speed. The present study evaluated the Psychology Experiment Building Language (PEBL) pursuit rotor task. Children (N= 427, ages 9–13, 44.4% females) completed a handedness inventory followed by four pursuit rotor trials with each hand. The total time on target increased with age with the dominant hand as well as non-dominant hands. A small, but significant, sex difference favoring males was also observed (Cohen's $d = 0.27$). Dextrals spent more time on target than sinistrals with their dominant hand ($d = 0.66$) but the reverse pattern was observed for the non-dominant hand ($d = 0.74$). These group differences were independent of prior computer experience. These findings indicate that the freely downloadable PEBL pursuit rotor task is a useful measure of psychomotor function in children and adolescents.

Keywords

motor; child; human; computer; female; dextral; sinistral

1. Introduction

The rotary pursuit is a classic test in experimental psychology and behavior neurology. The objective of this simple test of fine motor function is to use a stylus to follow a moving target that rotates clockwise at a constant speed. Rotary pursuit performance improves with age and shows a pronounced male advantage during childhood (Ammons et al., 1955). Further, this type of procedural learning is sensitive to striatal damage (Cavako et al., 2010). However, despite bilateral hippocampal resection, patient H.M. showed clear evidence of both rotary pursuit learning and memory (Corkin, 1968).

Over the past several years, an increasingly large collection of neurobehavioral tests has been computerized and made available (<http://pebl.sf.net>) without a license fee to the neuroscience community. The present report evaluated the pursuit rotor test (PRT) within the Psychology Experiment Building Language (PEBL) battery which is developed and maintained by Shane Mueller. The PRT is modeled after the rotary pursuit but does not

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require large specialized equipment. Completion of the PRT involves using a computer mouse to follow a rotating target. However, one potential concern with using technology that may be commonly encountered outside the laboratory is that participants with more computer experience may find the PRT less challenging. Therefore, a moderate sized sample of middle-school students were tested on the pursuit rotor to determine if there were differences based on age, sex, handedness, or regular computer use.

2. Materials and methods

Middle-school students (N=427) attending the “Lets Get Healthy” fairs in La Grande, Oregon were invited to play a computer game. This age (9 to 13) was selected based on prior rotary pursuit data (Ammons et al., 1955) which identified pronounced improvements during this age. Subjects provided their age, computer experience (how many hours did you spend last week using a computer mouse?) and a handedness inventory (Chapman & Chapman, 1985). Participants were asked which hand they used to complete common activities (draw, write, use bottle opener, throw a snowball, use a hammer, toothbrush, screwdriver, eraser, strike a match, stir paint, or swing a bat) with the options being right (1 point), either (2 points), or left (3 points). A laterality score was calculated by summing the points on all items. Participants were also asked which hand they used with a computer mouse. All procedures were approved by the institutional review board of Oregon Health and Science University.

Subjects received verbal and visual instructions prior to each computerized test. The instructions were slightly modified from version 0.11 of the PEBL default to read:

In this task, you will track a red circle moving steadily around a circular path. Try to keep your mouse button on the path at all times. There will be a total of 8 trials, each lasting 15 seconds. On the first four trials, please use your DOMINANT hand. On the last 4 trials, please use your NONDOMINANT hand.

A reminder to use their non-dominant hand on each of the last four trials was provided and the screen resolution was 800 × 600. Pilot testing with another sample (ages 6 to 80) revealed that the default speed (2 full circular rotations/15 seconds) was moderately challenging but avoided either ceiling or floor effects. PEBL is programmed primarily in C++ and uses flex and bison for parsing. A screen shot of the task is available at: <http://pebl.sourceforge.net/battery.html>. PEBL was run on Windows® desktop computers with an ambidextrous mouse on a pad positioned at the participant's midline prior to testing.

The PEBL output (text files) were imported into Excel and all analyses were subsequently conducted using SPSS, version 16.0 (SPSS Inc., Chicago, IL). The scores (time or target or error, the difference in pixels between the cursor and target) were examined across age groups (9, 10, 11, 12, or 13) with ANOVA followed by Tukey post-hoc tests or analysis of covariance (ANCOVA). Cronbach's α was calculated as an index of the internal consistency on the handedness questionnaire for participants that completed all items. Participants were divided into two handedness groups: consistent right-handers or dextrals (Laterality Index = 12 and only used a mouse with their right-hand, N = 259) and left-handers or sinistrals (Laterality Index ≥ 20 and only use a mouse with their left-hand, N = 22, note that ambidextrous participants were excluded from this analysis for simplicity) with missing responses scored as the average of the remaining items. Subjects were also grouped based on regular computer mouse use (< 1 hour/week, N = 321 versus >1 hour/week, N = 87). Mean data is presented with the SEM and $p < .05$ considered statistically significant. Cohen's d was also used to express the magnitude of group differences with an effect size ≈ 0.2 as small, 0.5 as medium, and ≥ 0.8 as large.

3. Results

The computerized rotary pursuit task was sensitive to group differences in age and handedness and, to a lesser extent, sex and computer usage. The total time on target with the dominant-hand showed a main effect of age ($F(4,411) = 15.54, p < .0005$) with thirteen-year olds having longer times than ages nine (Cohen's $d = 1.23$) and ten (Tukey post-hoc tests $p < .0005$) as well as eleven ($p < .05$; Figure 1A). Time on target with the non-dominant hand also exhibited an age effect ($F(4,411)=14.63, p < .0005$) with thirteen-year olds spending more time than all ($p < .01$) younger ages. Nine-year olds spent less time on target ($p < .005$) relative to all older ages except ten-year olds ($p = .059$). The error showed a very similar pattern with an age effect with the dominant ($F(4,407)=8.45, p < .0005$) and non-dominant hands ($F(4,407)=11.72, p < .005$).

Notably, as there were significant age differences in the time spent using a computer mouse (Table 1), additional analyses were conducted with this variable as a covariate. Computer usage did not account for a significant amount of the variance for any analysis and therefore ANCOVA findings were indistinguishable from the ANOVA results.

The total time on target for males (30.9 ± 0.7) was 9.7% larger than females (28.2 ± 0.7 , $t(410) = 2.69, p < .01, d = 0.27$) with the dominant hand. Further examination over the course of testing revealed that males spent more time on target during the first three trials. This difference was also evident with the non-dominant hand (Males = 19.3 ± 0.6 , Females = 17.5 ± 0.6 , $t(410) = 2.19, p < .05, d = 0.22$, Figure 1C). However, only the first trial with the dominant hand showed a sex difference when using the error (Figure 1D). Importantly, mouse use time each week was indistinguishable between males (3.9 ± 0.6) and females (4.2 ± 0.6).

Dextrals spent more (27.0%) total time on the target (30.6 ± 0.7) than sinistrals (23.8 ± 2.2) when using their dominant hand ($t(269) = 2.98, p < .005, d = 0.66$). However, sinistrals (24.0 ± 2.1) outperformed dextrals (17.5 ± 0.5) with their non-dominant hands overall ($t(269) = 3.69, p < .005, d = 0.74$) and on each trial (Figure 2E). This same general pattern was less pronounced but still apparent with the error (Figure 2F). Weekly mouse usage was larger, albeit non-significantly, in sinistrals (8.9 ± 3.2 hours) relative to dextrals (4.0 ± 0.6 , $t(22.3) = 1.54, p = .14$). When mouse usage was included as a covariate, the main effect of handedness was retained with the dominant ($F(1,267) = 11.44, p \leq .001$) and non-dominant ($F(1,267)=12.12, p \leq .001$) limbs.

The amount of time each week spent using a mouse showed very small, but significant, correlations with the time on target with the dominant ($r(408) = 0.14, p < .005$), and non-dominant ($r(408) = 0.112, p < .05$) hands but not with the error ($p > .05$). Further analyses were completed by dividing the sample into low (< 1) and high (> 1 hours/week) user groups. Low-users spent less total time on target (29.1 ± 0.6 sec) than high users (31.7 ± 1.2 , $t(406) = 2.06, p < .05$, Cohen's $d = 0.24$, data not shown for each trial) with their dominant hand. Similarly, high-users spent longer on target (20.5 ± 0.9 sec) relative to low-users (17.9 ± 0.5 , $t(406) = 2.57, p \leq .01, d = 0.31$) with their non-dominant hand. Conversely, error was unaffected by mouse usage ($p > 0.20$).

Target time was inversely related to the error with the dominant ($r(412) = -0.77, p < .0005$) and non-dominant ($r(412) = -0.76, p < .0005$) hands. Finally, the internal consistency of the 12-item handedness inventory was high (Cronbach's $\alpha = 0.951$). A shorter version with 6-items (draw, write, hammer, screw, eraser, paint) also retained good consistency ($\alpha = 0.946$) with high item to total score correlations (lowest = 0.846 for hammer to highest = 0.932 for draw).

4. Discussion

Behavior on the original rotary pursuit test exhibits a clear developmental progression during grades three to twelve with clear sex differences favoring males at each age (Ammons et al., 1955). Although the PRT differs from rotary pursuit in several non-trivial aspects including the equipment (mouse versus stylus) and speed and diameter of rotation, the present findings of group differences based on age and sex are congruent across instruments. To our knowledge, no prior research with the rotary pursuit has been sufficiently powered to compare motor behavior based on handedness. Time on target was better by dextrals while completing the PRT with their dominant limbs and by sinistrals with their non-dominant limb. This novel finding is also broadly concordant with other results (Judge & Stirling, 2003).

Although the costs associated with obtaining the rotary pursuit equipment may be prohibitive for smaller laboratories or for investigators from developing nations, a potential advantage of the original (non-computerized) test is that the paradigm will be completely novel for the vast majority of participants. On the other hand, examination of the effect sizes in this study reveals that age had a large group differences and those based on handedness were moderate. In contrast, the effect size for mouse experience was small in some analyses while other statistics were non-significant. Future investigations that are concerned about this issue could consider coupling PEBL PRT with a horizontal touchscreen monitor and a touchscreen stylus. Alternately, including many more trials with longer inter-trial intervals will result in learning curves and the resultant data could be then expressed as the change relative to the baseline to minimize any pre-existing individual differences.

It should also be noted that the handedness inventory of Chapman and Chapman (1987) was originally validated with adults and has been extensively used with that age. The current findings with adolescents indicate that a shorter-version of that instrument also offers very good internal consistency.

The present endeavor is not the first effort to develop a computerized version of the rotary pursuit test. Other research groups have also pharmacologically validated these procedures with alcohol and caffeine (Fillmore & Vogel-Sprott, 1994). The benefit of the PEBL PRT is that the open-source software is freely downloadable, modifiable, and PEBL is well documented (Mueller, 2010). As some neuroscientists may have limited computer programming skills, PEBL also has a list-serve for a community of users to share their experiences with the PRT or other neurobehavioral tests.

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References

Ammons RB, Alprin SI, Ammons. Rotary pursuit performance as related to sex and age of pre-adult subjects. *J Exp Psychol.* 1955; 49:127–133. [PubMed: 14354120]

- Cavaco S, Anderson SW, Correia M, Magalhaes M, Pereira C, Tuna A, Taipa R, Pinto P, Pinto C, Cruz R, Lima AB, Castro-Caldas A, da Silva AM, Damasio H. Task-specific contribution of the human striatum to perceptual-motor skill learning. *J Clin Exp Neuropsychol*. 2010 in press.
- Corkin S. Acquisition of motor skill after bilateral medial temporal lobe excision. *Neuropsychologia*. 1968; 6:255–265.
- Chapman LJ, Chapman JP. The measurement of handedness. *Brain Cogn*. 1987; 6:175–183. [PubMed: 3593557]
- Fillmore MT, Vogel-Sprott M. Psychomotor performance under alcohol and under caffeine: Expectancy and pharmacological effects. *Exp Clin Psychopharm*. 1994; 2:319–327.
- Judge J, Stirling J. Fine motor skill performance in left- and right-handers: Evidence of an advantage for left-handers. *Laterality*. 2003; 8:297–307. [PubMed: 21218372]
- Mueller, ST. Programming and usage guide for the Psychology Experiment Building Language PEBL Version 0.11. Available at: <http://pebl.sourceforge.net>

Figure 1. Psychology Experiment Building Language Pursuit Rotor behavior by Age, A–B, $p < .05$ versus age nine (n), ten (t), eleven (e), or twelve (*); sex, C–D, * $p < .05$ versus males, and handedness, E–F, * $p < .05$ versus right-handers.

Table 1

Characteristics of study participants including sex, hours spent per week using a computer mouse, and laterality score with consistently right-handed (CRH) = 12 and consistently left-handed = 36, by age.

		Age			
		9	10	11	13
N		64	81	82	86
% Female		32.8%	43.2%	46.3%	51.5% *
<u>Laterality</u>					
Mean		15.2 (0.8)	14.5 (0.7)	14.3 (0.5)	15.2 (0.6)
% CRH		64.1%	67.9%	59.8%	53.5%
<u>Computer use</u>					
Median		0.5	1.5	2	3
Mean (SEM)		1.3 (0.3)	3.5 (0.7)	5.5 (1.6) *	4.1 (0.7) *

* p < .05 versus nine-year olds