Dynavision Normative Data for Healthy Adults: Reaction Test Program

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Importance: Previous research has calculated normative data for the Dynavision D2 Visuomotor Training (D2) System among healthy athletes to understand concussion management, but to date no studies have identified the norms for healthy adults over a large age range (18–80 yr) for physical response speed.

Objective: To provide normative data for the D2 for physical response speed in adults ages 18–80 yr.

Design: Cross-sectional, descriptive study to obtain normative data on physical response speed using the D2 for adults in age categories 18–40, 41–60, and 61–80 yr.

Setting: Genesis Physical Therapy and Wellness Center, a Midwestern outpatient hospital-based therapy center.

Participants: Three hundred adults, stratified into three different age categories. Normal standards with quartiles were identified for each age and sex category.

Outcomes and Measures: Multiple regression model of the inverse response times.

Results: The results showed a significant difference in physical response speed between men and women and between the different age groups. Women in all age categories were slower than men. Physical response speed increased with age in both sexes, but each had significantly different age and sex main effects ($p < .0005$).

Conclusions and Relevance: Occupational therapy practitioners can use the normative standards identified in this study in their assessment of clients with visual and cognitive deficits after a brain injury, stroke, or other neurologic pathology.

What This Article Adds: This study's results can be added to the battery of other common evaluation measures that occupational therapists use to evaluate visual and cognitive deficits after neurological impairments.

The Dynavision (West Chester, OH) D2 Visuomotor Training System (D2) is used in practice today as a tool to assess visual scanning, peripheral visual awareness, visual attention, and visual-motor reaction times (RTs) in numerous populations (Klavora et al., 1994; Klavora, Gaskovski, & Forsyth, 1995; Klavora, Gaskovski, Martin, et al., 1995). It is used in clinical rehabilitation with people with brain injury to assess and improve psychomotor skills for everyday tasks (Crotty & George, 2009; Klavora et al., 2000; Klavora, Gaskovski, Martin, et al., 1995; Klavora & Warren, 1998; Vesia et al., 2008).

The D2 is a 5-ft × 4-ft computerized board consisting of 64 target buttons with five rings that illuminate randomly when in use (Klavora et al., 1994; Klavora & Warren, 1998; Vesia et al., 2008). The user must hit the light as it illuminates as quickly as possible for the next button to light up. An auditory stimulus is heard as the button is struck. This device is designed to challenge users to expand their range of motion, improve visual scanning skills, quicken RTs, and improve cognitive functions (Klavora & Warren, 1998; Vesia et al., 2008; Wells et al., 2014).

Several studies have established that the D2 has moderate to strong test-retest reliability, with intraclass correlation coefficients ranging from .63 to .97 for tests of varying complexity within the system (Klavora et al., 1994; Klavora, Gaskovski, & Forsyth, 1995; Wells et al., 2013, 2014). The D2 has six preprogrammed psychomotor tests that

establish RT. It has been found to be significantly correlated to six common psychomotor tests that assess similar psychomotor abilities and visuomotor skills, such as eye–hand coordination, speed, and dexterity (Vesia et al., 2008).

Previous research has calculated normative data for the D2 system among healthy athletes to understand concussion management (Bigsby et al., 2014; Clark et al., 2017). However, to date there have been no studies identifying the norms for healthy adults over a large age range (18–80 yr) for physical response speed as measured by the D2 system. Having data on the RT of normal, healthy people would allow occupational therapists to better assess their patients' visuomotor skills and their ability to complete safe, daily activity. Therefore, the purpose of this study was to collect normative data for physical response speed for the D2.

Method

Study Design

This study was a cross-sectional, descriptive study to obtain normative data for physical response speed using the D2 for adults in the following age categories: 18–40, 41–60, and 61–80 yr. The study was completed at Genesis Physical Therapy and Wellness Center (Bettendorf, IA) and was approved by the Genesis institutional review board.

Participants

Adults between ages 18 and 80 yr were recruited to participate in this study. A valid driver's license confirmed demographic information. A therapist screening tool questionnaire was developed to determine whether potential participants met the inclusion criteria. People with previous neurological impairment, a history of seizures, partial to full blindness, cognitive impairments (moderate to severe dementia or inability to follow simple directives), hand numbness, and the inability to reach the entire range of the D2 were excluded. A bilateral upper extremity range-of-motion screen consisting of bilateral shoulder flexion, horizontal abduction, internal and external rotation, elbow flexion and extension, forearm supination and pronation, wrist flexion and extension, and fingertip opposition was used to determine whether participants could reach the D2.

Participants were stratified by age into three different categories (ages 18–40, 41–60, and 61–80 yr). The aim was to include 100 participants in each age category (50 men, 50 women). Staff recruited participants through community flyers, newspaper articles, and word of mouth to families and patients at Genesis. Interested participants were enrolled at one of numerous "Research Days" or were scheduled into an open appointment time in a therapist's schedule.

Procedure

Eligible participants provided informed consent and were then asked to complete the short bilateral upper extremity range-of-motion screen to ensure they could reach the entire range of the D2. The RT program measures *visual reaction speed*, which is the amount of time it takes to identify the target and initiate a reaction. It also measures the *motor response time*, which is the amount of time it takes to physically respond to the target after the initial visual reaction. Finally, the physical response speed is calculated by adding the visual reaction speed and the motor response time, which provides the total elapsed time from the introduction of the target stimulus to the physical completion of the task.

The researchers (Blackwell, Cary, Holst, Mandle, and Clemens) used a written protocol from the standard RT test provided by Dynavision to instruct each participant on how to complete each test. The testing environment was consistent throughout the study with the use of a private room and low noise level and lighting. The participant was asked to hold down a red button until a second red button lit up. The participant was told to quickly strike the second button, then return to the original red button and hold it down firmly until a third button illuminated. This continued for five repetitions, for a total of 10 stimuli. The participant then completed three different types of tasks, completed on each

hand, for a total of six tasks. Before starting the test, the researcher illustrated how to complete the test, and the participant completed a full practice test using both hands. We chose to use a practice test on the basis of previous literature that suggested that a learning effect could be associated with RT performance on the D2 (Klavora et al., 1994; Klavora, Gaskovski, & Forsyth, 1995; Wells et al., 2014).

Data Collection

Demographic data, including participant name, age, sex, race, educational background, hand dominance, and the use of corrective lenses, were collected using the therapist screening tool. Data regarding visual reaction speed, motor response time, and physical response speed were collected using the D2. Four occupational therapists and one occupational therapy assistant received training before the start of the study and used a standardized script and process for data collection. Using the standardized protocol script allowed the administrators to deliver consistent instructions for each participant. For each participant, results were generated from the D2 for all six tasks performed.

Data Analysis

Data analysis focused on the total physical response speed of the six tasks, with five repetitions each. The first sample collected consisted of 50 control adult volunteers who were at least age 60 yr and satisfied the inclusion criteria. From this sample, our goal was to identify the parametric distribution of total RTs, allowing us to reduce the number of participants needed from 1,200 to 300.

A literature search led to an article by Martín (2009) that proposed a model in which RTs have an inverse normal distribution. We denoted the total RT for Subject i as X_i and let $Y_i = 1/X_i$ be the reciprocal of the subject's total RT. Using this model, the reciprocals of the total RT data follow a normal distribution with mean μ and variance σ^2 , which can be approximated by the sample average $Y^- = \frac{1}{n} \sum_{i=1}^n Y_i$ and sample variance $s^2 = \frac{1}{n-1} \sum_{i=1}^n (Y_i - Y^-)^2$, respectively. In addition, the $i = 1$ 95% confidence interval for normal data can be approximated by taking $Y^- \pm 1.96 * s$. To obtain a confidence interval for the total RTs, we once again take the reciprocal of this interval. Therefore, our estimates for the normal limits are as follows: 2.5th percentile, $(Y^- + 1.96 * s)^{-1}$, and 97.5th percentile, $(Y^- - 1.96 * s)^{-1}$.

The six final distributions of RTs, the inverse normal transformation, proved to provide excellent fit. The median p value of the Anderson-Darling tests of normality was .595. A multiple regression model of the inverse RTs was performed simultaneously on age and sex to determine whether results needed to be analyzed separately by age and sex or whether the data could be collapsed across those variables. For ease of use, the standards are presented as the sum of mean physical response speeds of the six tasks where the means are of the five repetitions. The comparison of expected values by age and sex is secondary and not used to determine the estimates or presentation of the normal ranges or the quartiles.

Results

Three hundred participants met the inclusion criteria and were enrolled in the study from August 2014 to April 2017. One potential participant did not pass the bilateral upper extremity range-of-motion screen and was excluded from the study. The majority of participants were White, were right-handed, wore contacts or glasses, and had a college or post-graduate degree (Table 1).

A multiple regression model of the inverse RTs found that the total physical response speeds of the six tasks with five repetitions each had significantly different age and sex main effects ($p < .0005$ for both). For both men and women, physical response speeds increase as age increases. Table 2 displays the sums of the mean physical response speeds (in seconds) of the six tasks for men and women, respectively. The table also includes the normal limits and the

Table 1. Participant Demographics

Characteristic	n (%)
Race	
White	277 (92.3)
Other	23 (7.7)
Education	
College degree/postgraduate degree	246 (82.0)
High school degree/no high school degree	54 (18.0)
Handedness	
Right	272 (90.7)
Left	28 (9.3)
Vision	
Glasses or contacts	209 (69.7)
No glasses or contacts	91 (30.3)

quartiles for the norm so that patients can be informed of their performance relative to their age and sex. In addition, their progress over time can easily be tracked relative to these normative data.

Discussion

This study provides normative data for the D2 RT program for healthy adults ages 18–80. The results showed significant differences in physical response speed between men and women and between the different age groups. Women in all age categories were slower than men. In addition, physical response speed increased with age in both sexes. These results are consistent with those of previous studies examining RT (Deary & Der, 2005; Der & Deary, 2006; Fozard et al., 1994). The normal limits for

the D2 established in this study can be compared with those of similarly aged people recovering from a stroke, brain injury, or other neurologic pathology to identify when physical response speed returns within normal limits. The results also provide quartiles for the normal limits for each age group and sex. The quartiles are useful for benchmarking patients as they progress through treatment.

This study has several limitations. A convenience sample was used from one midwestern region of the United States, which resulted in limited variation in race and education. Compared with the 2017 general U.S. population, this study had a higher percentage of White participants (92.3% vs. 75.1%) and those with a college degree or higher (82.0% vs. 30.9%; U.S. Census Bureau, n.d.-a, n.d.-b). Racial and geographic differences are significant, with increased stroke risk noted for African-Americans and people living in the southeastern United States (U.S. Census Bureau, n.d.-a). Including a more diverse sample from a broader area in future studies would improve the generalizability of the results.

This study assessed and analyzed only the physical response speed portion of RT (see Table 2), which is the combination of visual reaction speed and motor response time. Normative results for the individual components of visual reaction speed and motor response time would be beneficial for therapists to better assess patients with visual and cognitive deficits. In addition, halfway through the study, the D2 was moved from one clinic location to another, which may have affected participants' experience with the system. However, every effort was made to re-create the same testing atmosphere as that of the original location. Another potential limitation was that participants' personality and competitiveness were factors in how they approached the tasks. Younger participants strove to be quicker than older

participants, who were less competitive. These factors may contribute to the slightly faster response times observed in the 18–40 age category. Finally, the cost of the D2 system limits the number of rehabilitation clinics that have access to the equipment.

Table 2. Normal Standards Across Six Tasks by Sex and Age Group

Sex and Age Group	Percentiles of Sum of the Task Means, s				
	2.5th	25th	50th	75th	97.5th
Male					
18–40 yr	5.718	4.860	4.394	3.954	3.084
41–60 yr	6.274	5.268	4.730	4.206	3.156
61–80 yr	8.162	6.688	5.914	5.162	3.702
Female					
18–40 yr	5.808	5.058	4.670	4.288	3.422
41–80 yr	6.798	5.790	5.264	4.738	3.730
61–80 yr	8.240	6.950	6.270	5.590	4.306

Note. Percentiles refer to the people in the age cohort; for example, a 41-year-old man who averaged 6 s on the tasks would be in the 2.5th percentile for his cohort.

Implications for Occupational Therapy Practice and Research

This study has the following implications for occupational therapy practice and research:

- D2 is easy to use, time efficient, and appropriate for a variety of patients.
- Therapists can use the D2 as an assessment tool to compare with normative standards.

- Future research should establish normative data for pediatric and adult populations with more variable representation of race, ethnicity, education, and socioeconomic status.

Conclusion

D2 activities can be used in conjunction with occupations for improved vision and visual activities. Evidence supports the effectiveness of visual scanning retraining for an impaired visual field, audiovisual stimulation, and the application of a cognitive retraining approach (Berger et al., 2016). This study provides occupational therapy practitioners with normative data they can use to compare patients' physical response speed to age- and sex-matched healthy adults. The testing results can be added to the battery of other common evaluation measures occupational therapists use to evaluate visual and cognitive deficits after a brain injury, stroke, or other neurologic pathology. ■

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