

THE EFFECTS OF LANDMARK INSTRUCTION
ON WAYFINDING IN PERSONS
WITH DOWN SYNDROME

by

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ABSTRACT

Previous research has suggested that individuals with Down syndrome experience specific hippocampal dysfunction which may impair their ability to navigate from one environment to another. One strategy used to enhance spatial navigation is the instruction of prominent landmarks along a path. The current study examined the effects of landmark instruction on wayfinding ability in persons with Down syndrome in comparison to typically developing children of the same mental age and individuals with intellectual disability not resulting from Down syndrome of the same chronological age. The results indicated that the participants with Down syndrome performed significantly worse on the wayfinding task than both the typically developing participants and those with mixed-etiology intellectual disability, despite showing an improvement in performance due to landmark instruction. Future research could examine the direct connection between hippocampal dysfunction and impairment in spatial navigation as well as explore the role of prior experience in wayfinding ability.

LIST OF ABBREVIATIONS AND SYMBOLS

<u><i>B</i></u>	Beta: a standardized regression unit
<u><i>F</i></u>	Fisher's <i>F</i> ratio: a ratio of two variances
<u><i>M</i></u>	Mean: the sum of a set of measurements divided by the number of measurements in the set
<u><i>p</i></u>	Probability associated with the occurrence under the null hypothesis of a value as extreme as or more extreme than the observed value
<u><i>r</i></u>	Pearson product-moment correlation
<u><i>SD</i></u>	Standard deviation
<	Less than
=	Equal to
CA	Chronological Age
DS	Down syndrome
ID	Intellectual disability
IQ	Intelligence quotient
KBIT-II	Kaufman Brief Intelligence Test – 2 nd edition
K-ABC	Kaufman Assessment Battery for Children
MA	Mental age
TD	Typically developing
WAIS-R	Weschler Adult Intelligence Scale - Revised
WISC-R	Weschler Intelligence Scale for Children – Revised

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INTRODUCTION

Down syndrome is the most common genetic disorder that results in intellectual disability, occurring in approximately 1 of every 733 live births. Due to a chromosomal abnormality involving an extra twenty-first chromosome, or trisomy 21, people born with Down syndrome experience intellectual and learning impairments throughout their childhood and adult development. Accompanied by other health complications such as heart problems and hearing deficits, Down syndrome often has a drastic effect on cognitive development, thus causing a generalized downward trend in IQ in comparison to the typical population. Individuals with Down syndrome generally fall between the IQ range of 25-55 and very rarely surpass the mental age of approximately 7 or 8 in adulthood (Pennington, Moon, Edgin, Stedron, & Nadel, 2003). Accordingly, persons with Down syndrome generally acquire gross/motor and personal/social skills later than most typically developing children and struggle with the complex rules of language throughout their lives (National Down Syndrome Society, 2010). Further, Down syndrome often causes premature aging in middle adulthood which results in a further decline in IQ and even early onset Alzheimer's (Pennington et al., 2003).

Neuropsychological Research and Deficits of the Hippocampus

Research on individuals with Down syndrome has recently shifted towards a more neuropsychological approach. By examining specific brain regions, researchers have been able to identify certain structures that may be responsible for the weaknesses in cognitive functioning associated with Down syndrome. Although the brains of persons with Down syndrome appear normal at birth, they show obvious signs of abnormality by adulthood (Nadel, 2003). While

results in such brain studies have been mixed, findings have consistently revealed that individuals with Down syndrome show volume reductions in the hippocampus, prefrontal cortex, and cerebellum in comparison to normal controls (Lawrence, Lott, & Haier, 2005; Nadel, 2003; Pennington et al., 2003).

Due to the consistency of these findings, a major focus of such research has centered on the results implicating the hippocampus and its role in cognitive deficits. While no reductions in hippocampal volume have been found in the first few years of life, such decreases are evident prior to adolescence, suggesting that these deficits are not entirely due to the early onset Alzheimer's associated with Down syndrome (Pennington et al., 2003).

Accordingly, Pennington et al. (2003) explored whether the neuropsychological development of persons with Down syndrome was more consistent with hippocampal, prefrontal, or generalized deficits. By using hippocampal measures such as the Ecological Memory Questionnaire and the Virtual Morris water maze, the researchers examined the performance of individuals with Down syndrome on hippocampal and prefrontal measures in comparison to a mental age match. The results of this study indicated that persons with Down syndrome performed consistently worse than their typically developing peers on tasks associated with the hippocampal measures but did not significantly differ on the prefrontal measures, thus demonstrating specific hippocampal dysfunction (Pennington, 2003). Therefore, while it should be noted that deficits in the hippocampus are not the lone source of abnormal development in Down syndrome, hippocampal functioning may play a crucial role in delays of cognitive development that are specific to Down syndrome.

The Role of the Hippocampus in Spatial Navigation

In light of such findings, it becomes important to examine the role of the hippocampus in specific cognitive functions. While the hippocampus is involved in a wide range of cognitive activities, much research has indicated its role in spatial navigation (Burgess, Donnett, & O'Keefe, 1998; O'Keefe, Burgess, Donnett, Jeffery, & Maguire, 1998; Tripp, 2001). Several studies conducted on rats have found place cells in the hippocampus that code for destinations, directions, and speed of movement (O'Keefe et al., 1998). Further, lesion studies in rats have indicated that damage to the right temporal lobe, the area in which the hippocampus is found, can result in disruptions of spatial orientation, as well as the inability to recall the location of previously learned objects (Burgess et al., 1998; O'Keefe et al., 1998; Tripp, 2001).

Unobtrusive measures of hippocampal function indicate a similar role for the hippocampus in humans. Maguire, Burke, Phillips, and Staunton (1996) examined PET scans of London taxi drivers while recalling either navigational routes or famous local landmarks. The results of this study indicated increased activation in the right hippocampus during the recollection of routes; however no changes in hippocampal activity during the recall of the famous landmarks were recorded. Later MRI studies revealed an enlargement in the posterior hippocampus of these London taxi drivers that was found to have occurred during their career as drivers (Maguire et al., 2000). Further, similar to the results of experiments conducted on animals, human lesion studies have found that damage to the hippocampus can result in deficits in spatial memory and navigation (Smith & Milner, 1981). Overall, these studies, as well as those conducted on animals, demonstrate the role of the hippocampus in spatial navigation.

Wayfinding in Persons with Down Syndrome

Although no published research has specifically examined the wayfinding abilities of persons with Down syndrome, the neuropsychological research available on such individuals as well as the research on the role of the hippocampus in navigation suggests that individuals with Down syndrome will demonstrate impairment in wayfinding ability. Further, there has been some research on the wayfinding performance of persons with mixed-etiology intellectual disability. Benson, Merrill, Conners, Roskos-Ewoldsen, & Rawls (2009) compared the performance of individuals with intellectual disability, including some participants with Down syndrome, on a virtual wayfinding task to typically developing college students of approximately the same chronological age and typically developing children of approximately the same spatial reasoning ability. In general, the wayfinding task required participants to find their way through a series of hallways until they were able to complete the task without any errors. Overall, the results indicated that those participants with intellectual disability did commit significantly more errors during the task than both the CA- and MA-matched groups. Although the Benson et al. (2009) study only looked at individuals with mixed-etiology intellectual disability, the findings of hippocampal dysfunction in Down syndrome suggest that this population may experience an even greater deficit in wayfinding than individuals with intellectual disability. Therefore, one of the goals of the present study is to compare the wayfinding performance of persons with Down syndrome to a comparison group of individuals with intellectual disability of approximately the same chronological age.

Due to this suggestion that persons with Down syndrome will experience a deficit in wayfinding, it is important to then examine ways to overcome such impairments. Because wayfinding is such a practical and relevant part of everyday life, research should begin looking at

possible ways to enhance the wayfinding abilities of individuals with Down syndrome. Therefore, another goal of the present study is to move beyond the findings of Benson et al. (2009) and examine potential wayfinding intervention strategies through the manipulation of variables that enhance the performance of individuals with Down syndrome, such as landmark instruction.

The Role of Instruction in Children's Wayfinding

One line of research that is relevant to wayfinding in Down syndrome individuals involves the use of instruction in the identification of landmarks. Although no research has specifically been conducted using populations with intellectual disability, research with children has found that identifying prominent landmarks along a path can enhance navigational performance (Cornell, Heth, & Broda, 1989; Cornell, Heth, & Rowat, 1992). Cornell et al. (1989) examined the effects of landmark identification on navigational error in 6- and 12-year old children. While some of the children were guided along a path with no instruction at all, others were told to look at either close or distal landmarks at choice points, or points where changes in direction occurred. The results revealed that both age groups exhibited increases in navigational accuracy when instructed to look at specific landmarks, with the closer orientation cues delivering a more facilitative effect. Further, the 12-year old children completed the task with fewer errors than the 6-year olds (Cornell, et al., 1989). Overall, these results indicate that the navigational accuracy of children is enhanced by the identification of prominent landmarks at choice points.

Purpose and Hypotheses

In general, previous research has demonstrated that the presence of landmark instruction may enhance the performance of Down syndrome (DS) individuals in tasks involving spatial

navigation. Therefore, it is important to apply such research to possible deficits that these individuals experience in wayfinding. The purpose of the current study is to examine the facilitative effects of landmark instruction on a virtual wayfinding task in persons with and without Down syndrome. Further, it is also of interest to compare the performance of the DS group to another group of participants with mixed-etiology intellectual disability in order to determine if such a deficit in wayfinding is specific to Down syndrome or characteristic of intellectual disability (ID) in general. Accordingly, two hypotheses regarding overall wayfinding performance have been devised.

1. It is hypothesized that there will be a main effect for group such that the DS group will perform worse than both the typically developing (TD) and ID groups on the wayfinding task regardless of the instruction condition.
2. It is also hypothesized that there will be a main effect for instruction such that participants will perform better on the wayfinding task in the instruction condition regardless of group.

METHODOLOGY

Design

This study utilized a 3 x 2 design with the variables of interest being participant group (DS, ID, or TD) and presence of landmark instruction, thus resulting in the presence of six conditions. All of the independent variables were manipulated as between-subjects variables and participants were randomly assigned to one of the instruction conditions. A nonverbal intelligence test was also administered in order to match the participants with Down syndrome and intellectual disability to their typically developing peers on spatial reasoning ability. Due to the limited time required to complete the study, all tasks were administered in one testing session that lasted approximately 30 to 45 minutes.

Participants

66 total participants were recruited for this study including 20 individuals with Down syndrome, 16 individuals with mixed-etiology intellectual disability not resulting from Down syndrome, and 30 typically developing children. 4 participants, 1 TD and 3 DS, did not complete the study due to either a lack of desire to complete all of the tasks or an inability to meet the requirements of the tasks. Descriptive statistics for each group regarding chronological age and mental age as measured by performance on the KBIT-II can be found in Table 1.

Table 1

Descriptive Statistics for Participant Groups (Standard Deviations)

Participant Group	Chronological Age	KBIT-II Matrices	
		Standard Score	Spa. Reasoning Age
DS	18.6 (3.69)	50.76 (12.27)	5.61 (1.58)
ID	19.71 (0.83)	58.13 (14.31)	6.39 (1.92)
TD	7.93 (0.62)	99 (16.98)	8.01 (2.72)

The Down syndrome group was comprised of individuals between the ages of 12 and 25 (CA = 18.6) who had a documented chromosomal analysis indicating trisomy 21. This age was selected to avoid the effects of early onset Alzheimer’s in the Down syndrome individuals and so that mental age matches could be made with the typically developing children. All DS participants were recruited from local service organizations such as the CrossingPoints program on the University of Alabama campus, the Parent Advocates for Down Syndrome group, and the Exceptional Foundation. The mean age of spatial reasoning of this group was 5.61.

The ID group was also comprised of individuals between the ages of 12 and 25 (CA = 19.71) who had previously been tested and diagnosed as having an intellectual disability not resulting from Down syndrome. All ID participants were recruited from the CrossingPoints program on the University of Alabama campus. The mean age of spatial reasoning of this group was 6.39.

The typically developing comparison group consisted of children who had approximately the same spatial reasoning ability as the individuals with Down syndrome and

intellectual disability. Spatial reasoning ability was used as the matching criteria instead of chronological age so that true differences in intellectual ability could be measured. These children ranged in age from 6 to 9, with a mean age of 7.93 and were recruited from the Tuscaloosa County school system. The mean age of spatial reasoning of this group was 8.01.

Measures

Kaufman Brief Intelligence Test-II. The KBIT-II is a standardized intelligence test that is appropriate for people between the ages of 4 and 90 and consists of three subtests. For the purposes of this experiment, only the Matrices Subtest was used since measures of Verbal IQ are not required in our study of wayfinding. In general, the Matrices Subtest measures nonverbal intelligence by asking participants to view groups of pictures and then make comparisons and analogies between the relationships. The Matrices Subtest has been deemed an appropriate measure of intelligence in special populations and will be used as one of our criteria for matching on spatial reasoning ability. Further, Parker (1993) found high split-half reliability for this nonverbal subtest with $r = 0.87$, internal consistency reliability of $r = 0.93$, and test-retest reliability of $r = 0.94$. Parker also found that the composite score of the KBIT-II, which includes both the Verbal and Nonverbal portions, exhibited construct and external validity with other measures of intelligence and achievement, as well as internal validity with the K-ABC, WISC-R, and the WAIS-R.

Wayfinding Task. Wayfinding was assessed by having participants learn to navigate a simple virtual environment that was constructed using the software program FPSCREATOR. In this program, participants were instructed to learn the shortest path to a specific target object in order to deliver a message. This virtual environment consisted of a set of hallways with eight choice points along the way. In order to maintain variability and participant interest, four of the

choice points included two choices and four included three choices. Two of our choice points required participants to continue going straight, three required a right turn, and three required a left turn, with the locations being randomly determined. Sixteen landmarks were placed along the route, with half of the objects at choice points and the other half at non-choice points.

Procedure

After receiving parental consent and participant assent, all participants were administered the Nonverbal Matrices Subtest of the KBIT-II in order to determine mental age. This task took approximately 5-10 minutes to complete. Participants from each group were then randomly assigned to one of the two experimental conditions for completion of the virtual wayfinding task.

In all conditions, participants were exposed to an initial learning phase that introduced them to the virtual environment. During this phase, participants actively navigated the maze by following green lights that indicated the correct path and ignoring the red lights which indicated wrong turns. All participants were instructed to concentrate while traveling through the maze because the lights would be removed in the next part of the task. Further, participants in the landmark instruction condition were told to pay special attention to the landmarks because they may be helpful in navigating the maze. The participants in this condition were then asked to identify the landmarks in the environment that they passed by saying them aloud to the experimenter. All responses were recorded for accuracy of identification. However, participants in the no instruction condition were only given the directions on following the green lights and were not asked to identify any of the landmarks.

At this time, participants were then asked to actively navigate the environment on their own. During this test phase, the green and red lights were removed and the participants traveled through the maze based on their memories from the initial learning phase. The number of errors,

or wrong turns, and the amount of time it took to reach the end of the maze were recorded. Further, in order to avoid participant frustration and time issues, prompts were given to prevent the participants from returning to a previous portion of the maze in which they had already successfully completed. Accordingly, each time a participant attempted to return to a choice point that had already been successfully navigated, the participant was stopped, instructed that they had already been in that direction, and asked to choose another path. Each prompt was recorded and also coded as an error.

Upon completion of the test phase, participants were then asked to recall as many of the landmarks as they could from the virtual environment. The number correct out of sixteen was recorded. Further, participants were shown a version of the wayfinding maze with four of the choice point landmarks removed. Participants were then asked to select the landmark that was previously located in the missing area from four pictures. Again, the number correct out of four was recorded. Both the recall and missing landmark tasks served as measures of memory for landmarks, or how much the participants paid attention to the landmarks when navigating through the maze. In general, the wayfinding tasks and additional landmark memory measures took approximately 20 minutes to complete.

RESULTS

Because the focus of this study was wayfinding performance, the number of errors committed during the test phase of the wayfinding task served as our primary dependent variable. We were also interested in the number of prompts given by the experimenter during the test phase and the amount of time necessary to complete the task as secondary measures of wayfinding performance. The main effects of both group and condition as well as the interaction effect were examined for each dependent variable. In addition, we examined the effects of group and condition on our two measures of landmark recall, the straight recall task and the missing landmark task. These served as measures of the effectiveness of our manipulation of landmark instruction. A summary of the results can be found in Table 2.

Table 2

Means for Wayfinding and Recall Measures (Standard Deviations)

Participant Group	Wayfinding Errors	Wayfinding Prompts	Wayfinding Time (s)	Landmarks Recalled	Missing Landmarks
DS No Ins.	7.88 (2.75)	1.25 (0.71)	287.38 (120.51)	1.13 (1.36)	1 (0.76)
DS Ins.	5.89 (3.82)	1 (0.87)	313.44 (81.78)	4.11 (2.15)	1.89 (1.05)
ID No Ins.	3.13 (2.23)	0.63 (0.74)	154.63 (101.51)	2.88 (2.70)	1.75 (1.58)
ID Ins.	2.88 (2.47)	0.38 (1.06)	181.88 (197.56)	6 (0.93)	2 (1.85)
TD No Ins.	4.53 (3.85)	0.6 (1.12)	207 (145.47)	3.27 (1.39)	1.6 (1.35)
TD Ins.	2.21 (2.22)	0.36 (0.63)	171.5 (63.46)	5.36 (1.95)	2.79 (1.19)

Wayfinding Errors

The number of errors broken down by group and condition are provided in Figure 1. A multifactor analysis of variance was conducted to examine the effects of group and condition on the number of errors committed during the test phase of the wayfinding task. As expected, there was a significant main effect of group on errors ($F[2, 56] = 8.869, p < .001$), such that the group with Down syndrome ($M = 6.82$) committed significantly more errors than both the group with ID ($M = 3$) and the typically developing participants who were matched on spatial reasoning ability ($M = 3.41$). However, the ID and TD groups did not significantly differ from one another. Further, the effect of condition on number of errors was only marginally significant ($F[1, 56] = 3.583, p = .064$). Participants in the no instruction condition ($M = 5.03$) committed

more errors than those participants in the instruction condition ($M = 3.45$). Finally, the group \times condition interaction effect was not significant ($F[2, 56] = .621, p = .541$). While instructions improved overall performance, the effect was similar for the three groups.

Although we intended to match our typically developing group to our DS and ID groups on spatial reasoning ability as measured by performance on the nonverbal portion of the KBIT-II, the DS and ID groups performed lower than we initially expected, thus resulting in significant differences in spatial reasoning between the DS and ID groups and the TD group ($F[2, 60] = 6.203, p < .01$). Therefore, a hierarchical regression analysis was performed to determine whether the effect of group assignment was still significant after accounting for differences in spatial reasoning ability. In the analysis, wayfinding errors was the criterion variable, with spatial reasoning ability entered as the first predictor variable followed by group assignment and instruction condition, respectively. Spatial reasoning ability ($\beta = -.536, p < .01$) and instruction condition ($\beta = -.224, p = .037$) were significant predictors of wayfinding errors. The effect of group did not predict wayfinding errors beyond that predicted by spatial reasoning ability ($\beta = -.160, p = .153$).

Because a primary question addressed by this research was whether individuals with ID associated with DS performed more poorly than individuals with ID not associated with DS, a supplemental hierarchical regression was conducted on data from the DS and ID groups without the TD participants. Again, wayfinding errors was the criterion variable, with spatial reasoning ability, group, and condition entered in order as the predictor variables. The results indicated that group did predict wayfinding errors beyond that explained by spatial reasoning ability ($\beta = -.502, p = .002$). However, the effect of condition was not significant in this analysis ($\beta = -.167, p = .259$). It is therefore reasonable to suggest that the participants with DS exhibited difficulties

with wayfinding that were greater than would be expected based on spatial reasoning ability alone.

Other Wayfinding Measures

Several other measures of wayfinding performance were analyzed across group and condition. One supplementary variable of interest was prompts, or the number of times the experimenter had to stop the participant from returning to a part of the wayfinding environment that had already been successfully navigated. A multifactor analysis of variance revealed that there was a significant effect of group on total number of prompts required to complete the wayfinding task ($F[2, 56] = 3.194, p = .049$), such that participants with Down syndrome ($M = 1.12$) required more prompts than participants in either the ID ($M = 0.5$) or TD groups ($M = 0.48$). The ID and TD groups did not significantly differ from each other. Further, there was not a significant main effect of condition on number of prompts ($F[1, 56] = 1.124, p = .294$) or a significant group x condition interaction ($F[2, 56] < .001, p = 1.00$).

Time in seconds to complete the wayfinding task was a second supplementary variable of interest in regards to wayfinding performance. The timer was started as soon as the participant began moving through the environment and was stopped when the participant successfully reached the end point. A multifactor analysis of variance revealed a significant main effect of group on the amount of time required to complete the test phase of the wayfinding task ($F[2, 56] = 5.861, p = .005$), such that the DS group ($M = 301.18$) needed more time to complete the task than participants in the both the ID ($M = 168.25$) and TD ($M = 189.86$) groups. Again, the ID and TD groups did not significantly differ on this variable. Further, there was not a significant main effect of condition on amount of time required to complete the wayfinding task ($F[1, 56] = .034, p = .855$). However, the data clearly shows that participants in the DS and ID groups took

longer to complete the task in the instruction condition despite committing fewer errors, thus indicating that these participants are doing something fundamentally different than participants in the TD group. Finally, there was not a significant group x condition interaction ($F[2, 56] = .491, p = .615$).

Recall Measures

Overall, landmark recall performance was relatively poor, with none of the groups approaching 50% recall of the landmarks. Results of the landmark recall task can be found in Figure 2. A multifactor analysis of variance indicated that there was a significant main effect of group on the number of landmarks recalled ($F[2, 56] = 5.722, p = .005$). The participants with Down syndrome ($M = 2.71$) remembered fewer landmarks than participants in both the ID ($M = 4.44$) and TD groups ($M = 4.28$). The ID and TD groups did not significantly differ from one another on landmark recall. Further, there was a significant main effect of condition on the number of landmarks recalled ($F[1, 56] = 33.015, p < .001$). The participants in the instruction condition ($M = 5.16$) recalled more landmarks than participants in the no instruction condition ($M = 2.61$). This result indicates that the instruction manipulation was at least partially successful in that participants paid attention to and remembered more landmarks when instructed to do so. Finally, there was not a significant group x instruction interaction for the number of landmarks recalled on the wayfinding task ($F[2, 56] = .554, p = .578$).

A multifactor analysis of variance was also conducted on the number of missing landmarks recalled. This analysis indicated that there was a significant main effect of instruction condition ($F[1, 56] = 4.929, p = .03$). Participants in the instruction condition ($M = 2.32$) were better able to identify the missing landmarks correctly than participants in the no instruction condition ($M = 1.48$). However, there was not a significant main effect of group on the number

of missing landmarks recalled ($F[2, 56] = 1.711, p = .19$). Finally, there was not a significant group x instruction interaction effect for the number of missing landmarks recalled ($F[2, 56] = .643, p = .529$). Consistent with landmark recall, it does appear that instruction increased landmark learning associated with the identification of missing landmarks in the wayfinding task.

DISCUSSION

In this study, we wanted to determine if instruction to learn landmarks in a virtual environment would improve the overall wayfinding ability of participants both with and without intellectual disability. More specifically, we wanted to examine how the instruction of landmarks affected the wayfinding performance of three groups, participants with Down syndrome, participants with mixed etiology intellectual disability not resulting from Down syndrome, and typically developing participants of approximately the same spatial reasoning ability as the other two groups. Due to the evidence of hippocampal dysfunction in individuals with Down syndrome and the research implicating the role of the hippocampus in spatial navigation, it was hypothesized that participants with Down syndrome would perform worse on the wayfinding task than both participants in the ID and TD groups, regardless of instruction. As predicted, the DS group did perform worse on the wayfinding task than the two comparison groups in regards to the total number of errors committed during the test phase of the task and the number of prompts required from the experimenter to successfully complete the task. In addition, the performance of the ID and TD groups did not significantly differ from one another on either of these variables, thus suggesting specific wayfinding impairment for the Down syndrome group. Further, although only marginally significant, the presence of landmark instruction was found to enhance the wayfinding performance for participants in all three groups. Despite this improvement, participants in the DS group were still performing worse than participants in the ID and TD groups.

To further examine the impact of group on wayfinding performance, we wanted to determine if the effect was still present after controlling for spatial reasoning ability. After conducting a hierarchical regression analysis with spatial reasoning ability, group, and condition entered in that order as the predictor variables, it was found that group no longer had a significant effect on wayfinding performance after accounting for differences in spatial reasoning, thus suggesting that spatial reasoning ability does play a role in the variability of wayfinding performance. However, when the analysis was conducted using only the DS and ID groups, it was found that group did significantly predict wayfinding errors beyond that explained by spatial reasoning. Based on this finding, it is reasonable to suggest that the participants with DS demonstrated an impairment in wayfinding ability that was greater than what would be expected based on spatial reasoning ability alone.

Another interesting finding concerning wayfinding performance involved the amount of time required to navigate the environment. As expected, the DS group did require significantly more time to successfully navigate the environment than participants in the other two groups. However, participants in the ID and TD groups did not significantly differ from one another. Further, although the effect of condition on time to complete the task was not significant, it should be noted that participants in both the DS and ID groups required more time to finish the wayfinding task when instructed to pay attention to the landmarks than when placed in the no instruction condition, despite committing fewer errors. This suggests that while landmark instruction improved performance on the wayfinding task in regards to the number of errors committed, it did not allow participants in the DS and ID groups to navigate through the task any faster.

For this study, we were also interested in looking at the effects of group and condition on the ability of our participants to recall the landmarks that they viewed in the virtual environment. As expected, the participants with DS recalled significantly fewer landmarks than participants in the ID and TD groups in both the no instruction and instruction conditions. However, the ID and TD groups did not significantly differ from one another in their performance on this task, further suggesting a wayfinding impairment specific to intellectual disability resulting from Down syndrome. Also, in order to check the effectiveness of our manipulation of instruction, we examined the effects of condition on performance on both of the recall tasks, the straight recall task and the missing landmark task. Accordingly, participants from each of the three groups recalled significantly more landmarks on both tasks when in the instruction condition rather than the no instruction condition, suggesting that our manipulation of instruction was at least somewhat successful.

In general, our findings suggest that individuals with Down syndrome may exhibit a deficit in wayfinding ability in comparison to typically developing children of approximately the same spatial reasoning ability and individuals with mixed-etiology intellectual disability not resulting from Down syndrome. While landmark instruction did improve their performance on the wayfinding task, the participants with Down syndrome continued to perform worse than the other two groups on all of our wayfinding measures. One obvious limitation of our study is the discrepancy in spatial reasoning ability between the three groups. Although we conducted supplemental analyses to statistically control for spatial reasoning and significant results were still found, it would be beneficial to recruit additional participants in the future to make the groups more comparable on this variable. Another limitation to mention involves the effectiveness of our manipulation of landmark instruction. While the analyses revealed that our

manipulation did significantly improve overall performance on the wayfinding task, the participants were still only approaching a 50% recall rate of the landmarks in the instruction condition. In the future, it would be useful to examine more effective methods of landmark instruction, such as having participants complete the learning phase more than once. This additional instruction might provide us with a more accurate picture of how navigational learning occurs in real world situations and would allow us to further explore the discrepancy in wayfinding performance between individuals with Down syndrome and those of typical development or with mixed-etiology intellectual disability not resulting from Down syndrome.

Because these results indicate a possible impairment in wayfinding ability in individuals with Down syndrome, it now becomes important to examine the mechanisms behind this deficit. As proposed earlier in this paper, one possible cause for difficulties in wayfinding ability in persons with Down syndrome is generalized hippocampal dysfunction. Accordingly, a potential direction for future research could be to connect the previous research on the brain, specifically the hippocampus, with this research on wayfinding behavior. Potential methods for exploring this connection could involve the use of fMRI approaches to examine brain activity while participants navigate the virtual wayfinding environment or to correlate performance on the wayfinding task with other cognitive measures that rely on the hippocampus.

Another avenue for future research could examine the role of prior experience in wayfinding ability. In this study, our results indicated that participants with mixed-etiology intellectual disability not resulting from Down syndrome performed equivalently to the typically developing children of approximately the same spatial reasoning ability on all of our measures. One possible explanation for this similarity in performance is the role of prior wayfinding experiences. While the two groups were similar in spatial reasoning, the ID group was much

higher in chronological age and most likely had more experience engaging in activities involving wayfinding skills than the TD comparison group. Therefore, it would be useful to include some sort of measure of previous wayfinding experience, such as an indicator of independent living skills.

Although this study only examined wayfinding per means of a virtual environment, the skills associated with wayfinding are used on a daily basis to help people navigate from one place to another. The results of this study indicate that individuals with Down syndrome may experience a deficit in basic wayfinding ability in comparison to typically developing and intellectually disabled comparison groups. Further, the results revealed that the instruction of landmarks may be an effective strategy for successfully navigating an environment. Therefore, it is important to identify ways to make landmark instruction more effective as well as to develop new methods of learning that will assist individuals with Down syndrome in overcoming their suggested impairment in wayfinding.

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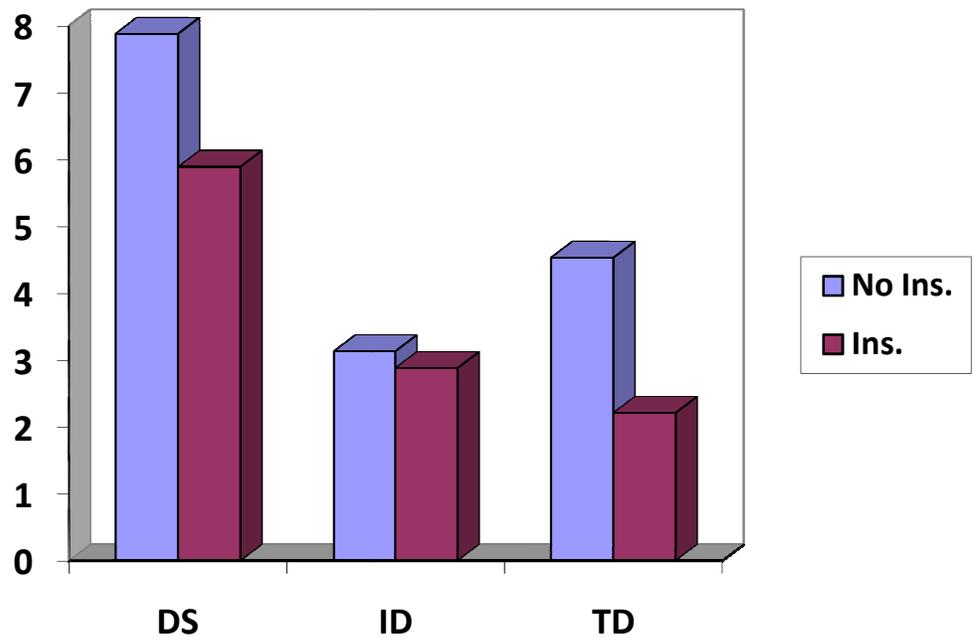


Figure 1.

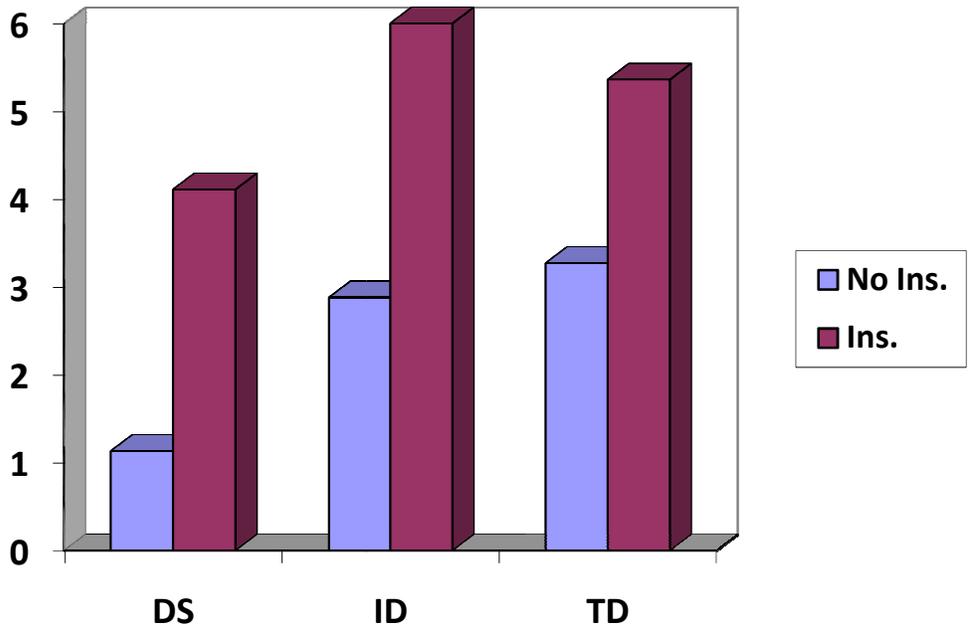


Figure 2.