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An Analysis of Pre and Post-COVID-19 Lockdown Spatial Ability Performance in Blind and Low-Vision Individuals

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Abstract

Historically, spatial ability assessments have been used to measure spatial thinking on specific constructs in students participating in science, technology, engineering, and mathematics (STEM) courses. High spatial ability is linked to greater performance in STEM courses and professional STEM career fields. A spatial ability test used commonly for this measurement is the Mental Cutting Test (MCT) developed in 1939 by the College Entrance Examination Board (CEEB). Unfortunately, the MCT is unable to measure the spatial ability of blind or low-vision (BLV) populations because it is only available in print with visual graphics.

In 2018, a research lab from Utah State University (USU) adapted the MCT into a fully accessible tactile version, called the Tactile Mental Cutting Test (TMCT). The test was split into two parallel forms, each containing 12 different questions from the MCT. The TMCT allows for researchers to measure and understand the spatial abilities of BLV populations. The majority of BLV participants that have taken the TMCT previously have been students at rehabilitation training centers, where congenitally and adventitiously BLV people go to develop blindness skills (e.g., cane travel, Braille) and independence. Additional data has been collected at the National Federation of the Blind's (NFB) summer youth engineering programs as well as national and state NFB conventions.

During the pandemic of COVID-19, many training centers across the country were closed for safety reasons, and many BLV people, like sighted people, were confined to their homes to avoid infection risk. In this paper, we compare pre-COVID-19 and post-COVID 19 (2021) TMCT assessment data from 74 BLV participants including scores and test duration between 2019 and 2022. The pre-COVID group consisted of 27 participants and the post-COVID group consisted of 47 participants. Results show a statistically significant difference in how long it took participants to complete the TMCT between the two timeframes. We hypothesize that this time difference is due to post-2021 participants experiencing general burnout and lower spatial awareness as a result of the effects from the COVID-19 pandemic.

Introduction

The ability to represent, manipulate, and transform mental imagery has often been defined as spatial ability [1]. Research has shown that students with higher spatial ability tend to perform better in both STEM educational settings and STEM occupations [2]. Furthermore, we know from previous research that spatial ability is something that can be improved upon over time through the implementation of interventions and/or training [3]. These findings highlight the importance of assessing spatial ability for future performance predictions, and also for the implementation of effective interventions and/or training for increasing spatial ability.

Most previously designed spatial ability assessments have been designed as visual tests, such as the Mental Cutting Test (MCT), the Mental Rotation Test (MRT), and the Purdue Spatial Visualization Test: Rotations (PSVT:R). The MCT in particular is a commonly used assessment that is comprised of a paper and pencil test of 25 problems where the participant must identify the correct cross-sectional shape of an object that is being divided by a two-dimensional illustrated plane [4]. The MCT has been evaluated as an effective and reliable assessment for measuring spatial ability [5]. However, one drawback of the MCT and all other visual spatial ability tests, is that because of their visual-only accessible format they are not able to be taken by blind or low vision (BLV) populations. A lack of accessibility for the BLV populations among standard STEM assessments is not surprising however, as historically BLV populations have been largely excluded from STEM since STEM content in the past has been deemed too visual [6]. Spatial ability has been generally understood as arising from visual perception [7]. However, past studies have shown that blind individuals are able to use their other senses, such as touch, proprioception, kinesthesia, and audition to acquire and develop spatial knowledge [7] - [8]. Tactile information acquired through touch, for example, can help blind individuals with spatial mapping and orientation skills, such as when navigating environments [9]. Furthermore, research has shown that multisensory tools and learning methods can help BLV populations to learn science and develop spatial-cognitive abilities [10] - [11].

In order to help further the body of literature surrounding BLV populations and their spatial ability in STEM, a research team from Utah State University (USU) created a tactile adaptation of the MCT assessment that is fully accessible to BLV populations, the Tactile Mental Cutting Test (TMCT). The TMCT draws direct inspiration from the MCT paper version, and presents the isometrically illustrated MCT items to the BLV populations as 3-D printed tactually accessible objects [5]. The MCT answer key was also adapted into an accessible tactile graphic version with Braille labels for the TMCT [5]. The TMCT has since been split into two parallel forms of equal difficulty, each using 12 different questions from the original TMCT [12].The TMCT has been found to be a reliable spatial ability instrument among small-samples of BLV people [13], and has the potential to help researchers better assess and understand how spatial ability develops, changes, and compares among the BLV populations [5]. Specifically, the TMCT has been used to aid research in qualitatively identifying spatial strategies used by BLV populations when completing tactile spatial exercises [14].

Since 2018, the TMCT has been used to gather data from BLV populations that participate in training centers for the blind, youth STEM programs sponsored by the National federation of the Blind (NFB), and national and state NFB conventions [13]. These training centers, STEM programs, and conventions serve to help BLV populations to maintain and further develop their skills and abilities, spatial ability included. During the height of the COVID-19 pandemic (defined here as post March 2020 to June 2021) many BLV individuals lost or had restricted access to educational services and training centers for the blind [15] - [16]. Restricted access to education and training centers led to missed opportunities for hands-on-work-based learning and important skill development in the community [15]. Also, social distancing guidelines and fear of receiving the virus through physical contact created a physical barrier for many BLV individuals who use touch as a source of tactile information and navigation [15], [17]. Furthermore, due to the pandemic, many BLV individuals were at greater risk of infection and also disproportionately affected emotionally, socially, and mentally [16].

Due to the potential impacts of COVID-19 on the BLV learning, we analyzed the TMCT scores from pre and post COVID-19 data to search for any significant differences among the two groups regarding spatial ability performance on the TMCT instrument.

Methods

The TMCT was developed at Utah State University as part of NSF AISL funded research involving Utah State University, the National Federation of the Blind, and the Science Museum of Minnesota. The TMCT test was administered to BLV participants at training centers for the blind, youth camps sponsored by the NFB, and national and state NFB conventions. The tests were prepared in a controlled environment prior to participant arrival by the test proctors. Depending on the site location, up to six participants could take the test at the same time. The participants were instructed to not discuss their answers. Additionally, any low vision participants at blindness training centers were asked to wear blindfolds to prevent any visual aid. Prior to the test start participants were asked to sign an IRB-approved consent form.

The tactile test items were presented in front of each participant in separate sections on a lazy Susan turntable to allow for greater accessibility and autonomy for the participants. Originally the answer key was provided in two formats-large print or tactile graphic with Braille labels, depending on participant preference. For the purposes of this paper, only data from the tactile graphic format was analyzed. Participants were allowed to ask questions to the test proctor before beginning the test. The proctor also walked through two example problems prior to starting the test to help the participants orient themselves to the test format. The time limit of the original MCT test was eliminated to allow for adequate time for tactile interpretation. The participants were thus allowed unlimited time to take the spatial TMCT.

During preliminary testing all the participants were given all 25 TMCT items, however after preliminary testing the test was split into subtests A and B (each comprising half of the original 25 TMCT items) of equal difficulty. One item was eliminated from the selection due to its excessive difficulty among preliminary testing participants. Thus two distinct TMCT forms were developed from this work.

Population

A total of 196 BLV participants took the TMCT from 2018-2022. 178 participants chose the tactile graphics format answer sheets, and 18 used large print. Data on the participants' gender was not collected. Each participants’ age was not specifically requested, however all participants were between the ages of 14 and 65+. The pre-COVID-19 data comes from 119 participants who took the TMCT between July 2018 and early March 2020 before the onset of lockdowns at NFB conventions, the NFB Engineering Quotient (EQ) program for high school students, and training centers for the blind and visually impaired. The post-COVID-19 data comes from 77 participants who took the TMCT between June 2021 and July 2022 at training centers for the blind and visually impaired.

Table 1. Number of TMCT participants from each data collection site.

	NFB Conventions	NFB EQ Programs	Training Centers	Total
Pre-COVID	15	53	51	119
Post-COVID	-	-	77	77

Recruitment from training centers occurred at three locations; the Colorado Center for the Blind (CCB), the Utah Division of Services for the Blind & Visually Impaired (DSBVI), and the Idaho Commission for the Blind and Visually Impaired (ICBVI). Participants thus represent a convenience sample drawn from students at the centers at that time. The CCB is operated by the NFB while the DSBVI and ICBVI are operated by their respective state governments. Each training center assists students in achieving independence through courses in areas such as Braille reading, cane travel, woodshop, and home management. Many of the training center students have lost their vision recently before beginning the training program. Students typically graduate within six to nine months of enrollment at the center. In accordance with the nature of each training center, low vision students were required to utilize sleep shades (i.e., blind folds) to occlude their vision while taking the TMCT. The EQ program was offered for BLV youth as a week-long summer camp with non-visually accessible activities integrated into the program that were intended to encourage spatial thinking.

Data Analysis

Analysis of data from the pre-pandemic to post-2021 groups utilized hypothesis testing to test significance in test duration between the two groups. Although 196 BLV individuals participated in the study by taking one version of the TMCT, in the interest of comparing similar populations, this study only considers participants who were students at a blindness training center or participated in the EQ program for BLV youth between the years of 2019 and 2022. The small number of participants who chose to use the large print answer sheet format were excluded from the analysis due to differences in how visual illustrations of solutions are perceived. The data was further refined by only analyzing test duration from participants who completed all 12 questions contained in subtest A or B. In total, test durations were studied for 27 participants in the pre-COVID group and 47 from the 2021-2022 group.

TMCT test duration times for each participant were calculated from start and end times recorded during data collection, and converted to the average number of seconds per TMCT item each participant took. The test durations from the June 2019 to March 2020 group (pre-COVID-19) had a mean value of 149 seconds per TMCT item with a standard deviation of 84 seconds. The 2021-2022 group (post-COVID-19) had a mean value of 264 seconds and standard deviation of 207 seconds. Data from the two groups were then tested for normality using a Shapiro-Wilk test. Results indicate that the pre-COVID data are normally distributed ($p > 0.05$), and that post-2021 data are not normally distributed ($P < 0.01$). It was determined to use a Mann-Whitney U test to determine equivalence between the two groups. Results show that the 2021-2022 group of TMCT participants took significantly longer per item than the pre-COVID group with a test statistic of $U=329$, $p = 0.0006$. A similar analysis of TMCT scores was conducted, and found a noticeable but insignificant difference in scores. All calculations were performed using Microsoft Excel.

Table 2. Summary of results.

	Mean Duration (s)	Standard Deviation (s)	Shapiro-Wilk Normality	Mann-Whitney U test	Result
Pre-COVID	149	84	Normal ($p>0.05$)	U=329 ($p=0.0006$)	Statistically significant difference
Post-COVID	264	207	Non-Normal ($p<0.01$)		

Discussion

The TMCT has been shown to be a viable spatial ability instrument among small sample BLV populations [13]. The time it took to finish the TMCT differed significantly between BLV participants who took the test before the COVID-19 pandemic and those who took it after the height of the pandemic. During COVID-19, members of the BLV population were disproportionately affected by the pandemic [16], and thus may have had less opportunity to maintain and/or develop skills and spatial abilities due to restricted access to training centers, barriers to tactile input and urban navigation, and loss of skill building opportunities in the community [8],[15],[17]. Since these experiences are important for spatial ability development and maintenance, we hypothesize that these consequences of the COVID-19 pandemic, amongst other potential variables, may have reduced spatial thinking speeds for BLV individuals taking the test post-COVID when compared to those taking it pre-COVID. The work suggests that those impacted by such large invasive events like the COVID-19 pandemic may need more time to take critical tests and to use their spatial abilities. The work also suggests that these types of interruptions may impact spatial thinking and that spatial interventions may need to be developed and implemented to mitigate such impacts.

Future Research

The observation leads to potential areas for future research in similar global health or lockdown situations and argues for preparation to conduct investigations into spatial ability degradation during such events. Nevertheless, this work clearly shows that participants took significantly longer to finish the TMCT assessment when they had been subjected to a pandemic event. Any further research on investigating the lower spatial ability speeds in BLV populations after a pandemic, should also look to implement literature informed functional interventions for improving and/or maintaining spatial abilities in pandemic-like conditions. Indeed, educators may choose to implement spatial interventions in such isolating events for use in online maintenance of spatial skills. Such work would require preparation or organization of the interventions beforehand. We believe that this paper presents a good starting point for considering how pandemic-like conditions can affect spatial abilities among BLV populations.

Conclusion

Our data shows a statistically significant difference between time-to-completion of BLV participants who took the TMCT pre-COVID-19 and post-COVID-19. We hypothesized that the difference in time-to-completion arose from BLV participants' spatial abilities being negatively affected by the pandemic's direct and indirect effects. This study provides direction for future work to experimentally look into how the BLV population's spatial abilities are affected by factors such as lack of access to training facilities, increased stress levels and burnout, and reduction of urban navigation.

Limitations

There are some potential limitations to the work. One involves the potential of seasonal effects as the tests which were administered during spring for both groups. Additionally the participants reflect a convenience sample that was drawn from the BLV population. The participant population spans a large range of ages and due to the population size in the pre-COVID and post-COVID groups the research was unable to be segregated into smaller age ranges. Finally, there are different levels of vision within low vision participants and even though participants wore blindfolds this does bring a small level of potential differentiation into how they may have developed their spatial abilities in the past.

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