# Tower of London

## CogQuiz Neuropsychological

## Assessment Tests

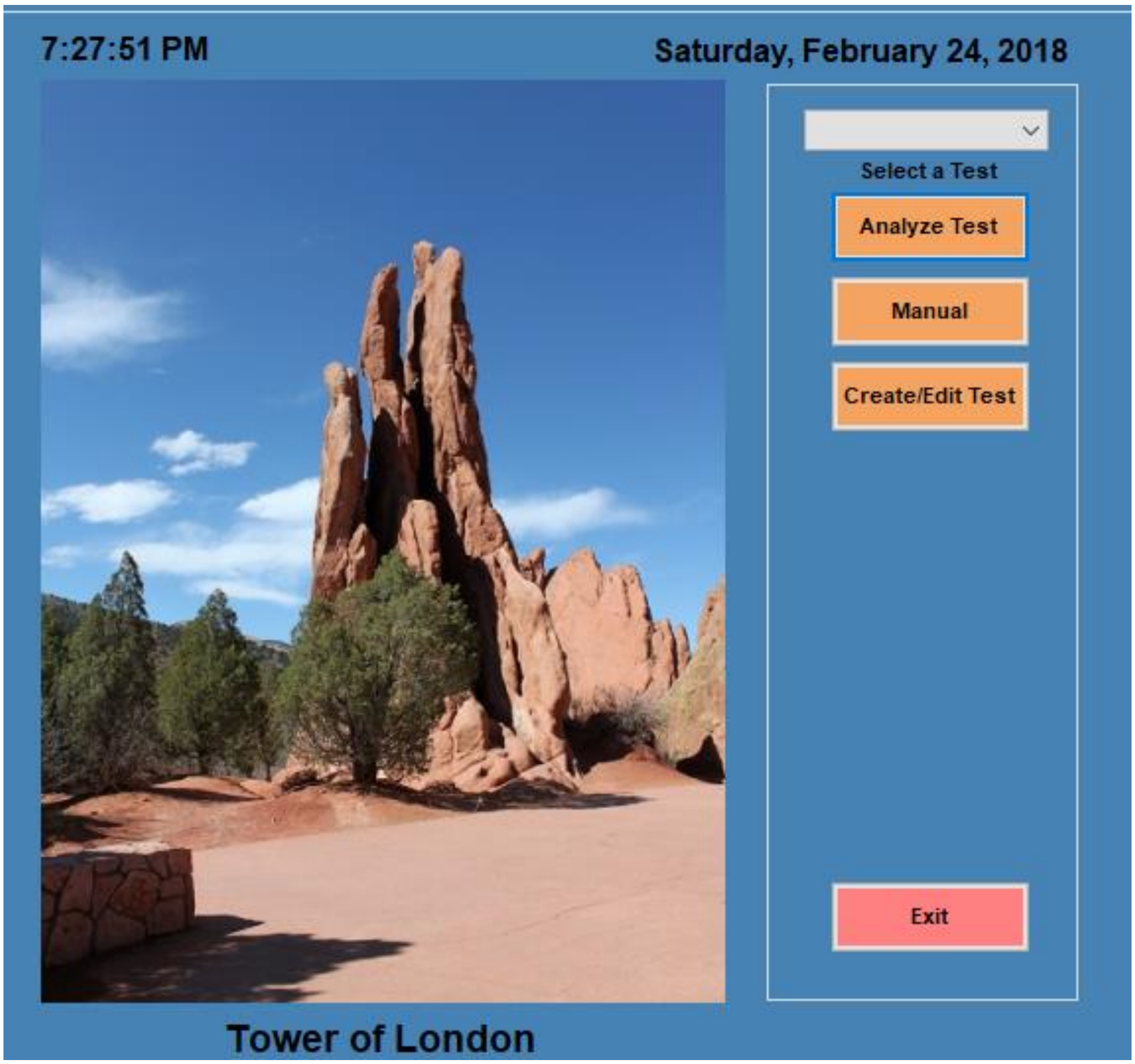


**Figure 1**

## SANZEN Neuropsychological Assessment Tests' Tower of London Test

The CogQuiz Tower of London test establishes a new standard of excellence in computerized assessment tests. CogQuiz Neuropsychological Assessment Tests' **Tower of London** comes with eight pre-programmed Tower of London tests, but then offers the user flexibility in either modifying these pre-loaded tests or creating new tests from scratch. The CogQuiz Tower of London test has enough flexibility to program any of the problem sets currently being used in cognitive or neuropsychological research and assessment (i.e., Culbertson and Zillmer, 1998; Berg and Byrd, 2002; Kaller, Unterrainer, & Stahl, 2012).

Design options include the choice of three to five pegs and a custom color palette for beads. Response modalities include both touch screen and mouse – the latter offering either a point and click option or a slide bar option.

Trials can be specified as either timed (i.e., the trial is terminated after a predetermined amount of time has elapsed) or untimed. Trials can also be set to terminate after a specified number of moves.

Custom instructions can be written for each trial; and even the few built-in directional messages can be altered to reflect the language needs of the participant population.

The analysis screen provides the user with a running record of all relevant test events including all stimulus events, participant responses, and the time (to the nearest millisecond) that the system detected the event, as well as a trial-by-trial analysis of participant performance and a summation of performance across trials. A playback feature allows the user to review the sequence of moves made by the participant in solving the problem on any trial.

As part of an ongoing research program, a substantial number of test results have been obtained using a CogQuiz computerized version of the Tower of London test. The descriptive statistics, broken out in ten-year cohorts for those test results, are provided at the end of this manual in the "normative data" section.

## Introduction: The Tower of London

Problem solving, a skill used by people of all ages to reach goals and complete tasks, has long attracted the attention of cognitive psychologist and neuropsychologist. Shallice (1982) developed the Tower of London (TOL) task to measure planning and problem-solving skills in patients with damage to the frontal lobes. Patients and control subjects were presented with a model where three beads were strategically positioned on three rods of descending heights. Participants were then asked to manipulate beads from a predetermined starting position on a different set of pegs to match the position of beads in the model. In Shallice's study, problem solving ability was determined by the number of excess moves made on the TOL problems. That is, the number of additional moves above the minimum number of moves needed to solve the problem was the dependent measure of problem solving. The larger the number of excess moves, the poorer the problem-solving ability. Shallice found that individuals with lesions in their left anterior frontal lobe made more errors and had longer planning times than members of a control group. Much of the subsequent research using the TOL has also focused on the problem-solving ability of individuals with brain damage and/or head trauma (e.g., Shum, Gill, Banks, Maujean, Griffin, & Ward, 2009). In general, for head injured patients findings mirror Shallice's results which indicate that damage to the prefrontal cortex impairs problem solving ability.

While the ecological validity of the TOL has been questioned by some researchers (Philips et al., 2006), it is still widely used to compare the problem solving and planning ability of typically developing individuals to individuals with genetic disorders (Azadi, Seddigh, Tehrani-Doost, Alaghband-Rad, &Ashrafi, 2009), mental health disorders such as autism (Robinson, Goddard, Dritschel, Wisley, & Howlin, 2009), attention-deficit hyperactivity disorder (Riccio, Wolfe, Romine, Davis, & Sullivan, 2004), dementia (Marchegiani, Giannelli, & ODetti, 2010), and/or schizophrenia (Morris, Rushe, Woodruffe, P.W.R., & Murray, 1995), to note a few. These studies have established normative baseline data and measured the extent to which TOL problem solving performance differs in clinical versus non-clinical populations.

To accurately measure the problem-solving ability of people with physical or mental health problems, variations of Shallice's original TOL have been created. For instance, some researchers use computerized versions of the TOL (Bugg et al., 2006; Kaller, Rahm, Kostering, & Unterrainer, 2011; Ouellet et al., 2004) while others use an actual board with pegs and beads that the participant can physically manipulate (Anderson, Anderson, & Lajoie, 1996; Baker et al., 2001; Culbertson & Zillmer, 1998; Krikorian, Bartok, & Gay, 1994). The minimum number of moves needed to solve each problem varies across studies and ranges anywhere from two (Luciana & Nelson, 1998) to eight moves (Raizner et al., 2006). Also, many studies use different methodologies and measure different aspects of planning and problem-solving performance. For example, some researchers use the number of excess moves to measure performance while others use a perfect solution score (the number or percentage of problems correctly solved using the minimum number of moves), the total cognition time (this variable represents the total time that the participant is not holding a bead after the first move is made), the initial think time (this represents the time from when the problem is first displayed to when the first move is made), or the total move time (the amount of time that the participant spends—per problem—holding onto a bead). Given that a wide range of dependent measures have been used to evaluate the various aspects of planning and problem-solving performance, one must use caution when interpreting the findings and making inferences about the development and decline of problem solving ability. The computerized CogQuiz TOL computes the typical dependent variables used in studies examining TOL performance. The results printout for the CogQuiz TOL test gives the number of excess moves for each problem, the initial think time before the initial move is made for each problem, the total think time on each problem, and the time taken to successfully complete each problem. Figure 8 (on page 24) shows a typical printout of results.

Magnetic resonance imaging (MRI) studies suggest that the prefrontal cortex area takes longer to develop than most brain areas and does not fully mature until the early 20s (Geidd, 2004). Age-related declines in frontal lobe functioning and volume, suggest that this area may be one of the first brain areas to decline with increased age (Haug, Barmwater, Eggers, Fischer, Kuhl, & N. L. Sass, 1983). Accordingly, problem-solving abilities should show full development in the twenties and decline in late life, but the literature contains mixed findings. Normative data has been collected in studies using different age groups such as children (e.g., Luciana, Collins, Olson, & Schissel, 2009), adults (e.g., Byrd, Case, & Berg, 2011), and older adults (e.g., Andres & Van Der Linden, 2000; Phillips, Smith, & Gilhooly, 2002). The majority of samples found in the problem-solving literature are mostly limited to children, adolescents, young adults, and college students. Few studies investigate the problem solving performance of mid-aged adults and older adults. With the exception of the research described in this manual, there are no studies with large sample sizes that investigate the use of the TOL as a measure of problem solving performance across the lifespan.

The literature on the TOL problem solving performance of children and young adults demonstrates some consistent developmental patterns. In general, young children demonstrate poor problem-solving performance, but as they develop their problem-solving performance improves (Luciana et al., 2009). Some researchers have suggested that there are periods during childhood and adolescence in which children display a developmental "spurt" in problem solving ability. For instance, between the ages of four and five (Luciana & Nelson, 1998), seven and eight, and at age 12 (Anderson, Anderson, & Lajoie, 1996), there is a significant increase in problem solving performance. The discoveries of developmental spurts in problem solving performance on the TOL beg the question: why do older children generally perform better than younger aged children? Luciana and Nelson suggest that young children have yet to develop the ability to plan and use effective strategies that guide working memory processes. Other researchers have proposed that children are unable to search ahead

(Kaller, Rahm, Spreer, Mader, & Unterrainer, 2008). As for reaching asymptotic performance, researchers suggest that problem solving peaks during adolescence (Asato, Sweeney, & Luna, 2006; Baker, K., Segalowitz, S. J., & Ferlisi, M., 2001; Luciana, M., Collins, P. F., Olson, E. A., & Schissel, A. M., 2009; Ward, H., Shum, D., McKinlay, L., Baker-Tweney, S., & Wallace, G., 2005), the 20s (Huizinga, Dolan, & Van Der Molen, 2006).

The literature does not offer a clear idea as to when problem solving performance on the TOL begins to decline. Typically, studies have compared a young group in their 20s to an elderly group of individuals 60+ years of age making it difficult to determine when age deficits first appear on the TOL. However, clear age effects between young and older adults have been detected on the TOL. Phillips and colleagues have shown that older adults perform worse on the TOL than younger aged adults (Phillips et al., 2006; Phillips et al., 2002).

## Intrapersonal Factors that Affect Problem Solving Performance

The TOL literature has consistently linked a wide array of intrapersonal factors to TOL performance. Some of the more commonly investigated factors include age, fluid intelligence, speed of processing, planning time, and executive functions such as response inhibition, working memory, and shifting. The following subsections will describe each of these variables and the amount of influence they exert on TOL performance.

**Age.** The participant's age has been identified as a variable that predicts problem solving performance on the TOL. The literature contains mixed findings as researchers have found the effect size for age to range anywhere from medium (Anderson et al., 1996; Bugg et al., 2006; Robbins et al., 1998) to large (Bull et al., 2004; Huizinga et al., 2006; Kaller et al., 2008; Krikorian et al., 1994; Luciana et al., 2009; Luciana & Nelson, 1998; Ward et al., 2005; Zook et al., 2006). Although there are clear age differences in TOL performance (i.e., young children to adolescents and adolescents to young adults), it is possible that other variables may explain the variation in problem solving performance across different age groups. For instance, some researchers found evidence suggesting that fluid intelligence mediates the relationship between age and problem-solving performance (Zook et al., 2006). These researchers used an analysis of covariance (ANCOVA) and found the age effect on problem solving performance disappeared when fluid intelligence was statistically controlled for. Although the sample size was small and only consisted of older adults, this study highlights the possibility that age itself might not be a sufficient predictor of problem solving performance on the TOL.

**Fluid intelligence**. Out of all the intrapersonal variables, fluid intelligence appears to have the strongest effect on problem solving performance as the vast majority of the effect sizes found in past studies were large (Unterrainer et al., 2004; Zook et al., 2004; Zook et al., 2006). Fluid intelligence involves the ability to reason and think abstractly; both of which are required when planning and solving TOL problems. Higher scores in fluid intelligence are associated with better performance in problem solving tasks (Unterrainer et al., 2004; Zook et al., 2004; Zook et al., 2006) while other measures of intelligence such as verbal (Unterrainer et al., 2004) and full-scale intelligence (Luciana et al., 2009) were not. This further supports the notion that fluid intelligence specifically, best predicts problem solving performance.

Past research indicates a possible overlap between fluid intelligence and other variables that have been linked to TOL performance. For instance, it has been suggested that fluid intelligence and executive functions utilize similar cognitive processes (Goldstein and Green, 1995). Other intrapersonal factors such as processing speed (Bugg et al., 2006) and age (Zook et al., 2006) have also been linked to performance on both fluid intelligence measures and TOL performance. Compared to fluid intelligence, the effect of these other intrapersonal variables on TOL performance appear to be weaker. In short, the relationship between other related intrapersonal factors and performance on the TOL may be mediated by fluid intelligence. To date, only one group of researchers has examined this possibility. In their study, Zook et al. (2006) found that fluid intelligence mediates the relationship between age and TOL problem solving performance.  Given the limitations of this study, more research will be needed to better understand the relationship between fluid intelligence, its related intrapersonal variables, and problem solving performance on the TOL.  The samples used in future studies should be larger in size and contain representations of all age groups (i.e., children, adolescents, young adults, mid-aged adults, and for replication purposes, older adults).

**Processing speed.**  Speed of processing has been theorized to account for age related changes in cognition (Salthouse, 1996).  Specifically, cognitive processing is degraded because required operations cannot be accomplished within a restricted time frame and this results in the loss of early stage processing (results) during later stage processing.  The literature on the effect of processing speed on TOL performance is limited and the evidence is mixed (Asato et al., 2006; Phillips et al., 2006).  For instance, Phillips and colleagues found higher levels of processing speed are associated with fewer errors (excess moves).  Asato et al. (2006) found that speed of processing moderately affected performance on TOL problems that could be solved in four moves (the effect size was .08).  These findings were not supported across other TOL problems which contained a different number of minimum moves (i.e., three or five move problems).  Although there is little evidence that directly links processing speed to problem solving performance, there may be indirect effects.  For instance, it has been found that processing speed--both independently and concurrently with age--account for some of the variance in measures of fluid intelligence (Bugg et al., 2006).  In general, more research will be needed to investigate the influence of processing speed on TOL performance.

**Planning time**.  The time taken to develop an effective plan prior to engaging in a goal directed behavior(s) may influence one's ability to complete a task both effectively and efficiently.  To efficiently solve problems on the TOL, the participant must plan a sequence of moves that will enable the goal state to be reached while using a minimal number of moves.  Planning time, also known as initial think time (e.g., Asato et al., 2006), represents the time from when the participant is first exposed to the TOL problem to the time when the participant picks up the first bead.  Most researchers use planning time as a dependent measure and investigate the extent to which other variables influence planning time (i.e., Kaller et al., 2008; Luciana et al., 2009). Only a few researchers have measured the amount of influence that planning time has on problem solving performance on the TOL (Asato et al., 2006; Phillips et al., 2001; Unterrainer et al., 2004). The results are both limited and mixed. For instance, Philips et al. (2001) found no differences in performance between participants who were directed to plan their moves versus those who were not given directions to plan.

This suggests that planning time doesn't necessarily predict TOL problem solving performance. It is necessary to note that all the peg heights were the same length and five disks were used as opposed to the three balls used in many other studies. This may have affected the difficulty of the task and in turn, the results obtained by these researchers.

Subsequent studies, however, were able to successfully link planning time to problem solving performance. For instance, Unterrainer et al. (2004) found that the good performers on problem solving tasks spent twice as much time on preplanning time compared to intermediate and poor performers. Asato et al. (2006) examined participants between the ages of 8 and 30 and found that plan time increases with age. In this study, planning time had a large impact on problem solving performance. For instance, children had the shortest planning time and they performed worse than the older age groups in the study.

These findings suggest that the relationship between planning time and TOL performance is complex and not fully understood. Past research has yielded evidence highlighting age differences in planning time and problem-solving performance in children, adolescents, and adults. Unfortunately, the extent to which planning time and problem-solving performance are related, for other age groups such as young adults, mid-aged adults, and older adults, has yet to be investigated in published reports. The norms contained in this manual contains planning time across the lifespan (from 5 to 90). Further, the output from your program will allow you to examine the role of planning time in any sample you might examine on TOL performance. The output from the current software will allow you to investigate the nature of this variable across age groups or any special population you might study and to clarify the extent to which plan time predicts problem solving performance.

**Inhibition**. Inhibition refers to one's ability to inhibit a prepotent, dominant, or automatic response (Miyake, Friedman, Emerson, Witzki, & Howeter, 2000). Solving TOL problems requires one to inhibit moving a bead onto its goal position when an indirect move is required for an optimal solution. That is, for some problems one must inhibit moving a bead into its goal position and rather, move it onto a different peg to free up the other beads, in order to solve some problems optimally. Most of the studies that have investigated the relationship between inhibition and TOL performance typically correlate the performance on the inhibition task to performance on the TOL. While the method used to investigate the relationship is similar in most studies, the findings have been mixed. Findings on the effect of inhibition when solving TOL problems is mixed with effect sizes ranging anywhere from no effect (KoppenolGonzalez et al., 2001; Pulos & Denzine, 2005), to a medium effect (Zook et al., 2004), or to a large effect (Luciana et al., 2009; Welsh et al., 1999). All these studies, with the exception of Luciana et al. (2009) who used the Go-No-Go task to measure inhibition in children, used the Stroop test to measure inhibition in college students. The sample size for most of these studies was low and the dependent variables of interest for both the Stroop test and the TOL differed across studies. This may explain the mixed findings in the literature regarding the relationship between inhibition and problem-solving ability. There is an inadequate amount of research that investigates this relationship in children, adolescents, middle-aged adults, and older adults. Furthermore, the studies that investigated this relationship in the college population contain mixed findings. The literature would greatly benefit from future studies that investigate this relationship in each of the age groups.

**Working memory**. Working memory involves the processes used to temporarily store and manipulate information during distraction and processing (Jaeggi, Buschkuehl, Perrig, & Meier, 2010). Miyake et al. (2000) highlighted the importance of a working memory known as updating. This requires one to code and monitor information required for a task and to alter any existing information held in working memory by replacing old, irrelevant information with more relevant information that is required for task completion. Thus, when completing TOL problems, participants execute a plan by cognitively "keeping track" of any subsequent move in the sequence that needs to be made while discarding any of the other steps that had pertained to previous moves. Miyake suggested that the role of the updating function increases as task difficulty increases in a problem-solving task such as the Tower of Hanoi (TOH). Although findings suggest that the TOH and the TOL are not identical problem-solving tasks (Humes, Welsh, Retlaff, & Cookson, 1997), both require the participant to cognitively formulate a plan and to successfully carry it out in order to increase the likelihood of solving the problem optimally. Thus, it is reasonable to suspect an updating role for working memory in solving TOL problems.

Research on the effect size of working memory on problem solving performance ranges anywhere from non-existent (Pulos & Denzine, 2005; Zook et al., 2004) to medium (Asato et al., 2006; Koppenol-Gonzalez et al., 2010) to large (Luciana et al., 20009; Unterrainer et al., 2004; Welsh et al., 1999). The mixed findings may be a product of the wide array of working memory tasks used. A major concern, however, is that most of the working memory tasks used did not contain an updating function. For instance, at least half of the studies that measure working memory use the digit-span task, a verbal working memory span task. In contrast, The TOL is a visuo-spatial task (Gilhooly et al., 2002) that most likely requires the constant update of working memory in order to keep track of the necessary components of the plan while releasing information that is no longer pertinent (i.e., the steps of the plan that have already been executed, thus an updating rather than span working memory task) to the plan in order to solve problems optimally.

The mixed findings in the literature suggest that the extent of the relationship between working memory and problem solving is unclear. Furthermore, the clear majority of the participants used in these studies were college age students. Although it would be beneficial to clarify the mixed findings in the literature by using participants from the college population, future research should also investigate this relationship using different age groups (i.e. children, middle aged adults, and older adults). Furthermore, future research that seeks to investigate the effect of working memory on TOL performance should consider using a visuospatial working memory task that contains an updating function, thus, replicating the nature of the working memory component that is required to solve TOL problems.

**Shifting.** Shifting refers to the ability to shift back and forth between tasks and mental sets (Miyake et al., 2000). The literature on shifting ability and its relation to problem solving performance on the TOL contains mixed findings. For instance, a lifespan study found a linear, inverse relationship between performance on a shifting task and problem-solving ability (Bugg et al., 2006). In other words, better performance on the shifting task was related to fewer excess moves on the TOL task (which demonstrates better performance). Furthermore, these researchers found age related declines with shifting. Given the relationship between shifting and problem-solving ability, it follows that shifting ability and problem-solving performance would also decline with age. Although the findings from this study were able to link shifting ability to problem solving performance, other studies were unable to find a relationship between these variables (Pulos & Denzine, 2005; Zook et al., 2004). It should be noted that different assessments were used to measure one's shifting ability. For instance, some researchers used Part B of the Trails Making Test (Pulos & Denzine, 2005) while others used the Wisconsin Card Sorting Task (WCST; Bugg et al., 2006; Zook et al., 2004) to measure shifting ability. Although the use of different assessments may account for some of the discrepant findings, shifting ability and its relationship to TOL performance remains unclear.

## Limitations of the Previous Research

Although many researchers have studied the effect of the above factors on TOL performance, there is still a lack of consensus regarding the extent to which these factors influence performance. There are a few possible explanations for this. One explanation involves the statistical analyses used. Most studies used correlation or an analysis of variance (ANOVA) to measure the extent to which these factors influence

TOL performance. Research has demonstrated that some of these intrapersonal factors are related and even interact to influence TOL performance. Thus, the effect sizes obtained for each factor when using these two statistical analyses may be misleading due to the possibility that the effect size obtained for each factor will likely represent a combination of both unique and shared variance which would provide an inaccurate representation of the extent to which each factor independently influences TOL performance.

The sample used may also contribute to the large range of effect sizes obtained for each factor. For instance, some studies investigated multiple factors despite having a small sample size (e.g., Pulos & Denzine, 2005). The sample itself may also account for some of the discrepancies between the findings in the literature. While there are a few studies that include middle aged and older adults, most of the samples used tend to consist of children and young adults from the college population. The age of the participants needs to be strongly considered because children and adolescents' mental abilities have not fully developed. Thus, findings on the relationship between intrapersonal variables and TOL performance from studies that contain young children and college freshmen will only be representative of these variables during the time of their development. To gain a better, general perspective of how these variables influence TOL performance, it will be necessary to include participants of all ages.

Researchers' definition of problem solving performance represents another possible explanation that may account for differences in the effect sizes. Many studies measure problem solving ability based on the number of excess moves made. That is, the number of moves above the minimum number of moves needed to solve the problem (Phillips, Wynn, Gilhooly, Sala & Logie, 1999; Salthouse & Davis, 2006). Other studies, use the weighted performance score—the summed number of moves for correctly solved problems (Unterrainer et al., 2004)—and the total number of correctly solved TOL problems (Shallice, 1982; Albert & Steinberg, 2011) as the dependent variables.

Lastly, structural parameters of the TOL problems have been shown to influence problem solving performance. Previous researchers have demonstrated that manipulating the parametric properties of the TOL problem such as the minimum number of moves necessary to solve the problem, the number of indirect moves per problem, the position of the beads in both the start and goal states (the start and goal hierarchies, respectively), can influence the difficulty level of each problem (Berg et al. 2010; Kaller et al, 2004; Kaller et al. 2011). Until recently, the influence of these parametric properties went unrecognized by researchers. Thus, the versions of the TOL that were used in previous studies did not account for these parameters. Consequently, the difficulty level of the problems and overall performance varied. This likely explains the wide range of results obtained from the previous studies which aimed to measure the effect of intrapersonal variables on TOL performance. Important Note: The normed 3,4,5 peg bead test with norms included suffers from these short comings of not considering many of the task parameters. Norms for tests taking into account recommendations by Kaller and colleagues and by Berg and Byrd will be included by 2019.

In sum, the literature suggests that problem solving ability, when measured by one's performance on the TOL, may be influenced by several factors such as age, planning time, speed of processing, executive functions, fluid intelligence, and various combinations of these variables. The extent to which these intrapersonal variables independently influence performance on the TOL is unclear due to the different statistical methods used, the age range of the populations, and the different TOL versions used. More research addressing these issues will be necessary to improve researchers' understanding of which intrapersonal variables, and the extent to which they influence problem solving performance.

## Data Management

All CogQuiz desktop Neuropsychological Assessment Tests share a single Participant Database. Whether you are using only one of our tests or all of them, all participant information and test results are stored in a single database file called the "Participant Database." This approach greatly facilitates the management of participant information as well as security of the data. To assure the privacy of each participant, access to this database is usercode/password protected.

To personalize access to and control over this database, a user must create and set up a Participant Database "administrator." Therefore, if a user starts to run a test and generate data before setting up an administrator for the Database, the user will be prompted to read this section of the manual before proceeding further.

## Participant Database Set-up

Setting up one's own administration of the COGQUIZ Participant Database requires only a few simple steps but, since this process both determines access and insures the security of the database, the process is important and, as such, is highlighted in red below.

PLEASE NOTE: Since all COGQUIZ tests share the same Participant Database, if you have previously installed any other COGQUIZ test(s) then setup of the Participant Database was already done in that previous CogQuiz test installation and this step can be skipped.

If, however, this is the first installation of a COGQUIZ Neuropsychological Test then a unique participant database administrator will need to be set up. The test comes programmed with a single generic database administrator already assigned a preprogrammed USER NAME, USER CODE, and PASSWORD. The pre-programmed User Name is "CogQuiz Administrator," the User Code is the word "admin," and the Password is "CogQuiz." For database security, we recommend that the user create a new Database Administrator and then, when that has been successfully accomplished, that the generic, pre-programmed CogQuiz Administrator be deleted. The following steps will guide you through this process.

From the test's **WELCOME** screen (Figure 1), login to the **PARTICIPANT DATA MANAGEMENT** window by clicking the **Participant Database** button to the right of the screen. This will result in the display of the **LOGIN** window shown below in Figure 3.

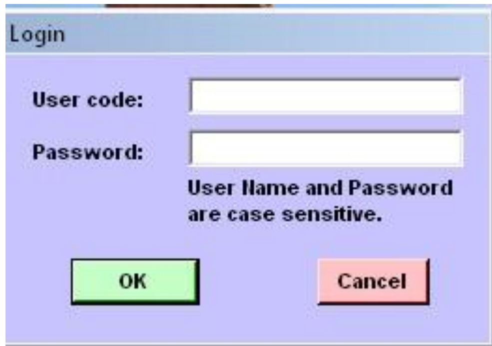


**Figure 3**

In the ***User Code*** box type in the word “admin” and in the ***Password*** box type the word “sanzen” (no quotation marks). Both user codes and passwords are case sensitive so be sure to use lower-case. Now press the **OK** button.

Pressing the **OK** button will result in the display of the **PARTICIPANT DATA MANAGEMENT** window shown in Figure 4, below.

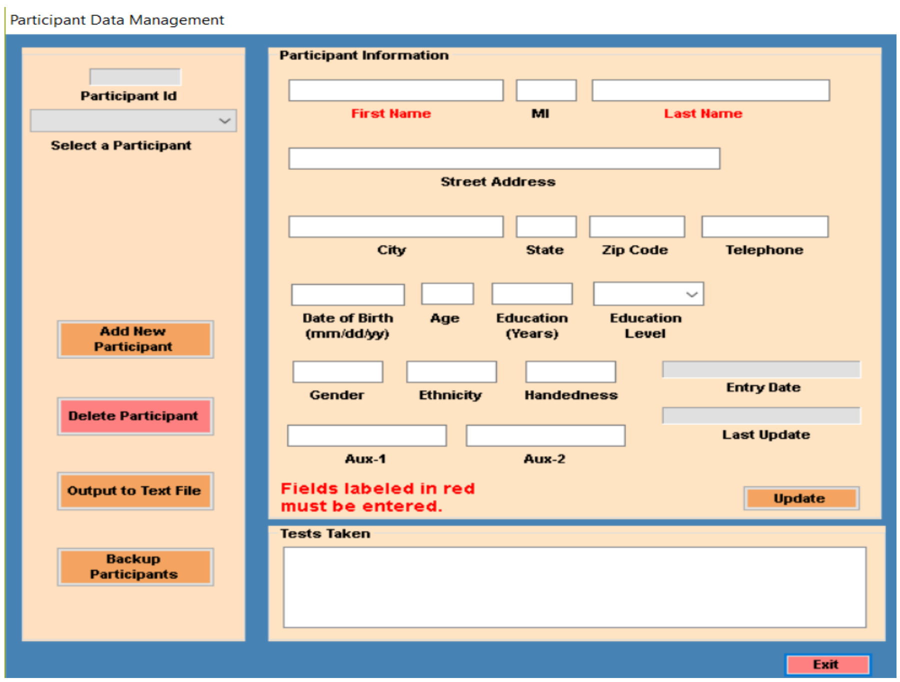


Figure 4

On the opening CogQuiz window click the **System Administration** button to open the **ADMINISTER USERCODES/PASSWORD** window shown in **Figure 5.**

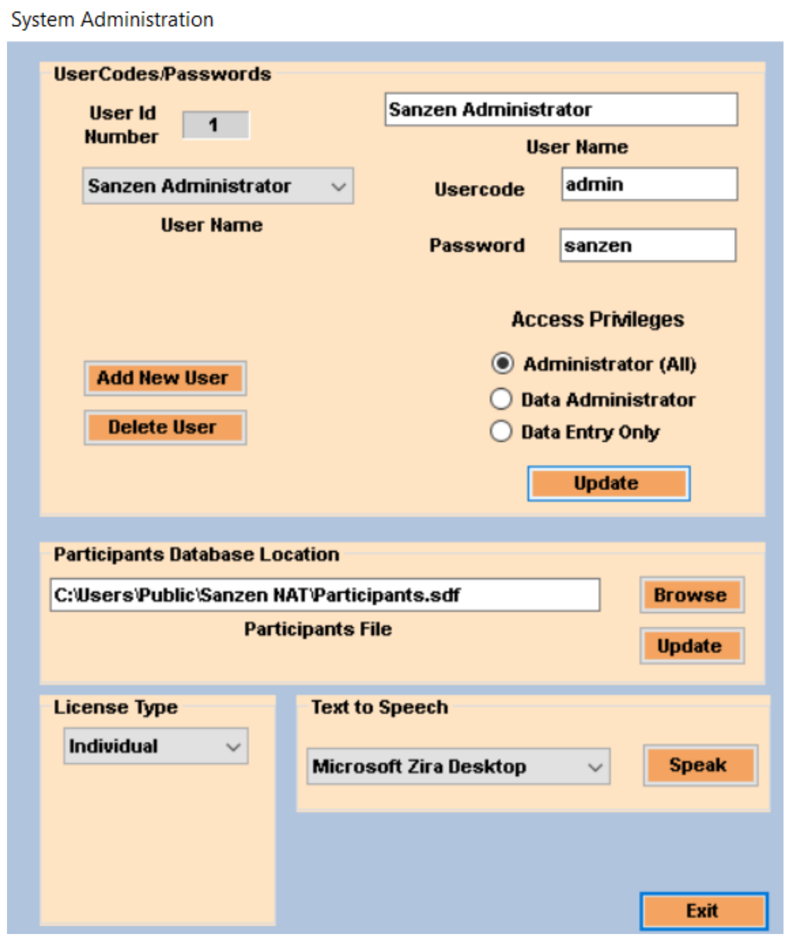


**Figure 5**

You are going to create a new administrator. First, click the **Add New User** button. Now enter a ***User Name*** that can identify this user from others. Then enter a unique login ***User Code*** and “Password” for this user. Under the “Access Privileges” box, be sure to give this user ***Administrator (All)*** privileges as only users with this level of privilege can get access to this screen to create new or delete existing users. (User privileges will be explained in more detail below). Click the **Update** button and then **Exit** the **ADMINISTER USERCODES/PASSWORD** window.

Return to the **WELCOME** screen and click on the **Participant Database** button. Now attempt to login to the database administration system using the User Code/Password you have just created. This should allow you access to the **PARTICIPANT DATA MANAGEMENT** window.

Once you have ascertained that your new login information will allow you access to the **ADMINISTER USERCODES/PASSWORD** window, it is then safe to delete the preprogrammed sanzen administrator. In the **ADMINISTER**

**USERCODES/PASSWORD** window, select “Sanzen Administrator” from the **Select User** pull down list and click the **Delete User** button to delete the pre-assigned Sanzen Administrator. You may simply want to leave the Sanzen Administrator in place as you know this usercode and password.

**A word of warning**: only users with Administrator (All) privileges can create new users, so don’t lose this usercode/password. You can, of course, consistent with your own security policy, create as many Administrator (All) accounts as you wish. See the section on User Privileges below for a discussion of the access rights of the other two levels of security.

## User Privileges

From the **ADMINISTER USERCODE/PASSWORDS** window (accessed, as described above, via the opening window) an administrative user can create new users and determine their level of access to the system. A user can be assigned any one of three levels of access.

At the lowest level, **Data Entry Only**, the user can only enter information for a new participant. They cannot print, edit or even view other participant records. This is a level likely to be assigned to an individual whose only responsibility is to test participants.

At the **Data Administrator** level, the user can enter new participant information, view and edit all participant records, delete a participant, and print participant records.

Users with **Administrator (All)** privileges can do all that a Data Administrator can do but can also add new users to the database security system.

## Adding New or Editing Existing Participants

From the **PARTICIPANT DATA MANAGEMENT** window (Figure 3, above), add a new participant by first clicking the **Add New Participant** button. The Participant Information frame will be cleared, and the cursor will be positioned in the first field “First Name.” At a minimum, a first and last name must be entered to register a Participant. After entering the relevant information, click the **Update** button and the new Participant will be added to the Participant Database.

Alternatively, an existing Participant's information can be displayed and/or edited by selecting a Participant from the pull-down list located immediately above the **Add New Participant** button. The Participant's current information and a list of the tests they have taken will be displayed. Of course, all of this can be done only by a user who has "Data Administrator" or "Administrator" privileges.

## Text Output

Participant data cannot be printed directly from the data management system, however, clicking the **Output to Text File** button (on the **PARTICIPANT DATA MANAGEMENT** window, Figure 3) allows the user to write to a file's selected information in formats compatible either with popular word processors, spreadsheets or statistical packages. **Figure 5** (below) shows the window for selecting and formatting the text file.

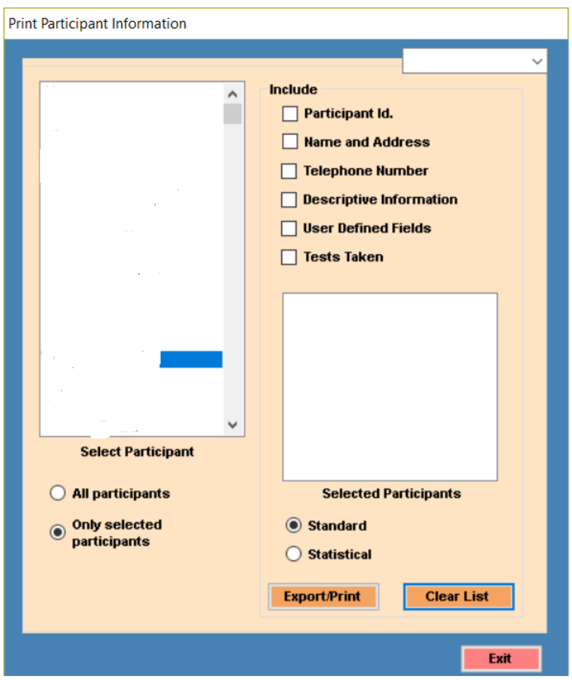


Figure 6

The “Select Participant” box on the left side of the screen automatically and alphabetically lists all participants currently in the system. A scroll bar will appear to the right of this list if there are more participants than can be accommodated in the visible area. Directly beneath this list, the user can choose to send to the text file either the entire list of Participants or only a selected subset by “checking” either **All Participants** or **Only Selected Participants**.

If the “**Only Selected Participants**” option is chosen, clicking on the name of each selected participant in the left-hand Participant list will cause that name to appear in the **Selected Participants** list on the right side of the screen.

Double-clicking on a participant’s name in the **Selected Participant** list will remove that name from the list.

Once the list of selected participants has been generated then the data items to be included in the list (Participant ID, Name and Address, etc.) can be selected by “checking” the appropriate boxes.

Finally, the user can specify whether the data is to be formatted in either a “standard” multiline text format suitable for either a text editor or a spreadsheet, or as a single line (one for each participant selected) comma delimited format suitable for being read by popular “statistical” packages. Clicking the **Export/Print** button will show a standard “save file” dialog box.

## Backup Participant File

It is important that from time-to-time a backup copy of the Participants’ database be made. Loss of data can, at the very least, be frustrating and though today’s computers and disk drives are very reliable, they do still sometimes fail. Clicking the **Backup Participant File** produces a “save file dialog” allowing a copy of the Participants Database to be made. This copy should be made to some external storage device such as an external (usb) disk drive or to a “thumb drive.”

# Executing a Tower of London Test

On the **<u>WELCOME</u>** screen (see Figure 1), select one of eight tests from the pull down "Select a Test" list. This will produce the **SELECT A PARTICIPANT** window (Figure 6). Select a participant from the "Select a Participant" pull down list. This assumes that the participant has already been added to the Participant Database; if the participant has not yet been added, then before proceeding you will need to return to the **<u>WELCOME</u>** screen (by clicking the **Cancel** button) and add the participant to the database (see the section on adding new participants). Once a participant has been selected there is an option to then enter the tester's name; if entered, the name of the person administering the test will be added to the participant's test record. After selecting the participant and, optionally, adding the tester's name, click the **Run Test** button.

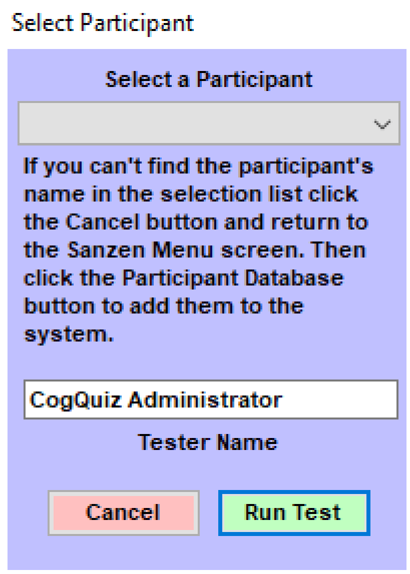


**Figure 6**

The CogQuiz Tower of London Test comes with eight pre-programed tests: a computerized version of Shallice's 1982 original test and CogQuiz Neuropsychological Assessment Tests' "Normed 3,4,5 peg bead" test plus six additional tests.

Figure 7 (below) shows the first screen for CogQuiz Neuropsychological Assessment Tests' Tower of London "Normed 3,4,5 peg bead" test. The first trial of all Tower of London tests is always assumed to be a practice trial and, as such, the instructions for taking the test are displayed at the bottom of the screen. In subsequent trials the instructions are suppressed.

Depending on how the test has been set up, participants can respond via touch screen or mouse, the latter offering either a "point and click" or slide bar option. (1) If a **touch**

**screen** is used, the participant can touch the bead, base, or peg area of the bead to be moved. (2) **Using the mouse**, the participant can left click either on the bead to be moved, the base area under the peg holding the bead to be moved, or on the area immediately surrounding the peg holding the bead to be moved. (3) Finally**, using the slide-bar** option, as in the "Normed 3,4,5 peg disk" test displayed in Figure 7, (in which the mouse pointer has been captured by the slide-bar under the **Work Space)**, the participant can simply move the slider to a position under the peg containing the bead to be moved and then click the left mouse button.

We have included the slide-bar response input for solving the Tower of London. There is anecdotal evidence that the slide-bar is more easily used by senior participants.

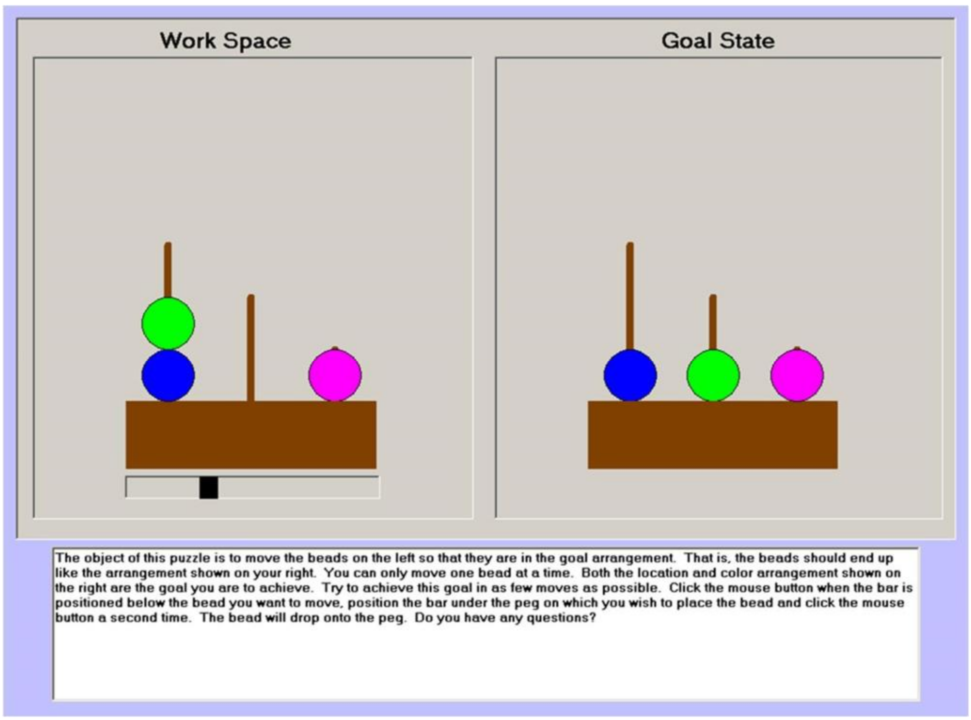


**Figure 7**

Depending on how the test has been setup, the participant may be given certain feedback messages after each trial. (Note: Feedback messages will be explained in more detail under the section below on how to "Create/Edit a Tower of London test"). At the end of the test the participant will be thanked for their participation and control will be returned to the <u>**WELCOME**</u> screen.

As with all CogQuiz tests, the Tower of London test can be terminated at any time by pressing Ctrl x. On initiating this sequence, the user will be asked to confirm the choice to terminate the test; if the choice to terminate is affirmed, the test will be terminated and <u>no data from the test will be saved</u>.

# Analysis of Results

Clicking the **Analysis** button on the **<u>WELCOME</u>** screen (Figure 1) will produce the **ANALYSIS** window (Figure 8, below).

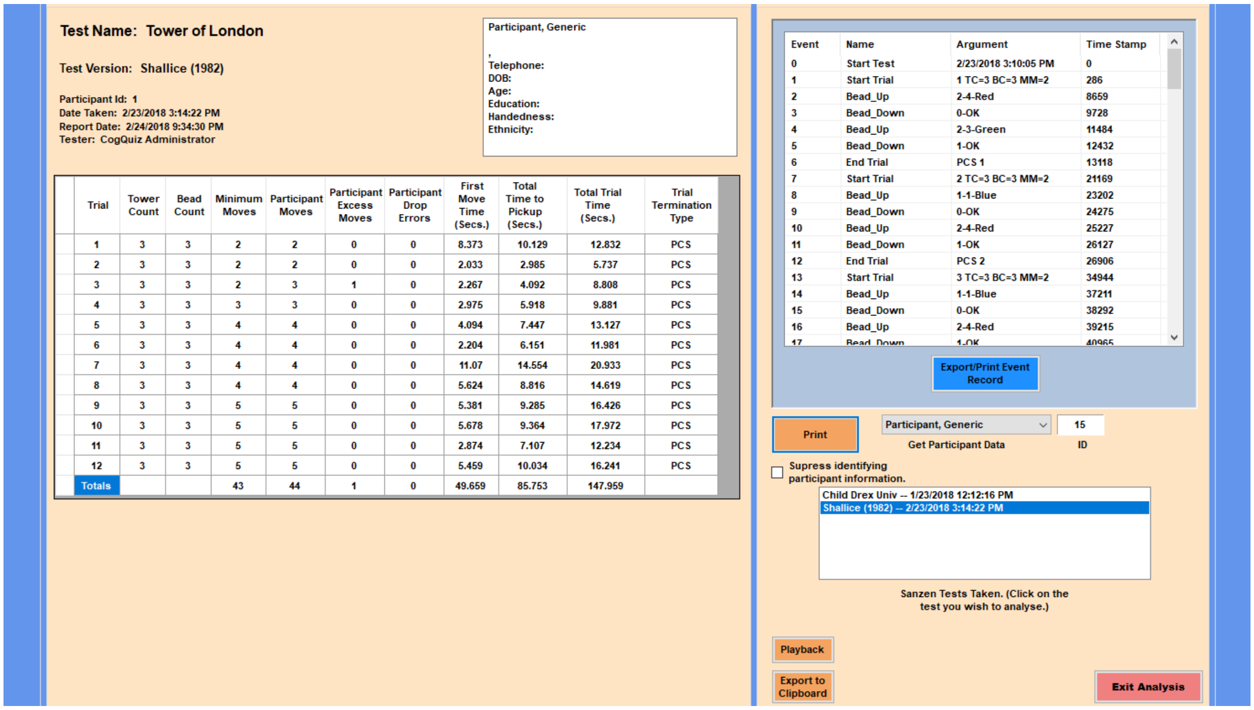


**Figure 8**

To see a participant's data, select the participant's name from the "Get Participant Data" pull-down list.  A list of all versions of the Tower of London Test the selected participant has taken will appear in the "Tower of London Test(s) Taken" box at the bottom right of the screen.  Click on the specific test to be analyzed.  A small box will open requesting the user to select the block of trials to be included in the summary analysis of the participant's test performance.  This allows the user to exclude "practice" or "demonstration" trials from the test summary analysis (up to the first five trials can be excluded from the analysis).  The selection of a starting trial will cause the analysis to automatically display.  The first trial used in the analysis is indicated by ">" next to the trial number; in the analysis displayed in **Figure 8** the first trial included in the analysis was trial one.

Clicking the **Print** button will send a copy of the results to the printer along with the participant's unique identification number (assigned at the time the participant was added into the Participant Database); the test version name; the date and time the test was administered; the date and time the report was generated; and the name of the person administering the test (if it was entered).

Checking the ***Suppress Participant Identification Information*** box for the

Participant(s) selected will suppress all personal identifying information and will include only the non-personal identifying information outlined in the paragraph above -- that is, the contents of the text box above the grid will not appear on the printout. This is useful when printed copies of the data may need to be kept in less secure environments or when the individual evaluating the data needs to be "blind." The linkage between suppressed participant information and test results can always be recovered by those having at least "Data Administrator" level access to the Participant Database, or by reprinting the analysis with the "Suppress Participant Identification Information" box unchecked.

Clicking the **Export to Clipboard** button will place a spreadsheet compatible copy of the summary table on the clipboard.

Clicking the **Playback** button produces the playback window shown below in Figure 9. This window allows for the "playback" of all moves made by the participant for the selected trial. Select a trial from the "Select Trial" pull down list, and then click the **Play** button. The moves made by the participant for the selected trial will be displayed in the **Work Space** area. The speed of playback can be controlled using the **Speed Control** slider.

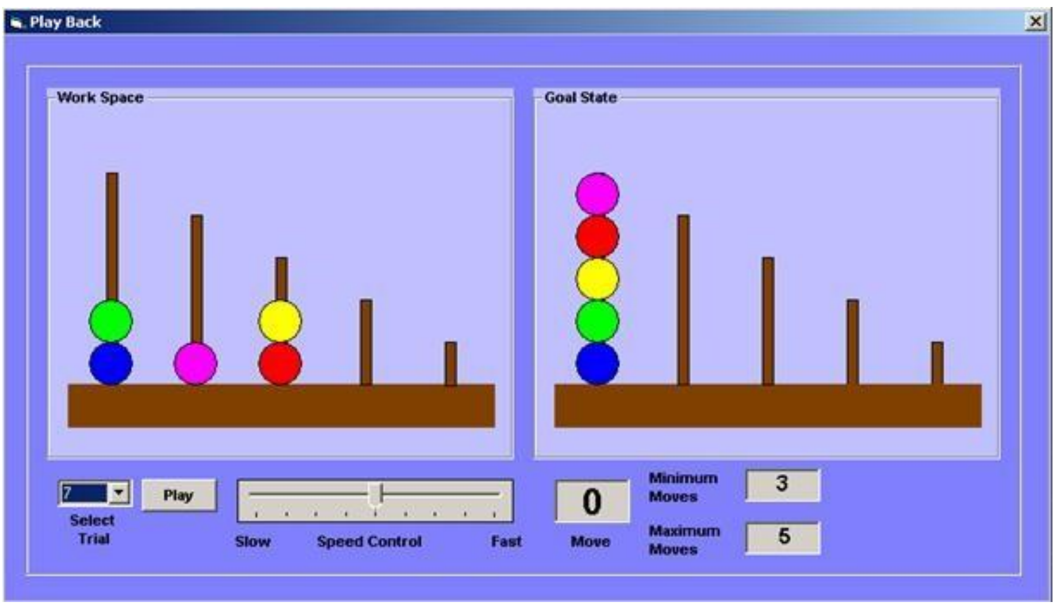


**Figure 9**

The grid located on the right side of the **ANALYSIS** window contains a "real time" record of the participant's performance for the analyzed test. This record is provided in case the test user wishes to perform an analysis not given by summary statistics. The grid provides information about all the salient events that occurred during the test.

The first column is simply the event's ID and reflects its occurrence position in the test.

The second column displays the nature of the event. The third column contains an “argument” qualifying the nature of the event. And the fourth column contains a “timestamp” indicating to the nearest millisecond when the system detected the event.

For example, event 4 is “Start Trial,” an event occurring coincidentally with the display of the trial, and the argument “1” indicates that it is the start of trial 1. This event occurred 1,139,072 milliseconds after the last start time for the computer running the test. (The computer maintains a running clock indicating the time in milliseconds since it was last started.) Event 5 was a bead pickup response indicated by the event designation “BeadUp” and the argument “35” indicates that the bead in position 5 located on peg 3 was the one picked up. (**Figure 10,** below, shows the bead positions and peg numbers.) Event 6 was a “BeadDn” event, the argument 15 indicates that bead 5 was dropped on peg 1.

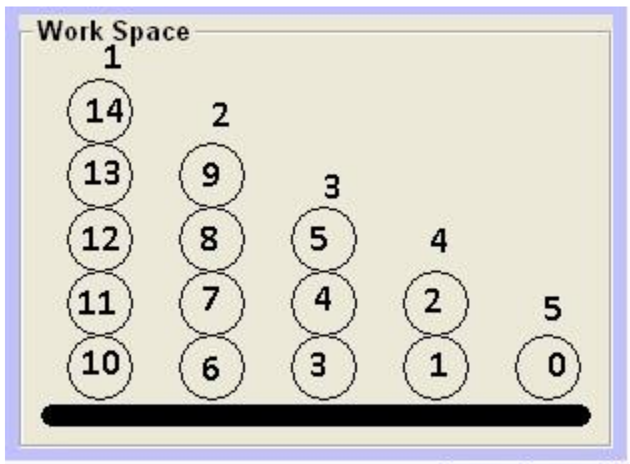


**Figure 10**

The contents of this grid can be printed by clicking the **Print** button. Alternatively, by clicking the **Export** button the grid’s contents can be sent to the “clipboard” in a format that can be pasted into a spreadsheet.

## Creating and Editing a Tower of London Test

Create a new or edit an existing Tower of London test by first clicking the **Create/Edit Tower of London** button on the **WELCOME** screen. This will produce a screen like the one shown below in Figure 11. The initial **CREATE / EDIT** screen will have none of the information filled in.

### Create a New Test:

Before beginning the process of constructing a new Tower of London Test, it is helpful to first plan the test’s features. In other words, it facilitates the creation process to first design the test before you attempt to construct it.

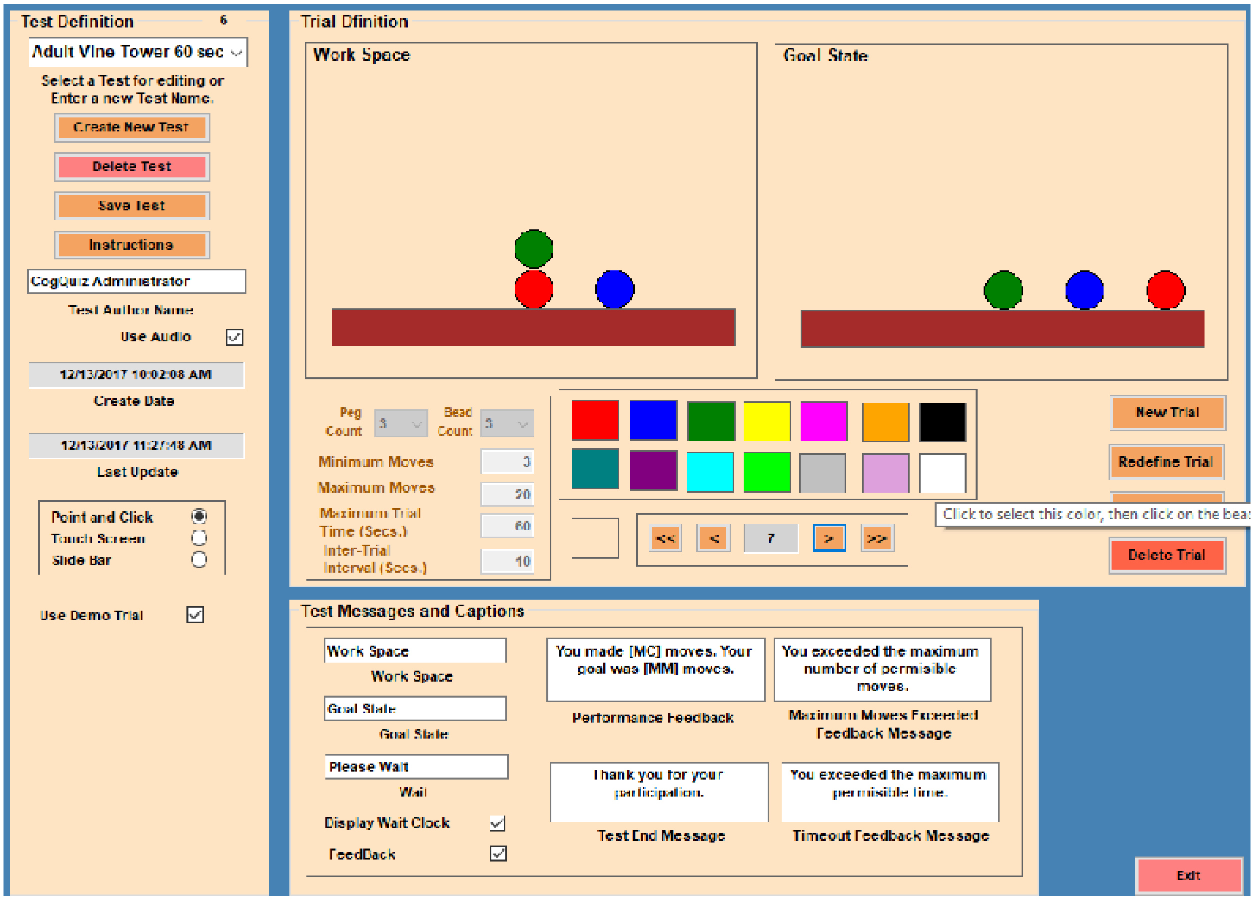


**Figure 11**

Create a new test by clicking the **Create New Test** button.  The cursor will then be positioned in the “Test Name” text box.  Type a unique name for the new test and, if needed, specify the name of the “Test Author.”

Before specific trials can be created and added to a new test’s definition, certain overall parameters for a test must first be decided and defined.  These parameters include: **inter-trial interval; maximum trial time; maximum moves; and certain optional feedback messages**.  The initial buttons needed to be activated are in the right hand upper window. Each of these will be discussed in turn below.

**<u>Inter-Trial Interval</u>:**  This number will determine the amount of time (in seconds) that will elapse in a given test between the end of one trial and the beginning of the next.

**<u>Maximum Trial Time</u>**:  If a **Maximum Trial Time** other than 0 is specified then a trial which has not been completed within the specified time will be terminated.  Leaving the **Maximum Trial Time** at 0 means a trial will <u>not</u> timeout.  (Note:  If a maximum trial time is set, then after the specified time has elapsed the trial will end and the “please wait” message of the inter-trial interval will be displayed.  Alternatively, if the feedback box is checked, when the trial abruptly ends the participant will first receive a message explaining that the trial has timed out, and then the "please wait" message of the inter-trial interval will display.)

**Maximum Moves**: Setting **Maximum Moves** to a value other than 0 causes a trial to terminate if the number of moves made by the participant is equal to the specified Maximum Moves value and has not resulted in a solution to the problem. Setting the value to 0 means there is no maximum on the number of moves a participant may make in attempting to solve a trial's problem. (Note: If a maximum number of moves is set, then after the specified number of moves have been made by the participant the trial will end and the "please wait" message of the inter-trial interval will be displayed. Alternatively, if the feedback box is checked, when the trial abruptly ends the participant will first receive a message explaining that the number of permissible moves for that trial has been exceeded, and then the "please wait" message of the inter-trial interval will display.)

**Messages:** All of a test's messages can be changed to meet the language needs of the participant population or deleted altogether.

Some test messages are basic to a participant's understanding of the test, and as such, unless the text within the message box for that message is deleted and the box left blank, these messages will automatically be displayed to the participant.

Basic test messages include: Work Space; Goal State; a "Please Wait" message; and a "Test End" message. **Work Space** indicates the active window in which the participant will be working to solve the problem. **Goal State** indicates the static window in which the problem's specified goal will be displayed to the participant. The **Wait Message** is displayed on the screen (for the number of seconds specified in the Inter-trial interval box) to participants between trials, and the **Test End Message** is displayed to the participant at the end of the test.

**Feedback Messages:** Unlike the basic test messages described above, Feedback Messages are optional and are only made active by checking the ***Feedback*** box at the bottom of the lower right hand window.

Checking this option when defining a test causes the test to provide participants feedback after each trial. Feedback Message options include: a "performance" option which reports the minimum number of moves required to solve the problem and the number of moves the participant made in solving the problem; a "timeout" message which displays if the participant exceeds a set maximum time; and an "exceeded maximum moves" message if the participant exceeds a set number of maximum moves.

The **performance feedback** message contains two special tokens [MC] and [MM] which must appear in the message irrespective of other changes that may be made to the message's composition. At the time that feedback is given to the participant, [MC] is replaced by the actual **M**ove **C**ount of the participant on the trial and [MM] is replaced by the **M**inimum number of **M**oves required for the problem's solution.

Feedback messages for trial termination due to either exceeding the Maximum Moves value or the timeout value can also be tailored to meet the tester's need. Even if the ***Feedback*** box has been checked, these messages will only be displayed if a maximum number of moves and/or a maximum trial time have been designated (as described above under paragraphs entitled "Maximum trial Time" and "Maximum Moves").

**<u>Use Demo Trial</u>**: If the ***Use Demo Trial*** box at the bottom of the left hand window is checked, then the first trial of a test is initiated by the participant or tester solving the problem shown above the instruction window; otherwise, if the box is unchecked, the first trial is initiated by the participant either clicking or touching the instruction window.

**<u>Response Modality</u>**: Toward the bottom left of the Create/Edit screen, three response options are provided -- **Point and Click, Touch Screen, and Slide Bar.** Select a response modality to be part of a test's definition by checking the box next to it. The preferred response modality for any given test can be changed at any time; to do this, from the **<u>CREATE/EDIT</u>** screen, select the test from the "existing tests" drop-down menu, then check the preferred response option, then click "Save Current Test."

Selecting the **Point and Click** option requires the participant to point (with the mouse pointer) to either the bead they wish to move, the "peg" on which it resides, or the base immediately under the peg -- and then to click the left mouse button. The peg on which the bead is to be deposited is similarly selected by pointing (with the mouse pointer) at the targeted peg and clicking the left mouse button. Note: Even when the "point and click" option has been selected for a given test, if a touch screen computer is being used, the touch screen option will still be active.

The **Touch Screen** option is identical to the Point and Click option except that the participant will use their finger to touch the bead they wish to move and then the peg on which it is to be deposited. NOTE: When the touch screen option is selected, the mouse curser will be hidden but the mouse, if available, will still be operational; therefore, if the touch screen modality is to be used, the mouse should not be available to the participant.

The **Slider** option "captures" the cursor in a slide bar located directly under the base of the Working Area display. The cursor (a black square) can be moved left or right by moving the mouse left or right. A bead is selected for moving by positioning the cursor under the peg holding the bead and clicking the left mouse button. The peg on which the bead is to be deposited is selected by positioning the cursor under the selected peg and clicking the left mouse button. This option is particularly useful when working with participants with motor control problems who may have difficulty positioning either the mouse pointer or their finger with the precision necessary to accomplish the test.

**<u>Instructions:</u>** The test creator has two options for creating a new instruction. An instruction file that was created at an earlier time can be imported using the **Import From File** capability, or the new instruction can be typed directly into the edit field of the **Instruction Editor**. The "Import from file" approach is preferred when the same or a similar instruction is going to be used for a number of different tests, or when the instructions' text format is particularly complex.  If an external text editor is used, it must save the file in Richtext (rtf) format.

## Adding Trials

Once the overall parameters for a test have been defined, then specific trials for that test can be created and added to the test definition. To add a trial (or a number of trials) to a test, first select the appropriate test by highlighting it in the "Existing Tests" drop-down list.

In creating a trial for a test, the user initiates the trial creation process and simultaneously determines a new trial's order by selecting one of the following buttons: Add New Trial; Redefine Trial; or Delete Current Trial.  The **Add New Trial** button adds a new trial to the end of a selected test's existing trails.  If there are currently no defined trails within a test, clicking Add New Trial will create Trial number one.  The **Redefine Trial** button clears the currently displayed trial's definition and allows for a new definition of that trial.  The **Delete Current Trial** button completely deletes the currently displayed trial from the selected test.  Each of these will be explained in more detail below.

**Adding a new Trial**:  Clicking the **Add New Trial** button adds a new trial to the end of the test.  That is, if a current test already has 6 trials, then clicking the **Add New Trial** button will add a $7^{th}$ trial at the end of the existing six trials.

Clicking the **Add New Trial** button causes the cursor to be positioned in the **Peg Count** text box.  Enter a number between 3 and 5 to specify the number of pegs (or towers) this trial will have.  Entering a number here will cause that number of pegs to display in the Work Space window.

The cursor will then move to the ***Minimum Moves*** text box where the minimum number of moves required to solve the problem must be entered before the trial can be created. This number is used both for test results analysis and, (if the feedback box is checked), for participant feedback, and therefore should be calculated based on the test author's intended trial design.  Please note:  the system will not correct an erroneous entry here, so it is the test designer's responsibility to ensure that the "minimum moves" entered at the time of a trial's creation correctly describes the trial design.

Specifying the "minimum moves" will cause the display of the appropriate number of beads and pegs to be displayed in the **Work Space** window and a "color palette" of five colors to be displayed below that window.  Define the work space by first clicking on one of the color swatches and then clicking the bead in the work space area that is to have that color.  Continue doing this, selecting a new color each time, until the appropriate number of beads has been colored (e.g., three beads for a three-tower problem, five beads for a five-tower problem). If a mistake is made in selecting/coloring a bead, right click the improperly selected bead to de-select it, then left click the correct bead to select/color it.

Completing the definition of the work space automatically results in the appropriate display of pegs and beads in the **Goal State** window. Use the same process to populate the goal state window as was used to place beads in the work space.

Once the Goal Space has been defined, a message will appear on the screen stating that the trial definition has been successfully completed. If no more trials are going to be added to the test, then click “ok” on the displayed message to collapse it, and then click “Save Current Test” to save the newly added trial to the test definition.

If, on the other hand, more trials are going to be added to the same test, then click “ok” on the displayed message to collapse it, and then click the Add New Trial button, and repeat the process described above. Repeat this process to add as many trials as desired to the selected test, and then, when finished and before exiting, click “Save Current Test” to save all the newly added trials to the test definition.

If a test or trial has been changed and the user attempts to exit without saving, a message will be displayed warning the user that changes have been made that have not yet been saved and asking the user to confirm the command to EXIT without saving the new changes.

**<u>Redefine Trial:</u>** Clicking the **Redefine Trial** button clears the currently displayed trial’s definition and allows for a new definition of that trial. The process for creating that new trial is identical to the one described (above) for adding a new trial.

**<u>Delete Current Trial</u>**: Clicking the **Delete Current Trial** button completely deletes the selected trial from a test, thus changing the numerical order of any other subsequent trials within that test. For example, in a test with four trials, if trial #3 is deleted, then trial #4 would become the new trial #3, and after the deletion the test would now have a total of three trials.

**<u>Design Grid</u>**: To the left and below the **Work Space** window is a grid that contains the actual data used by the Tower of London Test to construct each trial.

**<u>Navigation Buttons</u>**: Immediately below this grid are four buttons **<<**, **<**, **>**, **>>** that allow navigation among the defined trials and gives the trial number.

On the left a line specifies the number of pegs (towers) and beads the problem uses; and the third line specifies the minimum number of moves required to solve the problem along with several other parameters the test creator will enter.

## <u>Editing an Existing Test:</u>

On the **<u>CREATE/EDIT</u>** screen, select a test to be edited from the “Existing Tests” pull down list. The process from this point on is identical to the one described for creating a new test (See **<u>Create A New Test</u>** above).

A selected test can be edited in several ways. The parameters of the test can be edited, and individually selected trials within a test can be edited.

A previously defined trial can be edited in specific details related to that trial (e.g., instructions, maximum trial time, maximum moves, etc); however, the design set-up of the trial (the number of beads, number of pegs, and minimum moves) cannot be changed once it has been defined. Instead, in order to change any of these basic setup features of a specific trial's design, it is necessary to use the Redefine Trial button, and start from scratch in designing the trial.

**Save Current Test**: The Save Current Test button is used to save added or changed features to a given test (and, as described above in "Adding New Trials, it is also used to save additions/changes made to trials within a test). Once a test has been created or edited, the **Save Current Test** button must be clicked to save any additions or changes to the test's parameters. If a user makes changes to a test and attempts to exit without first clicking the Save Current Test button, a warning message pops up asking the user to confirm the wish to exit without saving the changes to the test.

**Delete Current Test**: A test can be deleted by first selecting it from the "Existing Tests" list, then clicking the **Delete Test** button.

## Normative Data

Participants were recruited from a college student population, relatives of students, or from a local senior center. Participants under 18 years of age received five dollars per hour and participants over 60 years of age received 10 dollars per hour. Participants between the ages of 18 and 59 received extra course credit for their participation.

Participants reported no head injuries, neurological diseases, or psychiatric illnesses that they believe would affect their performance.

**Demographics**

| Topic and Age Group | | Mean | Standard Deviation | Standard Error | Sexes Male:Female (same for all variables) |
|---|---|---|---|---|---|
| Age Group | 5 to 9 | 7.13 | 1.36 | .08 | 135:173 |
| | 10 to 14 | 11.95 | 1.45 | .09 | 145:144 |
| | 15 to 19 | 17.9 | 1.26 | .05 | 181:412 |
| | 20s | 22.77 | 2.74 | .11 | 185:487 |
| | 30s | 33.88 | 2.89 | .21 | 56:140 |
| | 40s | 44.39 | 3.07 | .23 | 39:142 |
| | 50s | 53.86 | 2.71 | .22 | 36:119 |
| | 60s | 64.27 | 2.8 | .2 | 56:143 |
| | 70s | 74.55 | 2.83 | .18 | 74:164 |
| | 80s | 83.25 | 2.67 | .24 | 43:79 |

| | | | | |
|---|---|---|---|---|
| Years of Education 5 to 9 | 1.91 | 1.34 | .08 | |
| 10 to 14 | 6.48 | 1.64 | 1.0 | |
| 15 to 19 | 12.57 | 1.42 | .06 | |
| 20s | 14.72 | 1.16 | .05 | |
| 30s | 15.14 | 1.57 | .11 | |
| 40s | 14.92 | 1.9 | .14 | |
| 50s | 15.45 | 2.11 | .17 | |
| 60s | 15.16 | 2.15 | .15 | |
| 70s | 14.69 | 2.57 | .17 | |
| 80s | 14.6 | 2.41 | .22 | |
| WASI Verbal IQ 5 to 9 | 119 | 15 | 2 | |
| 10 to 14 | 124 | 15 | 2 | |
| 15 to 19 | 114 | 13 | 1 | |
| 20s | 114 | 13 | 1 | |
| 30s | 114 | 13 | 2 | |
| 40s | 119 | 10 | 1 | |
| 50s | 122 | 11 | 1 | |
| 60s | 118 | 13 | 1 | |
| 70s | 121 | 13 | 1 | |
| 80s | 121 | 16 | 2 | |
| WASI Performance IQ 5 to 9 | 111 | 20 | 2 | |
| 10 to 14 | 112 | 13 | 1 | |
| 15 to 19 | 109 | 11 | 1 | |
| 20s | 111 | 11 | 1 | |
| 30s | 115 | 14 | 2 | |
| 40s | 115 | 10 | 1 | |
| 50s | 116 | 10 | 1 | |
| 60s | 113 | 14 | 1 | |
| 70s | 120 | 16 | 1 | |
| 80s | 120 | 17 | 2 | |

| | | | | |
|---|---|---|---|---|
| WASI Full IQ 5 to 9 | 118 | 14 | 1 | |
| 10 to 14 | 119 | 13 | 1 | |
| 15 to 19 | 110 | 14 | 1 | |
| 20s | 112 | 11 | 1 | |
| 30s | 116 | 12 | 1 | |
| 40s | 118 | 10 | 1 | |
| 50s | 121 | 10 | 1 | |
| 60s | 118 | 13 | 1 | |
| 70s | 123 | 15 | 1 | |
| 80s | 123 | 16 | 2 | |
| WASI Matrix Raw Score 5 to 9 | 18.44 | 6.82 | .62 | |
| 10 to 14 | 27.51 | 3.92 | .35 | |
| 15 to 19 | 29.11 | 3.75 | .28 | |
| 20s | 29.08 | 3.17 | .21 | |
| 30s | 29.47 | 3.33 | .39 .4 | |
| 40s | 28.98 | 3.7 | .34 | |
| 50s | 27.43 | 3.24 | .46 | |
| 60s | 25.02 | 5.15 | .53 | |
| 70s | 24.11 | 6.9 | .71 | |
| 80s | 19.16 | 6.74 | | |

## Tower of London Excess Moves across 21 Trials for 10 Age Groups

Tower of London Performance by 5-9 Year Olds (N = 300)

| Trial | Mean Errors | Standard Error | 95% Lower Bound | 95% Upper Bound |
|---|---|---|---|---|
| 1 | .397 | .160 | .082 | .711 |

| | | | | |
|---|---|---|---|---|
| 2 | .380 | .043 | .296 | .464 |
| 3 | 1.140 | .094 | .955 | 1.325 |
| 4 | 1.640 | .077 | 1.489 | 1.791 |
| 5 | 1.637 | .085 | 1.470 | 1.803 |
| 6 | .967 | .072 | .825 | 1.108 |
| 7 | 1.017 | .110 | .800 | 1.233 |
| 8 | .917 | .044 | .831 | 1.003 |
| 9 | 2.853 | .101 | 2.655 | 3.052 |
| 10 | 1.507 | .137 | 1.237 | 1.776 |
| 11 | 1.713 | .094 | 1.529 | 1.898 |
| 12 | .940 | .052 | .838 | 1.042 |
| 13 | .590 | .031 | .529 | .651 |
| 14 | 2.120 | .115 | 1.894 | 2.346 |
| 15 | 3.607 | .110 | 3.390 | 3.823 |
| 16 | 8.887 | .401 | 8.100 | 9.674 |
| 17 | 2.387 | .080 | 2.231 | 2.543 |
| 18 | 1.790 | .075 | 1.642 | 1.938 |
| 19 | 4.493 | .227 | 4.049 | 4.938 |
| 20 | 2.897 | .102 | 2.696 | 3.097 |
| 21 | 1.330 | .073 | 1.187 | 1.473 |

-

Tower of London Performance by 10 14 Year Olds (N = 283)

| Trial | Mean Errors | Standard Error | 95% Lower Bound | 95% Upper Bound |
|---|---|---|---|---|
| 1 | .085 | .165 | -.239 | .409 |
| 2 | .021 | .044 | -.066 | .108 |
| 3 | .353 | .097 | .163 | .543 |
| 4 | .420 | .080 | .265 | .576 |
| 5 | .654 | .088 | .482 | .825 |
| 6 | .127 | .074 | -.018 | .273 |
| 7 | .343 | .114 | .120 | .565 |
| 8 | .226 | .045 | .138 | .315 |
| 9 | 1.300 | .104 | 1.096 | 1.505 |
| 10 | .558 | .141 | .281 | .835 |
| 11 | .908 | .097 | .718 | 1.098 |
| 12 | .191 | .054 | .086 | .296 |
| 13 | .191 | .032 | .128 | .254 |
| 14 | 1.180 | .119 | .947 | 1.413 |
| 15 | 1.159 | .114 | .936 | 1.382 |
| 16 | 3.841 | .413 | 3.031 | 4.651 |
| 17 | 1.021 | .082 | .861 | 1.182 |
| 18 | .336 | .078 | .184 | .488 |
| 19 | 2.675 | .234 | 2.217 | 3.133 |
| 20 | 1.035 | .105 | .829 | 1.242 |
| 21 | .548 | .075 | .400 | .695 |

Tower of London Performance by 15 19 Year Olds (N = 568)

| Trial | Mean Errors | Standard Error | 95% Lower Bound | 95% Upper Bound |
|---|---|---|---|---|
| 1 | .058 | .117 | -.171 | .287 |
| 2 | .040 | .031 | -.021 | .102 |
| 3 | .273 | .068 | .139 | .407 |
| 4 | .208 | .056 | .098 | .318 |

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|---|---|---|---|---|
| 5 | .454 | .062 | .333 | .575 |
| 6 | .079 | .052 | -.023 | .182 |
| 7 | .343 | .080 | .186 | .500 |
| 8 | .086 | .032 | .024 | .149 |
| 9 | .741 | .074 | .597 | .886 |
| 10 | .285 | .100 | .090 | .481 |
| 11 | .352 | .068 | .218 | .486 |
| 12 | .083 | .038 | .009 | .157 |
| 13 | .044 | .023 | .000 | .088 |
| 14 | .688 | .084 | .524 | .853 |
| 15 | .588 | .080 | .431 | .745 |
| 16 | 2.125 | .292 | 1.553 | 2.697 |
| 17 | .460 | .058 | .346 | .573 |
| 18 | .215 | .055 | .107 | .322 |
| 19 | 1.708 | .165 | 1.385 | 2.031 |
| 20 | .491 | .074 | .346 | .637 |
| 21 | .315 | .053 | .211 | .419 |

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Tower of London Performance by 20 29 Year Olds (N = 625)

| Trial | Mean Errors | Standard Error | 95% Lower Bound | 95% Upper Bound |
|---|---|---|---|---|
| 1 | .037 | .111 | -.181 | .255 |
| 2 | .019 | .030 | -.039 | .078 |
| 3 | .282 | .065 | .154 | .410 |
| 4 | .179 | .053 | .074 | .284 |
| 5 | .318 | .059 | .203 | .434 |
| 6 | .086 | .050 | -.011 | .184 |
| 7 | .280 | .076 | .130 | .430 |
| 8 | .080 | .030 | .020 | .140 |
| 9 | .480 | .070 | .342 | .618 |
| 10 | .331 | .095 | .145 | .518 |
| 11 | .314 | .065 | .186 | .441 |
| 12 | .061 | .036 | -.010 | .132 |
| 13 | .022 | .022 | -.020 | .065 |
| 14 | .350 | .080 | .194 | .507 |
| 15 | .384 | .077 | .234 | .534 |
| 16 | 2.426 | .278 | 1.880 | 2.971 |
| 17 | .432 | .055 | .324 | .540 |
| 18 | .142 | .052 | .040 | .245 |
| 19 | 1.696 | .157 | 1.388 | 2.004 |
| 20 | .482 | .071 | .343 | .620 |
| 21 | .122 | .051 | .022 | .221 |

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Tower of London Performance by 30 39 Year Olds (N = 184)

| Trial | Mean Errors | Standard Error | 95% Lower Bound | 95% Upper Bound |
|---|---|---|---|---|
| 1 | .136 | .205 | -.266 | .538 |
| 2 | .049 | .055 | -.059 | .157 |
| 3 | .174 | .120 | -.062 | .410 |
| 4 | .261 | .099 | .068 | .454 |
| 5 | .489 | .109 | .276 | .702 |
| 6 | .033 | .092 | -.148 | .213 |
| 7 | .185 | .141 | -.091 | .461 |
| 8 | .060 | .056 | -.050 | .170 |
| 9 | .582 | .129 | .328 | .835 |
| 10 | .283 | .175 | -.061 | .626 |
| 11 | .255 | .120 | .020 | .491 |
| 12 | .049 | .066 | -.081 | .179 |
| 13 | .071 | .040 | -.007 | .148 |
| 14 | .201 | .147 | -.088 | .490 |
| 15 | .315 | .141 | .039 | .592 |
| 16 | 1.978 | .513 | .973 | 2.983 |
| 17 | .505 | .102 | .306 | .705 |
| 18 | .168 | .096 | -.020 | .357 |
| 19 | 1.630 | .290 | 1.063 | 2.198 |
| 20 | .386 | .131 | .130 | .642 |
| 21 | .185 | .093 | .002 | .368 |

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Tower of London Performance by 40 49 Year Olds (N = 174)

| Trial | Mean Errors | Standard Error | 95% Lower Bound | 95% Upper Bound |
|---|---|---|---|---|
| 1 | .856 | .211 | .443 | 1.270 |
| 2 | .017 | .057 | -.094 | .128 |
| 3 | .230 | .124 | -.013 | .472 |
| 4 | .385 | .101 | .186 | .584 |
| 5 | .368 | .112 | .149 | .587 |
| 6 | .103 | .095 | -.082 | .289 |
| 7 | .253 | .145 | -.031 | .537 |
| 8 | .075 | .058 | -.038 | .188 |
| 9 | .523 | .133 | .262 | .784 |
| 10 | .448 | .180 | .095 | .802 |
| 11 | .241 | .123 | -.001 | .484 |
| 12 | .034 | .068 | -.100 | .169 |
| 13 | .040 | .041 | -.040 | .120 |
| 14 | .190 | .151 | -.107 | .487 |
| 15 | .391 | .145 | .106 | .675 |
| 16 | 2.172 | .527 | 1.139 | 3.206 |
| 17 | .529 | .104 | .324 | .734 |
| 18 | .213 | .099 | .019 | .407 |

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|---|---|---|---|---|
| 19 | 1.264 | .298 | .680 | 1.848 |
| 20 | .299 | .134 | .036 | .562 |
| 21 | .167 | .096 | -.021 | .355 |

Tower of London Performance by 50 59 Year Olds (N = 144)

| Trial | Mean Errors | Standard Error | 95% Lower Bound | 95% Upper Bound |
|---|---|---|---|---|
| 1 | .090 | .232 | -.364 | .544 |
| 2 | .035 | .062 | -.087 | .157 |
| 3 | .250 | .136 | -.017 | .517 |
| 4 | .271 | .111 | .052 | .489 |
| 5 | .375 | .123 | .134 | .616 |
| 6 | .118 | .104 | -.086 | .322 |
| 7 | .361 | .159 | .049 | .673 |
| 8 | .056 | .063 | -.069 | .180 |
| 9 | .410 | .146 | .123 | .696 |
| 10 | .306 | .198 | -.083 | .694 |
| 11 | .208 | .136 | -.058 | .474 |
| 12 | .118 | .075 | -.029 | .265 |
| 13 | .069 | .045 | -.019 | .157 |
| 14 | .299 | .166 | -.028 | .625 |

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|---|---|---|---|---|
| 15 | .444 | .159 | .132 | .757 |
| 16 | 2.521 | .579 | 1.385 | 3.657 |
| 17 | .417 | .115 | .192 | .642 |
| 18 | .243 | .109 | .030 | .456 |
| 19 | 1.556 | .327 | .914 | 2.198 |
| 20 | .472 | .148 | .183 | .762 |
| 21 | .146 | .105 | -.061 | .353 |

Tower of London Performance by 60 69 Year Olds (N = 186)

| Trial | Mean Errors | Standard Error | 95% Lower Bound | 95% Upper Bound |
|---|---|---|---|---|
| 1 | .253 | .204 | -.147 | .652 |
| 2 | .102 | .055 | -.005 | .209 |
| 3 | .565 | .120 | .330 | .799 |
| 4 | .554 | .098 | .361 | .746 |
| 5 | .478 | .108 | .267 | .690 |
| 6 | .204 | .092 | .025 | .384 |
| 7 | .333 | .140 | .059 | .608 |
| 8 | .097 | .056 | -.012 | .206 |
| 9 | .812 | .129 | .560 | 1.064 |
| 10 | .575 | .174 | .233 | .917 |

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|---|---|---|---|---|
| 11 | .344 | .119 | .110 | .578 |
| 12 | .065 | .066 | -.065 | .194 |
| 13 | .016 | .039 | -.061 | .094 |
| 14 | .414 | .146 | .127 | .701 |
| 15 | .763 | .140 | .488 | 1.039 |
| 16 | 3.005 | .510 | 2.006 | 4.005 |
| 17 | .543 | .101 | .345 | .741 |
| 18 | .296 | .096 | .108 | .483 |
| 19 | 1.828 | .288 | 1.263 | 2.393 |
| 20 | .828 | .130 | .573 | 1.083 |
| 21 | .231 | .093 | .049 | .413 |

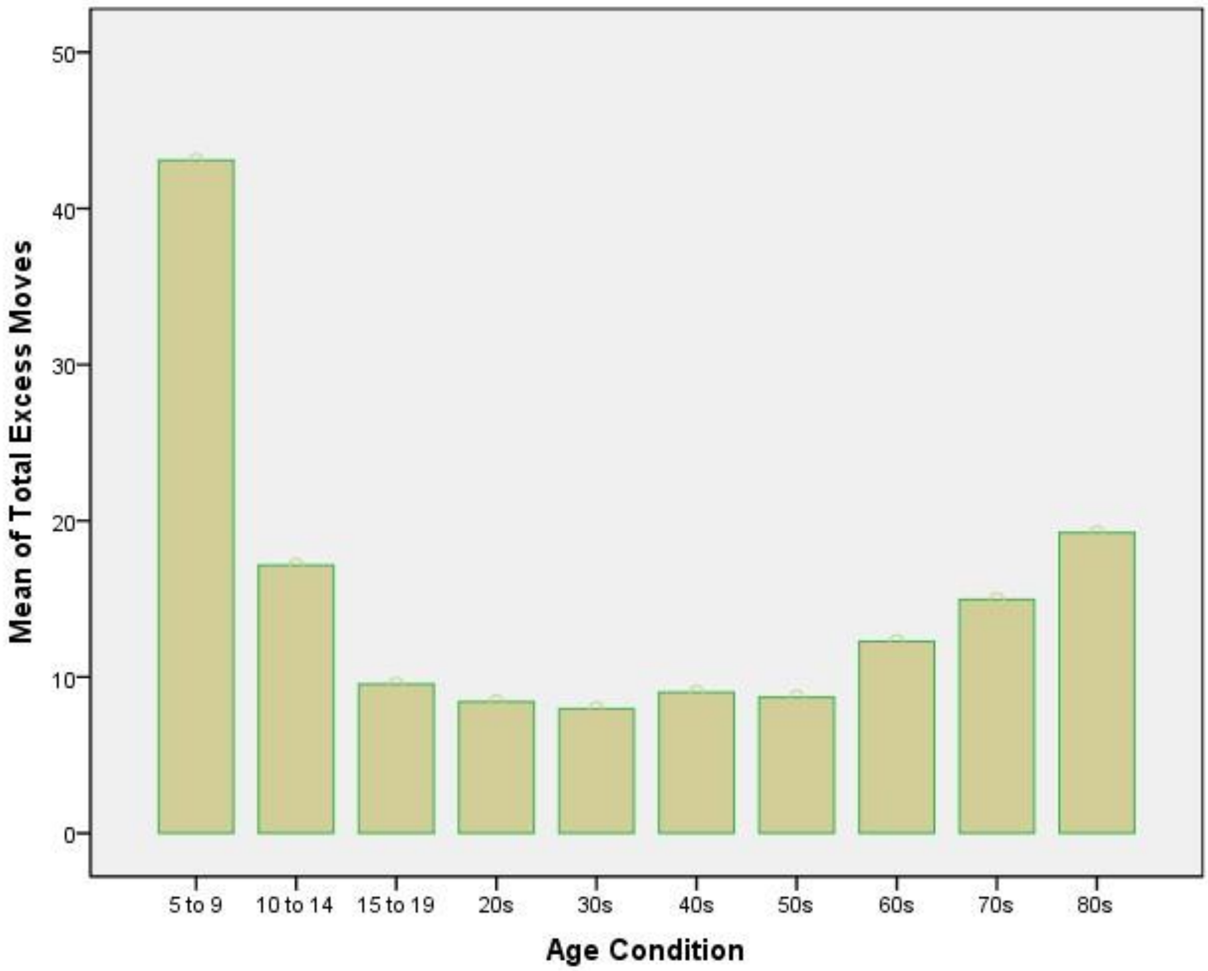
Tower of London Performance by 70-79 Year Olds (N = 225)

| Trial | Mean Errors | Standard Error | 95% Lower Bound | 95% Upper Bound |
|---|---|---|---|---|
| 1 | .120 | .185 | -.243 | .483 |
| 2 | .116 | .050 | .018 | .213 |
| 3 | .707 | .109 | .493 | .920 |
| 4 | .791 | .089 | .616 | .966 |
| 5 | .769 | .098 | .576 | .961 |
| 6 | .342 | .083 | .179 | .505 |
| 7 | .609 | .127 | .359 | .859 |
| 8 | .227 | .051 | .127 | .326 |
| 9 | .756 | .117 | .526 | .985 |
| 10 | .982 | .159 | .671 | 1.293 |
| 11 | .324 | .109 | .112 | .537 |
| 12 | .276 | .060 | .158 | .393 |
| 13 | .071 | .036 | .001 | .141 |
| 14 | .596 | .133 | .334 | .857 |
| 15 | 1.120 | .128 | .870 | 1.370 |
| 16 | 2.600 | .464 | 1.691 | 3.509 |
| 17 | .956 | .092 | .775 | 1.136 |
| 18 | .453 | .087 | .283 | .624 |
| 19 | 1.840 | .262 | 1.326 | 2.354 |
| 20 | 1.022 | .118 | .791 | 1.254 |
| 21 | .286 | .084 | .120 | .451 |

Tower of London Performance by 80-89 Year Olds (N = 117)

| Trial | Mean Errors | Standard Error | 95% Lower Bound | 95% Upper Bound |
|---|---|---|---|---|
| 1 | .248 | .257 | -.256 | .752 |
| 2 | .085 | .069 | -.050 | .221 |
| 3 | 1.162 | .151 | .867 | 1.458 |
| 4 | .615 | .124 | .373 | .858 |
| 5 | .838 | .136 | .571 | 1.105 |
| 6 | .350 | .115 | .124 | .577 |
| 7 | .350 | .177 | .004 | .697 |
| 8 | .496 | .070 | .358 | .633 |
| 9 | 1.265 | .162 | .947 | 1.583 |
| 10 | 1.009 | .220 | .578 | 1.440 |
| 11 | 1.026 | .151 | .730 | 1.321 |
| 12 | .316 | .083 | .153 | .480 |
| 13 | .145 | .050 | .048 | .243 |
| 14 | .940 | .185 | .578 | 1.302 |
| 15 | 1.436 | .177 | 1.089 | 1.783 |
| 16 | 3.855 | .643 | 2.594 | 5.115 |
| 17 | .991 | .127 | .742 | 1.241 |
| 18 | .641 | .121 | .404 | .878 |
| 19 | 1.538 | .363 | .826 | 2.251 |
| 20 | 1.573 | .164 | 1.252 | 1.894 |
| 21 | .359 | .117 | .130 | .588 |

**Total Excess Moves across 21 Tower of London Trails by Age Group**




**Tower of London First Move Think Time (msec)**

**across 21 Trials for 10 Age Groups**

Tower of London First Move Time (MSEC) by 5-9 Year Olds (N = 126)

| Trial | Mean Time | Standard Error | 95% Lower Bound | 95% Upper Bound |
|---|---|---|---|---|
| 1 | 7125.548 | 596.561 | 5955.135 | 8295.961 |
| 2 | 5564.341 | 495.077 | 4593.033 | 6535.650 |
| 3 | 6742.214 | 659.735 | 5447.859 | 8036.570 |
| 4 | 6726.056 | 562.435 | 5622.596 | 7829.515 |
| 5 | 6971.548 | 312.939 | 6357.582 | 7585.513 |
| 6 | 7866.341 | 388.170 | 7104.778 | 8627.905 |
| 7 | 8600.532 | 811.894 | 7007.649 | 10193.414 |
| 8 | 5774.397 | 313.116 | 5160.083 | 6388.710 |
| 9 | 7072.865 | 403.209 | 6281.795 | 7863.935 |
| 10 | 6482.651 | 458.318 | 5583.462 | 7381.839 |
| 11 | 6955.016 | 353.227 | 6262.009 | 7648.023 |
| 12 | 11070.810 | 1487.306 | 8152.815 | 13988.804 |
| 13 | 6525.698 | 521.589 | 5502.376 | 7549.021 |
| 14 | 8002.373 | 563.171 | 6897.469 | 9107.277 |
| 15 | 8028.579 | 847.111 | 6366.604 | 9690.554 |
| 16 | 7369.056 | 707.637 | 5980.720 | 8757.391 |
| 17 | 7592.937 | 579.860 | 6455.290 | 8730.583 |
| 18 | 8681.913 | 543.405 | 7615.789 | 9748.037 |
| 19 | 7043.944 | 766.955 | 5539.229 | 8548.660 |
| 20 | 8709.429 | 712.922 | 7310.724 | 10108.133 |
| 21 | 9700.698 | 608.594 | 8506.679 | 10894.718 |

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Tower of London First Move Time (MSEC) by 10 14 Year Olds (N = 136)

| Trial | Mean Time | Standard Error | 95% Lower Bound | 95% Upper Bound |
|---|---|---|---|---|
| 1 | 6075.684 | 574.210 | 4949.122 | 7202.245 |
| 2 | 4355.426 | 476.529 | 3420.509 | 5290.344 |
| 3 | 4162.706 | 635.017 | 2916.845 | 5408.566 |
| 4 | 5786.596 | 541.362 | 4724.479 | 6848.712 |
| 5 | 5887.963 | 301.214 | 5297.001 | 6478.926 |
| 6 | 5580.213 | 373.627 | 4847.183 | 6313.243 |
| 7 | 6629.485 | 781.476 | 5096.283 | 8162.688 |
| 8 | 5187.662 | 301.385 | 4596.364 | 5778.959 |
| 9 | 5358.029 | 388.102 | 4596.598 | 6119.460 |
| 10 | 4594.831 | 441.146 | 3729.332 | 5460.330 |
| 11 | 4150.640 | 339.993 | 3483.597 | 4817.682 |
| 12 | 4221.243 | 1431.582 | 1412.575 | 7029.910 |
| 13 | 4841.640 | 502.047 | 3856.658 | 5826.622 |
| 14 | 6810.816 | 542.071 | 5747.309 | 7874.323 |
| 15 | 7786.838 | 815.373 | 6187.132 | 9386.545 |
| 16 | 5078.456 | 681.124 | 3742.137 | 6414.775 |
| 17 | 5004.574 | 558.134 | 3909.551 | 6099.596 |
| 18 | 5465.735 | 523.045 | 4439.555 | 6491.915 |
| 19 | 6355.375 | 738.220 | 4907.036 | 7803.714 |
| 20 | 4316.676 | 686.211 | 2970.376 | 5662.976 |
| 21 | 5740.728 | 585.792 | 4591.444 | 6890.012 |

Tower of London First Move Time (MSEC) by 15 19 Year Olds (N = 258)

| Trial | Mean Time | Standard Error | 95% Lower Bound | 95% Upper Bound |
|---|---|---|---|---|
| 1 | 5577.360 | 416.899 | 4759.433 | 6395.287 |
| 2 | 3772.682 | 345.978 | 3093.896 | 4451.468 |
| 3 | 3534.919 | 461.047 | 2630.376 | 4439.461 |
| 4 | 5552.895 | 393.050 | 4781.758 | 6324.033 |

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|---|---|---|---|---|
| 5 | 5260.888 | 218.693 | 4831.826 | 5689.949 |
| 6 | 4881.806 | 271.267 | 4349.598 | 5414.014 |
| 7 | 6978.748 | 567.381 | 5865.584 | 8091.912 |
| 8 | 4337.364 | 218.817 | 3908.060 | 4766.669 |
| 9 | 4723.570 | 281.777 | 4170.742 | 5276.398 |
| 10 | 4377.488 | 320.289 | 3749.103 | 5005.874 |
| 11 | 3692.864 | 246.848 | 3208.566 | 4177.163 |
| 12 | 3573.357 | 1039.383 | 1534.156 | 5612.557 |
| 13 | 4645.682 | 364.505 | 3930.547 | 5360.817 |
| 14 | 6069.395 | 393.564 | 5297.248 | 6841.542 |
| 15 | 7192.442 | 591.992 | 6030.993 | 8353.890 |
| 16 | 6886.391 | 494.522 | 5916.172 | 7856.611 |
| 17 | 4462.795 | 405.227 | 3667.766 | 5257.823 |
| 18 | 4500.523 | 379.751 | 3755.477 | 5245.569 |
| 19 | 6952.837 | 535.976 | 5901.288 | 8004.387 |
| 20 | 4120.481 | 498.216 | 3143.015 | 5097.946 |
| 21 | 5246.992 | 425.307 | 4412.568 | 6081.417 |

Tower of London First Move Time (MSEC) by 20 29 Year Olds (N = 285)

| Trial | Mean Time | Standard Error | 95% Lower Bound | 95% Upper Bound |
|---|---|---|---|---|
| 1 | 5857.898 | 396.659 | 5079.679 | 6636.117 |
| 2 | 3598.761 | 329.182 | 2952.929 | 4244.594 |
| 3 | 3828.537 | 438.664 | 2967.907 | 4689.167 |
| 4 | 5715.239 | 373.969 | 4981.537 | 6448.940 |
| 5 | 4967.270 | 208.076 | 4559.038 | 5375.502 |
| 6 | 5115.281 | 258.098 | 4608.910 | 5621.652 |
| 7 | 7086.189 | 539.837 | 6027.066 | 8145.313 |
| 8 | 4165.326 | 208.194 | 3756.863 | 4573.790 |

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|---|---|---|---|---|
| 9 | 5047.446 | 268.098 | 4521.456 | 5573.436 |
| 10 | 4418.642 | 304.740 | 3820.763 | 5016.521 |
| 11 | 3494.039 | 234.864 | 3033.251 | 3954.826 |
| 12 | 4559.596 | 988.925 | 2619.393 | 6499.800 |
| 13 | 4635.460 | 346.810 | 3955.042 | 5315.877 |
| 14 | 6351.561 | 374.458 | 5616.900 | 7086.223 |
| 15 | 7026.674 | 563.253 | 5921.610 | 8131.737 |
| 16 | 6826.091 | 470.515 | 5902.973 | 7749.209 |
| 17 | 4429.656 | 385.555 | 3673.224 | 5186.088 |
| 18 | 4399.930 | 361.315 | 3691.053 | 5108.806 |
| 19 | 8426.456 | 509.956 | 7425.956 | 9426.956 |
| 20 | 4521.498 | 474.029 | 3591.486 | 5451.511 |
| 21 | 5465.568 | 404.660 | 4671.653 | 6259.484 |

Tower of London First Move Time (MSEC) by 30 39 Year Olds (N = 82)

| Trial | Mean Time | Standard Error | 95% Lower Bound | 95% Upper Bound |
|---|---|---|---|---|
| 1 | 7390.720 | 739.492 | 5939.886 | 8841.553 |
| 2 | 4027.122 | 613.693 | 2823.097 | 5231.147 |
| 3 | 4461.280 | 817.801 | 2856.809 | 6065.752 |
| 4 | 7662.866 | 697.189 | 6295.027 | 9030.704 |
| 5 | 6217.744 | 387.917 | 5456.678 | 6978.810 |
| 6 | 5799.805 | 481.172 | 4855.778 | 6743.832 |
| 7 | 8222.317 | 1006.417 | 6247.794 | 10196.840 |
| 8 | 5112.085 | 388.136 | 4350.588 | 5873.583 |
| 9 | 5871.671 | 499.815 | 4891.068 | 6852.273 |
| 10 | 6253.317 | 568.126 | 5138.691 | 7367.943 |
| 11 | 4389.427 | 437.857 | 3530.381 | 5248.472 |
| 12 | 4232.280 | 1843.651 | 615.161 | 7849.400 |

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|---|---|---|---|---|
| 13 | 6514.098 | 646.557 | 5245.597 | 7782.599 |
| 14 | 7792.049 | 698.102 | 6422.420 | 9161.678 |
| 15 | 9224.610 | 1050.071 | 7164.441 | 11284.779 |
| 16 | 9109.573 | 877.180 | 7388.605 | 10830.541 |
| 17 | 5766.573 | 718.789 | 4356.357 | 7176.789 |
| 18 | 5644.098 | 673.600 | 4322.540 | 6965.655 |
| 19 | 9769.732 | 950.711 | 7904.501 | 11634.963 |
| 20 | 5550.232 | 883.731 | 3816.410 | 7284.053 |
| 21 | 6744.183 | 754.407 | 5264.087 | 8224.279 |

Tower of London First Move Time (MSEC) by 40 49 Year Olds (N = 73)

| Trial | Mean Time | Standard Error | 95% Lower Bound | 95% Upper Bound |
|---|---|---|---|---|
| 1 | 8082.438 | 783.752 | 6544.769 | 9620.108 |
| 2 | 4396.014 | 650.425 | 3119.924 | 5672.103 |
| 3 | 4419.041 | 866.749 | 2718.538 | 6119.544 |
| 4 | 6944.342 | 738.918 | 5494.635 | 8394.050 |
| 5 | 6090.836 | 411.134 | 5284.217 | 6897.454 |
| 6 | 6139.904 | 509.971 | 5139.375 | 7140.434 |
| 7 | 8273.274 | 1066.654 | 6180.571 | 10365.977 |
| 8 | 5280.986 | 411.367 | 4473.911 | 6088.061 |
| 9 | 5731.877 | 529.730 | 4692.582 | 6771.171 |
| 10 | 6608.685 | 602.130 | 5427.346 | 7790.024 |
| 11 | 4410.055 | 464.064 | 3499.593 | 5320.516 |
| 12 | 4911.904 | 1953.998 | 1078.290 | 8745.518 |
| 13 | 6015.356 | 685.255 | 4670.932 | 7359.780 |
| 14 | 7184.260 | 739.885 | 5732.655 | 8635.865 |
| 15 | 9943.479 | 1112.921 | 7760.004 | 12126.955 |
| 16 | 8332.479 | 929.681 | 6508.507 | 10156.452 |

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|---|---|---|---|---|
| 17 | 5264.685 | 761.810 | 3770.064 | 6759.306 |
| 18 | 5363.452 | 713.917 | 3962.796 | 6764.108 |
| 19 | 11297.247 | 1007.613 | 9320.376 | 13274.117 |
| 20 | 5313.712 | 936.625 | 3476.117 | 7151.308 |
| 21 | 7881.808 | 799.560 | 6313.124 | 9450.492 |

Tower of London First Move Time (MSEC) by 50 59 Year Olds (N = 65)

| Trial | Mean Time | Standard Error | 95% Lower Bound | 95% Upper Bound |
|---|---|---|---|---|
| 1 | 9921.431 | 830.584 | 8291.881 | 11550.981 |
| 2 | 8507.831 | 689.290 | 7155.491 | 9860.171 |
| 3 | 4892.108 | 918.540 | 3089.994 | 6694.222 |
| 4 | 8488.908 | 783.071 | 6952.576 | 10025.240 |
| 5 | 6629.046 | 435.701 | 5774.230 | 7483.862 |
| 6 | 6347.554 | 540.444 | 5287.240 | 7407.868 |
| 7 | 9589.754 | 1130.390 | 7372.005 | 11807.503 |
| 8 | 6028.262 | 435.948 | 5172.961 | 6883.562 |
| 9 | 7636.077 | 561.383 | 6534.681 | 8737.472 |
| 10 | 7433.231 | 638.109 | 6181.303 | 8685.159 |
| 11 | 4936.862 | 491.793 | 3971.997 | 5901.726 |
| 12 | 5265.046 | 2070.756 | 1202.362 | 9327.731 |
| 13 | 7553.415 | 726.201 | 6128.658 | 8978.173 |
| 14 | 9109.431 | 784.096 | 7571.088 | 10647.774 |
| 15 | 10297.246 | 1179.421 | 7983.301 | 12611.192 |
| 16 | 11328.785 | 985.233 | 9395.824 | 13261.745 |
| 17 | 6902.246 | 807.331 | 5318.317 | 8486.175 |
| 18 | 7012.108 | 756.575 | 5527.758 | 8496.458 |
| 19 | 13200.708 | 1067.822 | 11105.713 | 15295.702 |

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|---|---|---|---|---|
| 20 | 6748.831 | 992.591 | 4801.433 | 8696.228 |
| 21 | 8651.708 | 847.337 | 6989.290 | 10314.125 |

Tower of London First Move Time (MSEC) by 60 69 Year Olds (N = 73)

| Trial | Mean Time | Standard Error | 95% Lower Bound | 95% Upper Bound |
|---|---|---|---|---|
| 1 | 11808.671 | 783.752 | 10271.002 | 13346.341 |
| 2 | 5261.521 | 650.425 | 3985.431 | 6537.610 |
| 3 | 5198.384 | 866.749 | 3497.880 | 6898.887 |
| 4 | 10512.466 | 738.918 | 9062.758 | 11962.173 |
| 5 | 7074.411 | 411.134 | 6267.793 | 7881.029 |
| 6 | 7307.123 | 509.971 | 6306.594 | 8307.653 |
| 7 | 11270.644 | 1066.654 | 9177.941 | 13363.347 |
| 8 | 5945.973 | 411.367 | 5138.898 | 6753.048 |
| 9 | 8112.493 | 529.730 | 7073.199 | 9151.788 |
| 10 | 6243.425 | 602.130 | 5062.086 | 7424.764 |
| 11 | 5542.384 | 464.064 | 4631.922 | 6452.845 |
| 12 | 5733.301 | 1953.998 | 1899.688 | 9566.915 |
| 13 | 7106.110 | 685.255 | 5761.685 | 8450.534 |
| 14 | 8819.274 | 739.885 | 7367.669 | 10270.879 |

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| | | | | |
|---|---|---|---|---|
| 15 | 12556.452 | 1112.921 | 10372.976 | 14739.928 |
| 16 | 10508.521 | 929.681 | 8684.548 | 12332.493 |
| 17 | 6620.726 | 761.810 | 5126.105 | 8115.347 |
| 18 | 6932.521 | 713.917 | 5531.864 | 8333.177 |
| 19 | 11796.260 | 1007.613 | 9819.390 | 13773.130 |
| 20 | 7926.616 | 936.625 | 6089.021 | 9764.212 |
| 21 | 9646.603 | 799.560 | 8077.919 | 11215.287 |

Tower of London First Move Time (MSEC) by 70 79 Year Olds (N = 92)

| Trial | Mean Time | Standard Error | 95% Lower Bound | 95% Upper Bound |
|---|---|---|---|---|
| 1 | 14456.424 | 698.146 | 13086.708 | 15826.140 |
| 2 | 8093.891 | 579.381 | 6957.184 | 9230.599 |
| 3 | 7017.185 | 772.077 | 5502.421 | 8531.949 |
| 4 | 13766.207 | 658.209 | 12474.845 | 15057.568 |
| 5 | 9244.022 | 366.228 | 8525.507 | 9962.536 |
| 6 | 11050.815 | 454.269 | 10159.570 | 11942.061 |
| 7 | 14750.457 | 950.147 | 12886.331 | 16614.582 |
| 8 | 9845.413 | 366.435 | 9126.492 | 10564.335 |
| 9 | 10053.033 | 471.870 | 9127.256 | 10978.809 |
| 10 | 9329.935 | 536.362 | 8277.629 | 10382.241 |
| 11 | 8370.185 | 413.376 | 7559.169 | 9181.200 |
| 12 | 8888.685 | 1740.571 | 5473.801 | 12303.568 |
| 13 | 11979.870 | 610.407 | 10782.292 | 13177.448 |
| 14 | 12108.587 | 659.070 | 10815.535 | 13401.639 |
| 15 | 16603.902 | 991.361 | 14658.919 | 18548.885 |
| 16 | 11319.815 | 828.136 | 9695.068 | 12944.562 |
| 17 | 10410.391 | 678.601 | 9079.022 | 11741.761 |
| 18 | 11591.250 | 635.938 | 10343.582 | 12838.918 |
| 19 | 15246.087 | 897.556 | 13485.143 | 17007.031 |
| 20 | 11723.522 | 834.321 | 10086.640 | 13360.404 |

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| | | | | |
|---|---|---|---|---|
| 21 | 12579.630 | 712.228 | 11182.288 | 13976.973 |

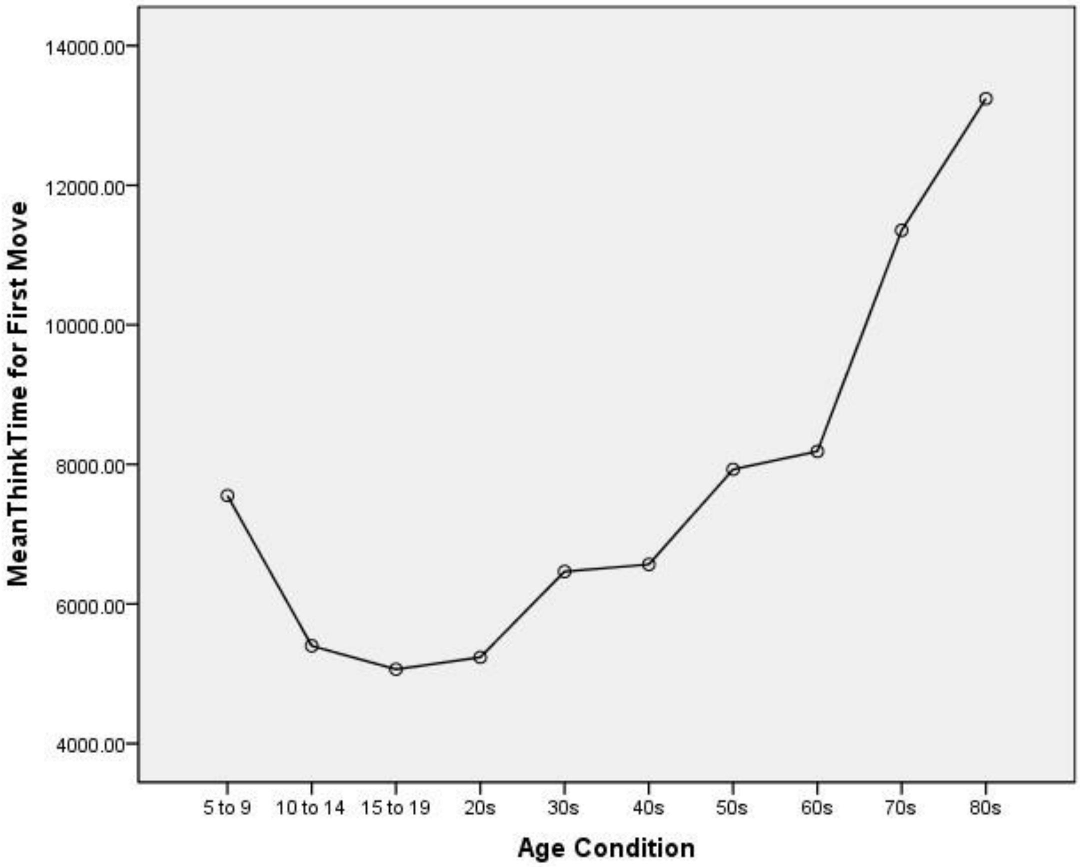
Tower of London First Move Time (MSEC) by 80 89 Year Olds (N = 26)

| Trial | Mean Time | Standard Error | 95% Lower Bound | 95% Upper Bound |
|---|---|---|---|---|
| 1 | 16161.538 | 1313.269 | 13584.994 | 18738.083 |
| 2 | 11282.038 | 1089.862 | 9143.801 | 13420.276 |
| 3 | 9653.731 | 1452.339 | 6804.339 | 12503.123 |
| 4 | 15913.962 | 1238.143 | 13484.807 | 18343.116 |
| 5 | 11360.423 | 688.904 | 10008.840 | 12712.006 |
| 6 | 11576.808 | 854.517 | 9900.304 | 13253.312 |
| 7 | 18071.577 | 1787.303 | 14565.008 | 21578.146 |
| 8 | 10706.269 | 689.294 | 9353.920 | 12058.618 |
| 9 | 12586.692 | 887.624 | 10845.233 | 14328.152 |
| 10 | 9366.077 | 1008.940 | 7386.605 | 11345.549 |
| 11 | 7514.154 | 777.593 | 5988.569 | 9039.739 |
| 12 | 12377.231 | 3274.153 | 5953.562 | 18800.899 |
| 13 | 13655.077 | 1148.225 | 11402.337 | 15907.817 |
| 14 | 19365.154 | 1239.764 | 16932.820 | 21797.488 |
| 15 | 22957.423 | 1864.829 | 19298.754 | 26616.092 |
| 16 | 14432.846 | 1557.790 | 11376.567 | 17489.125 |
| 17 | 9577.385 | 1276.502 | 7072.973 | 12081.797 |
| 18 | 13354.731 | 1196.251 | 11007.767 | 15701.694 |
| 19 | 13734.692 | 1688.374 | 10422.215 | 17047.169 |
| 20 | 8764.923 | 1569.425 | 5685.817 | 11844.029 |
| 21 | 15660.231 | 1339.757 | 13031.718 | 18288.744 |

**Mean First Move Planning Time in Msec. for Tower of London Problems**

MeanThinkTime

| | N | Mean | Std. Deviation | Std. Error | 95% Confidence Interval for Mean | | Minimum | Maximum |
|---|---|---|---|---|---|---|---|---|
| | | | | | Lower Bound | Upper Bound | | |
| 5 to 9 | 126 | 7552.7116 | 4319.15988 | 384.78134 | 6791.1816 | 8314.2417 | 3640.29 | 36825.67 |
| 10 to 14 | 136 | 5399.5865 | 1422.48505 | 121.97709 | 5158.3533 | 5640.8196 | 2337.76 | 10051.76 |
| 15 to 19 | 258 | 5063.8800 | 1947.83372 | 121.26683 | 4825.0768 | 5302.6832 | 2434.14 | 16183.10 |
| 20s | 285 | 5235.1009 | 2024.44372 | 119.91770 | 4999.0607 | 5471.1412 | 2456.29 | 18741.43 |
| 30s | 82 | 6464.5610 | 2559.76947 | 282.67925 | 5902.1179 | 7027.0040 | 2520.33 | 21016.57 |
| 40s | 73 | 6565.9922 | 4279.01394 | 500.82070 | 5567.6244 | 7564.3600 | 2990.95 | 38087.95 |
| 50s | 65 | 7927.6469 | 3547.94102 | 440.06792 | 7048.5101 | 8806.7836 | 3077.81 | 18105.81 |
| 60s | 73 | 8186.8513 | 4745.86973 | 555.46204 | 7079.5579 | 9294.1446 | 2810.81 | 32689.86 |
| 70s | 92 | 11353.7764 | 6447.27751 | 672.17515 | 10018.5830 | 12688.9698 | 3234.76 | 43192.95 |
| 80s | 26 | 13241.5696 | 6202.26314 | 1216.36388 | 10736.4213 | 15746.7179 | 2823.14 | 30397.10 |
| Total | 1216 | 6575.3677 | 3927.32435 | 112.62375 | 6354.4091 | 6796.3263 | 2337.76 | 43192.95 |

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# INDEX

6