Enhancements to Statistical Probability of Area Models based upon updated ISRID data collection for Autistic Spectrum Disorders and Typically Developing Children

Robert J Koester PhD, FRGS

School of the Environment, Geography and Geosciences, University of Portsmouth

dbS Productions

UK, USA

Email: Robert@dbs-sar.com

Abstract

Both Autism Spectrum Disorder (ASD) individuals and Typically Developing (TD) children are associated with Search and Rescue incidents. Though they are in the same age range, these two groups are typically placed into different subject categories in lost person behavior profiles. This work compares these two age similar profiles to critically examine what statistical differences do exist. In addition, a new geo-spatial statistical point model is introduced, potentially applicable to all lost person subject profiles. Retrospective data from the updated International Search & Rescue Incident Database (ISRID2) was used to examine both spatial and incident characteristics of individuals with ASD (n=338) and TD children (n=2335) who were reported missing and then were the subject of a search. The updated version of ISRID now contains 145,000 incidents. Those with ASD are 3-4 times more likely to require a search effort ($P << .0001$). ASD children (age 1-15) were not found to be statistically significant than ASD adults. The new point model and watershed model for ASD is introduced. Survivability curves are now reported out to the 5% chance of survival with findings of 7 days for ASD and 11 days for TD Children. Search incidents for missing ASD and TD children demonstrate significant differences but also have some common features. Both adults and children with ASD share the same geo-spatial outcomes.

Keywords: ISRID, Missing Persons, GIS, Lost Person Behavior, Models

Introduction

Spatial navigation is an essential everyday task integrating many sensory and central processes. Getting lost is the ultimate failure of spatial navigation (Dudchenko, 2010). Getting lost and requiring a formal search and rescue response represents a worst-case scenario associated with significant mortality (11.3%) and morbidity (14.3%) (Koester, 2008). We know that behavior when lost depends on both age and cognitive status, but so far there has been no formal field-based comparison between typically developing (TD) children and those with Autism Spectrum Disorder (ASD).

The goal of a search and rescue (SAR) incident is to locate the missing individual as quickly as possible using the tactical resources on hand. A search is ultimately a spatial problem (Doke, 2015). It requires placing resources where the subject is actually located. However, since this is by definition unknown, the various areas within the search area are given probabilities, referred to as Probability of Area (POA), which is also known as Probability of Containment (Charnes and Cooper, 1958). In order to best characterize the POA, three different approaches have been used: a probability map generated by human consensus (Mattson, 1980; Stoffel, 2006); a Monte Carlo simulation of moving particles based upon environmental parameters (Kratzke, Stone, & Frost, 2010; Lin & Goodrich, 2010); or a composite of different fixed spatial models based upon previous incidents (Koester, 2008). It is also possible to combine all three approaches with weighted factors. Central to all three approaches is placing the missing subject into a lost person behavior subject category in order to predict behavior. Syrotuck (1975) was the first to estimate POA by lost person behavior category. He defined several categories by age and activity type (e.g., hiker, hunter, child), and estimated probabilities for distance walked in different terrain. Hill (1998) created the walkaway category which included wandering/elopement of all types. Koester (2008) was the first to establish the SAR ASD profile.

All subjects with ASD are placed into the ASD category unless involved with abduction, water incident, or being transported by a vehicle. The current convention used by Koester for the ASD profile has two basic premises: 1) the classification of ASD is more important than the age of the subject; and the corollary 2) all subjects with ASD will fundamentally behave the same (Koester, 2008). The characterization of spatial behavior involves the horizontal movement (distance) away from the initial planning point, find location, scenario, survivability, and track offset. However, because there were few cases specifically identified as ASD, all of the geographic models typically used in SAR have not been described. Nor has any comparison been made to TD children who are also often the subject of search efforts. Important questions remain: Are searches for TD and ASD children different; are searches for ASD adults different from ASD children searches? As the number of ASD missing cases continues to grow, it is critical that recommendations passed onto SAR providers and law enforcement be based upon sound empirical data.

Literature Review

Children with ASD may be more prone to wander away from caregivers and place themselves at risk for becoming lost. Many of the search and rescue reports involving those with ASD mentioned wandering or elopements. Research into wandering or elopement among those with ASD is still at an early stage. The initial studies looked at treatment of wandering/elopement on an individual basis (Falcomata, Roane, Feeney, & Stephenson, 2010; Lang et al., 2010; Perrin, Perrin, Hill, & DiNovi, 2008). Matson and Rivet (2008) reported a prevalence of 34% for wandering/elopement among adults with severe ASD living in an institution. The most comprehensive research to date is an online survey to members of the Interactive Autism Network (IAN) looking at a sample of 1,218 children with ASD. In their 2012 and 2011 studies, Anderson, et al*.* and Law and Anderson respectively found the following data: 49% of children with ASD have wandered/eloped compared to 13% for TD siblings; the probability increases with severity of ASD; 24% were in danger of drowning; 65% were in danger of a traffic injury; elopement peaked at age 5.4; common last seen locations were the child's home (74%), stores (40%), and schools (29%); children were missing for 41.5 (SD 52.4) minutes on average; and law enforcement was contacted in 35% of cases. McIlwain and Fournier (2012) looked at ASD fatalities as a result of wandering/elopement reported in the media. For 2009-2011 they found accidental drowning accounted for 20 out of 22 (91%) of the fatalities subsequent to wandering/elopement for children (age 14 and below) with ASD. Koester (2008) looked at 62 missing ASD search and rescue (SAR) incidents and reported a 2% fatality rate in the wilderness environment and a 33% fatality rate for those not found in the first 24 hours. Most subjects were located in structures (45% in a wilderness setting and 70% in an urban setting). Distances between the Initial Planning Point and find locations were reported, finding a median of 1.0 km in an urban environment.

The major aim of this study is to identify risk factors that result in those with ASD becoming the subject of a search and rescue incident. It is expected that specific causes, activities, and scenarios will emerge that are unique to the ASD population. Another aim is to characterize the demographic factors. It is expected that a higher prevalence of searches for ASD subjects will exist and the age distribution may be different than the TD population. Search and rescue planners use spatial statistical models to best predict the probable locations of missing persons. It is expected that those with ASD will navigate and behave differently while missing, resulting in different spatial and incident outcomes. Most ASD search incidents are for children. Therefore, the final study aim is to compare ASD searches to those for TD children. It is expected that several differences will exist.

Methods

International Search & Rescue Incident Database (ISRID)

The International Search & Rescue Incident Database (ISRID) has been previously described including inclusion, exclusion, and database participants (Koester, 2008). A second round of data collection was collected from 2013-2014 and obtained data from 18 new sources along with updating previous sources. Data were either considered public domain or provided after a Freedom of Information Act (FOIA) request was made. Access to ISRID is arranged through the corresponding author.

Data Source	#ASD	ASD/TD Child%	# TD Child	Total searches
Project Lifesaver International	202	4040.0%	5	523
Oregon Emergency Management	49	10.9%	448	4529
NCMEC	29	34.1%	85	276
Ontario Provincial Police	19	20.2%	94	810
New Zealand Police	15	13.4%	112	1500
Maryland State Police	15	36.6%	41	470
UK Mountain Rescue	13	18.8%	69	653
Australian Police	9	13.2%	68	446
Georgia DNR	5	15.2%	33	128
Virginia Department of Emergency Management	4	2.2%	178	676
Santa Clara SAR	3	50.0%	6	144
ICE-SAR, Iceland	2	18.2%	11	89
Arizona SAR	2	8.7%	23	290
California	2	4.5%	44	124
NPS Yosemite	2	7.4%	27	213
British Columbia PEP	1	5.0%	20	134
Marin County SAR	1	14.3%	7	64
Colorado SAR Board	1	0.6%	172	1861
Idaho	1	20.0%	5	331
Maine Game	1	4.0%	25	169
New Mexico Public Safety	1	6.7%	15	1200
Pennsylvania DNR	1	1.1%	95	507
Utah	1	1.6%	62	3230
Washington SAR	1	2.4%	41	363
Sources with no ASD	0	0.0%	649	4757
Total	**380**	**7.6%**	**2335**	**23487**

Table 1: Data sources that contributed data with ASD incidents.

Subject Classification Hierarchy

All of the cases reported here fall into either the ASD or TD child (1-16) subject category. However, it is possible that a missing subject might have ASD but be placed into a different subject category based upon the ISRID algorithm used to determine subject categories. The five-step algorithm, new to ISRID2.0, shown in **Fig 1** classifies the subject category based upon external forces, transportation, cognitive condition, age, or activity.

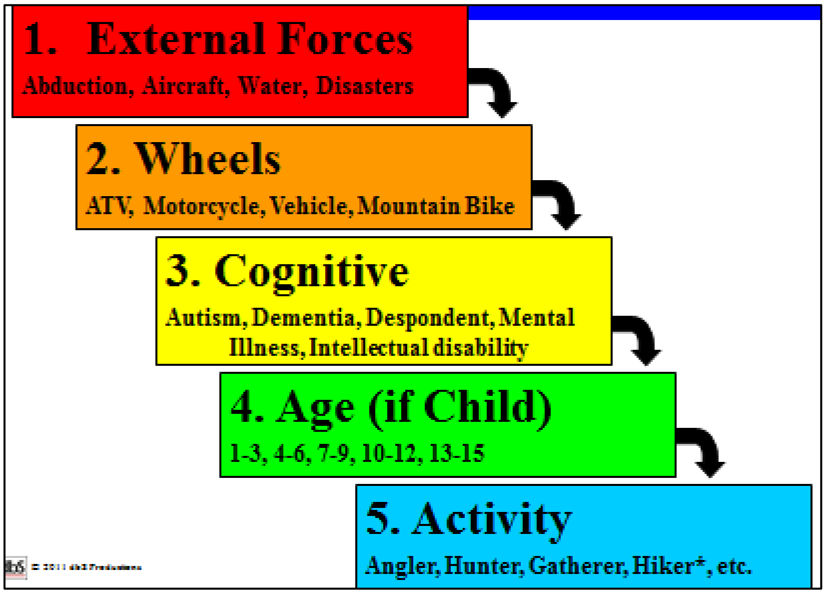

Figure 1 Subject category hierarchy used to classify incidents within ISRID2.0.

ISRID ASD Data

The subject classification of ASD was based solely upon the retrospective search records collected during the incident. The ISRID fields of subject category, sub-category, and comment fields were examined for potential references to ASD. Terms that led to classification as ASD included Autism, Autistic, ASD, Asperger's, and AS. During search incidents initial information is collected from the reporting party. In most cases this is the caregiver, however in some cases it may be a person not familiar with the missing subject. For more protracted searches the investigative process will typically contact the caregivers, medical professionals, and educators. Classification by SAR professionals is based solely upon these contacts. It is possible that the SAR interviewers may have neglected to record any ASD history or for shorter searches the reporting party (or even caregivers) may not disclose any ASD history to SAR. Some caregivers may have also avoided getting a diagnosis for a child who has ASD.

ISRID TD Children Data

ISRID categorizes TD children in the following age groups: Toddler (1-3), Preschool (4-6), School-Age (7-9), Pre-Teenager (10-12), and Adolescent (13-15). Sixteen and older were placed into categories based upon the activity they were participating in. The 2,335 cases of data on TD children reported here comprise the five child age groups (1-15). As previously described in the subject classification hierarchy section, children in missing aircraft, water incidents, ATV, mountain bikes, etc. are not included in the TD Child age brackets.

Notification and Search Times

The standards for notification and search times, Initial Planning Point (IPP) (either the Place Last Seen (PLS) or the Last Known Position (LKP)); incident cause, incident scenarios, and search outcomes can be found in *ISRID data standards* (Koester, 2016)

Geographic Descriptors

Several geographic models are used to describe the find location relative to various geographic features. A detailed description of the methodology for horizontal distance from the Initial Planning Point, use of the Bailey ecoregion domains, track offset, elevation change, find location, and mobility measurements can be found in Koester (2008; Bailey, 1995). The watershed methodology first described by Doke (2015) was modified for this study using the methodology found in Sava et al (2015).

The point model is a new geospatial model for SAR incidents not previously described in the literature. It describes the percentage of subjects who are located at two distinctive and discrete locations--the Initial Planning Point and a known destination. Every search incident has an IPP, but not every incident will have a known destination. IPP, Find, and Destination coordinates are all fields in the ISRID database. In addition, the comment field also allowed classification of the find as occurring at the IPP or destination.

Statistical Analysis

The raw data from ISRID were managed in a Microsoft Excel spreadsheet and exported as necessary to other statistical software. We performed statistical analyses to determine whether apparent differences were statistically significant. Analyses were done in Microsoft Excel 2010, GraphPad QuickCalcs and the Python SciPy suite (Jones et al., 2001; Oliphant, 2007; Perez and Granger, 2007; Hunter, 2007). All tests were 2-tailed.

Categorical comparisons used Chi-Square (χ^2) tests, with Laplace corrections when counts were low (Greenland, 2000). Means of continuous variables were compared using either analysis of variance (ANOVA—when more than 2 variables were being compared) or a parametric *t*-test (when 2 values were being compared) in GraphPad QuickCalcs. In many cases such as distance from IPP, an ANOVA or *t*-test is insufficient for two reasons: first, the distribution is known to be highly skewed; second, a difference in extremes is operationally as important as a difference in means. In these cases, the comparison was made using a nonparametric Kolmogorov-Smirnov (KS) two-sample test to determine if they likely came from the same (unknown) distribution. The KS tests were performed using the SciPy stats module ks_2samp procedure (Jones et al., 2001) Results are considered “significant” if they are less than 5% likely to occur by sampling error alone ($P < .05$), but actual *P* values are always reported.

Results

Characteristic	ASD		TD Child		P Value
	n		n		
# Search Incidents	380		2335		
Average Age	338	14.2	2124	8.8	P<0.0001
ASD Children	269/130	5.3%/7.2%	2335/1686		
ASD Adults	87	25.7 (avg age)		10.4	P<0.0001
Male	297	83.2%	1519	70.1%	P<0.0001
Female	60	16.8%	649	29.9%	
Solo while lost	357	100%	1752	89.6%	P<0.0001
Group while lost	0	0%	204	10.4%	
Notification time avg	243	1:34	816	3:43	P=0.15
Search time avg	297	1:43	1589	5:29	P=0.09
Found Well	324	88.5%	1684	88.7%	P=1.000
Found Injured	25	6.8%	103	5.4%	P=0.302
Found DOA	16	4.4%	93	4.9%	P=0.674
Never Found	1	0.3%	19	1.0%	P=0.180

Table 2 reports the overall demographic characteristics of ASD and TD Children who were the subjects of searches in the ISRID database. The age distribution of search incidents is statistically different between ASD and TD Children as seen in **Figure 2**. While ISRID contains 338 ASD adult and children cases, 202 of these came from Project Lifesaver International which specifically enrolls ASD and dementia cases. If both the Project Lifesaver International and adult cases are excluded this leaves 130 child ASD incidents. A total of 2465 ISRID incidents involved children (130 ASD Child + 2335 TD Child) for an ASD child prevalence of 5.3%. Some large data sources reported no ASD incidents. If the data sources that reported no cases of ASD are excluded then the number of TD child searches drops to 1686 and a total of 1816 incidents would involve children (130 + 1686) and the prevalence rate becomes 7.2%. The CDC reports the official prevalence of ASD among 8-year-olds as 1 in 59 for 2014 (1.7%)(Baio, et al., 2018). Using the most recent official CDC estimate of 1.7% and the range of ISRID prevalence of 5.3-7.2%, children with ASD are 3.1 - 4.2 times more likely to become the subject of a formal search. A higher incidence of search incidents occurs for those with ASD than TD children which is statistically significant ($\chi^2 = 325$; $P << .0001$).

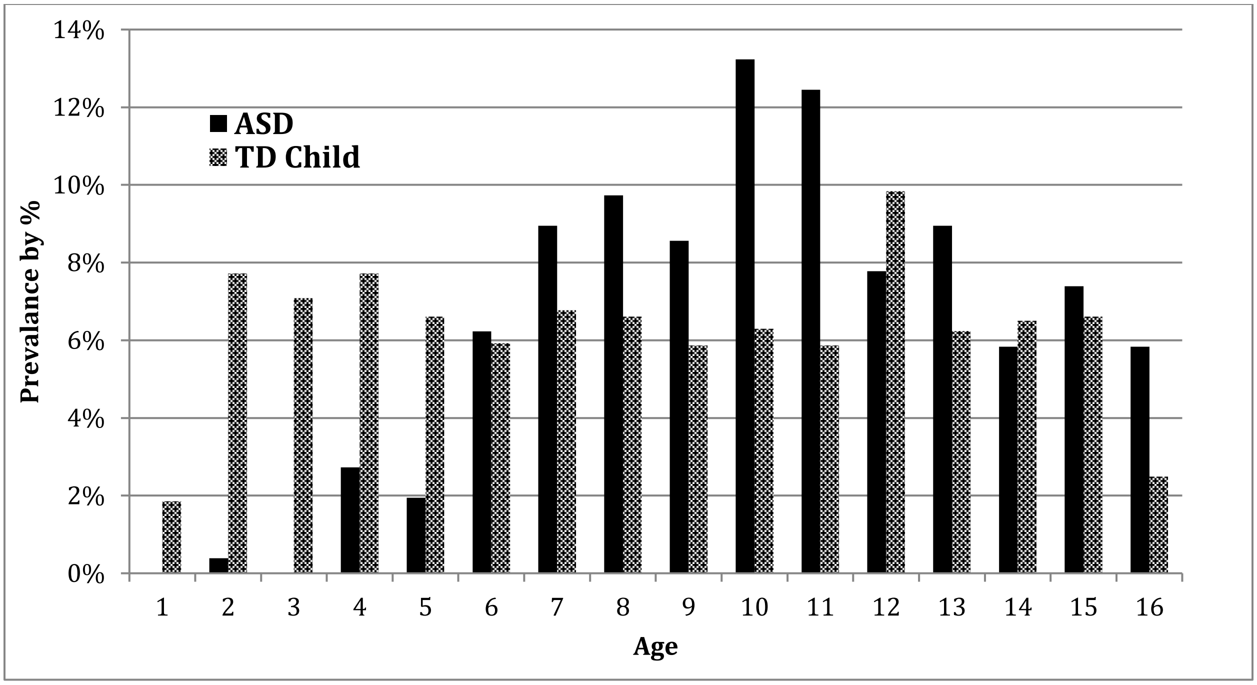

Figure 2. Distribution of prevalence of search incidents by age for 1-16 year-olds. ASD based upon 257 incidents and TD Children based upon 1891 incidents where the age was reported. The two groups are statistically different (F crit = 3.8, P<0.0001).

Search Scenario and Outcome

A general medical outcome was reported in 366 ASD cases and is reported in **table 2**. If the subject was not found in the first 24 hours after being last seen then survivability drops to 62% (n=8). However, when looking at the entire ISRID database, it is clear that the mortality rate among TD children (4.9%) and ASD (4.4%) is significantly lower than the overall ISRID mortality rate of 12% (χ^2=53.12; *P*<<0.0001). The search scenario is reported in **Table 8**. Additional survivability data is displayed in **Figure 3** and summarized in **table 9**.

Child ASD versus Adult ASD

The ISRID database contains 269 children (age 2-16) with ASD and 87 adults (17-75) with ASD. Twenty-four of the ASD subjects had no age reported. Among the spatial models no statistical difference was seen in distance from the IPP (KS; *P*=.429); track offset (Student's *t*-test; *P*=.38); elevation (χ^2 = 2.392; *P*=.302); survivability (χ^2 = 1.118; *P*=.29) or mobility (Student's t-test; *P*=.46).

Geographic Descriptors

Spatial statistics were collected for distance from the IPP, track offset from the nearest linear feature, total time mobile, vertical elevation change between the IPP and find location, point model which measures percentage found at the IPP or the intended destination, type of terrain found in, and the watershed model. The results are shown in **table 2-8**.

	Distance (horizontal) from IPP (km)						Track Offset (m)		Mobility (hours)	
	ASD			TD Child (1-16)			ASD	TD Child	ASD	TD Child
	Temperate	Dry	Urban	Temperate	Dry	Urban				
n	**233**	**10**	**31**	**903**	**115**	**129**	**174**	**55**	**21**	**272**
25%	0.4	0.7	0.4	0.3	0.8	0.2	0	2	1	1
50%	0.9	1.4	1.0	0.9	2.4	0.5	9	14	3	3
75%	2.3	3.0	2.1	2.4	4.0	1.6	46	53	4	5
95%	8.0	7.2	6.4	11.3	9.7	5.2	396	500	7	11
Avg.	2.1	2.4	1.7	2.7	3.2	1.4	81	104	3.2	3.7
SD	3.7	2.8	2.0	5.3	3.7	2.0	232	310	3.0	4.4

Table 3. Quartile and 95% for ASD and TD Children for distance, track offset, and mobility models. No significant difference was seen in the distance models (KS P=0.5) track offset model (K-S p=0.75), or mobility (KS, P=0.8).

		Watershed Model (%)			
Data Source	**n**	0: Same Watershed	1: Adjoining Watershed	2: Two Watersheds away	3: Three+ Watersheds away
ASD	15	67%	27%	7%	0%
Arizona[43]	122	47%	38%	6%	10%
New York[43]	102	70%	24%	3%	4%
Yosemite[3]	184	50%	43%	6%	2%

Table 4. Data for the Watershed model. Data from Arizona and New York from (Sava, Twardy, Koester, & Sonwalker, 2015). Data from Yosemite from Doke (2012)

Point Model (%)						
	ASD			TD Child		
Location	**Potential**	**Actual**	**%**	**Potential**	**Actual**	**%**
IPP	70	3	4%	408	55	13%
Destination	0	0	NA	153	17	11%

Table 5. New Point model based upon subject being found within 100 meters of IPP or destination. Potential means the IPP and/or destination was recorded. Actual means the subject was found at that location. ASD might have had a potential destination but failed to tell anyone.

Elevation Model (%)		
	ASD	**TD Child**
n	**16**	**462**
Uphill	31%	34%
Downhill	31%	37%
Same	38%	29%

Table 6. Elevation model with no significant difference.

	Find Location (%)					
	ASD			**TD Child (1-16)**		
	Temperate	Dry	Urban	Temperate	Dry	Urban
n	**228**	**12**	**29**	**343**	**32**	**128**
Structure	78%	75%	45%	34%	25%	59%
Road	7%	8%	28%	18%	22%	10%
Linear	0%	0%	3%	10%	13%	3%
Drainage	1%	0%	3%	6%	0%	3%
Water	5%	8%	14%	8%	13%	5%
Brush	0%	0%	0%	2%	6%	0%
Scrub	0%	0%	0%	1%	6%	2%
Woods	6%	8%	7%	16%	13%	8%
Field	2%	0%	0%	4%	0%	10%
Rock	0%	0%	0%	1%	3%	0%

Table 7. Data for find location. Note large difference in the find percentage for structures.

Scenario (%)		
	ASD	***TD Child***
n	***106***	***1116***
Avalanche	*0%*	*0.1%*
Criminal	*0%*	*0.4%*
Despondent	*0%*	*0.5%*
Evading	*17.0%*	*5.6%*
Investigative	*20.8%*	*12.8%*
Lost	*54.7%*	*67.7%*
Medical	*1.9%*	*0.4%*
Drowning	*2.8%*	*0.5%*
Overdue	*2.8%*	*9.9%*
Stranded	*0%*	*0.7%*
Trauma	*0%*	*1.4%*

Table 8. Different scenarios involved in cause of incident. Note differences in evading, investigative, drowning, and overdue.

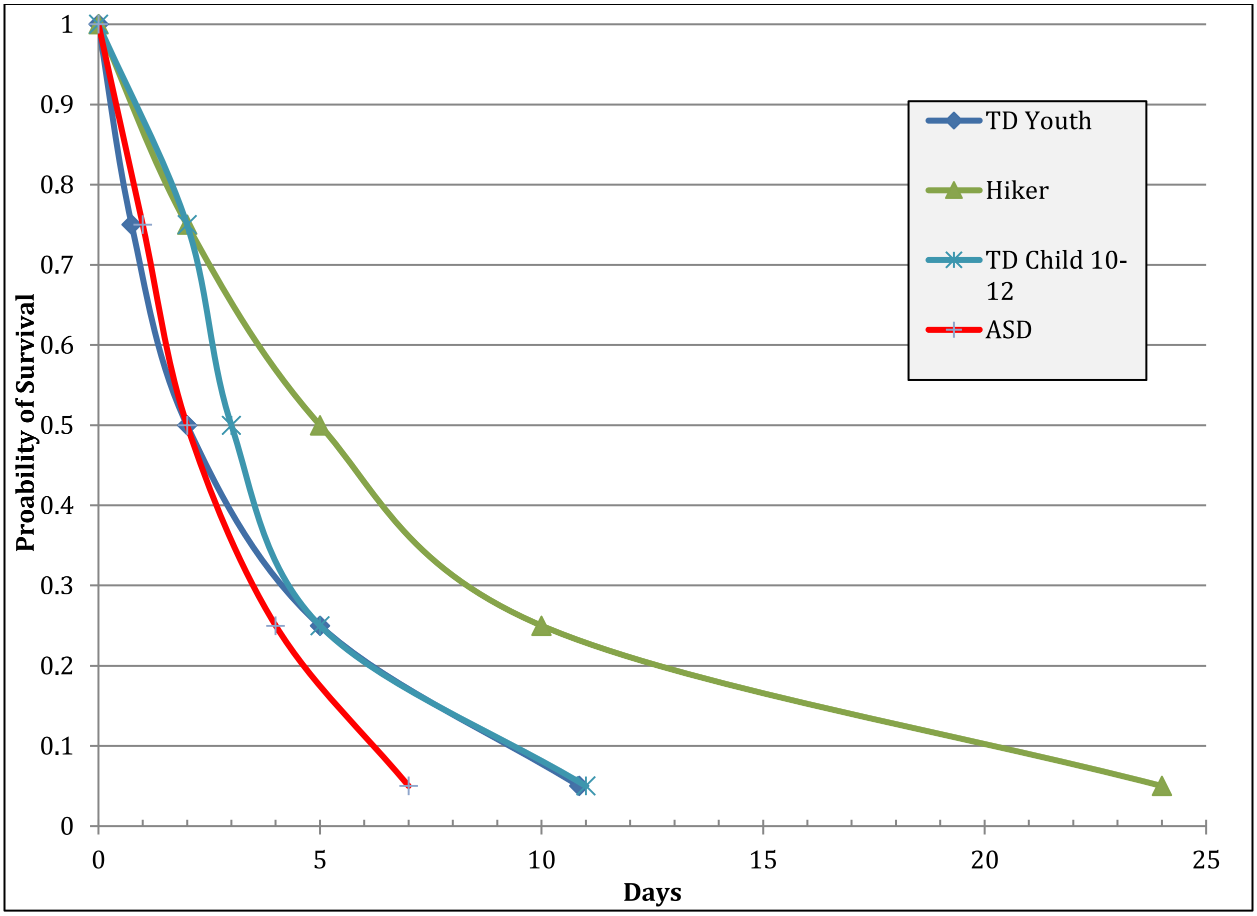

Figure 3: Long-term probability of survival curves. ASD curve is similar to both of the TD Youth (age 13-15) and the TD Child (10-12) curves. Although TD Children have a slightly better chance of long-term survival. The hiker curve (all adults) is provided for reference and has the best long-term survivability. The line provides the probability of finding the subject alive after that number of days have passed since the subject last being seen. For example, at four days, an ASD subject has an 25% chance of being found alive, at seven days, it drops to 5%. All data from searches, recoveries were excluded.

	Probability of Survival (days)			
	ASD	TD Child	TD Youth	Hiker
n	**24**	**73**	**224**	**962**
75%	1	2	0.75	2
50%	2	3	2	5
25%	4	5	5	10
05%	7	11.4	10.9	24

Table 9. Long-term probability of survival curves data that figure 3 is based upon. On the 7th day since the subject was last seen alive, the probability of finding an ASD subject alive would be 5%.

Discussion

Search incidents for missing ASD and TD children demonstrate significant differences but also have some common features. The newly updated ISRID database was able to examine 380 ASD and 2335 TD child search incidents. Based upon the findings of this study, children with ASD are 3.1 – 4.2 times more likely to become the subject of a search than age-matched TD children. This is comparable to the finding by Anderson, et al. (2012) that those with ASD were 3.8 times more likely to elope than their age-matched TD siblings. Furthermore, it is also possible the ISRID-based estimate may underestimate the prevalence of ASD. Within the ISRID database it is possible to have: undiagnosed ASD cases recorded as TD Child, failure of the caregiver to report the ASD diagnosis, or failure of the SAR team to record the ASD information on the data collection forms, all of which would result in the ASD incident being recorded as a TD Child incident. However, it would not be expected to have a TD child reported as an ASD incident. Subsequently, any ASD finding reported is potentially at the lower bound of actual results and any significant findings showing differences was able to rise above this potential obstacle.

The basic premise of lost person behavior is that the subject category can make meaningful predictions and generalizations about the subject of the current search. The algorithm used to determine the subject category implies that categorization as ASD better predicts the find location than age (Koester, 2008). This premise would predict that ASD children and ASD adults are more similar than ASD and TD children. This study is the first to critically examine and support this premise by finding that no statistical differences were seen between ASD adults and ASD children for distance from the Initial Planning Point (IPP), track offset, elevation, mobility, or survivability. However, it is important to note that a thoughtful search planner should use the ASD profile with confidence but should always consider other factors, such as age, in determining the search strategy.

Any search incident is an emergency. Search urgency charts have been developed to measure the need to respond (Stoffel, 2006). Typical ASD incident factors such as a solo subject, age, cognitive condition, experience profile, and equipment profile almost always places an ASD incident into the most urgent category. A search for an ASD child chronicled by King (2012) required 68,936 personnel hours, 5 days, and found the subject alive. The most common search scenario is that the child becomes lost for both ASD (55%) and TD children (68%). However, searchers should be aware that ASD search subjects are three times more likely to be evasive and five times more likely to be involved in a drowning.

This study also describes several different spatial relationships that search planners may use to help model probable locations of a missing subject. The spatial models described in this study include horizontal distance from the IPP, track offset, elevation, mobility, find location, point model, and watershed. This is the first time the track offset, mobility, watershed and point models have been described for ASD. All of the models except the horizontal distance and dispersion model require specific GIS layers in order to display and calculate the probabilities. All of these models may be integrated, with

Sava et al. (2015) and Wysokinski & Marcjan (2015) recently combining some of these models. An integrated model allows search planners to visualize potential locations and then deploy resources while computer programs may further enhance operational decision making by optimizing resources based upon search theory.

The horizontal distance from the IPP model helps to establish the formal search area and define areas of higher probability density. Between ASD and TD Child categories no significant difference was seen. However, the study did find that the environment plays a significant role in distances traveled from the IPP. While Koester (2008) previously reported subject category by ecoregion domains and treated the urban environment as its own domain, this is the first time distance from the IPP has been shown to be statistically significant due to the environment for ASD. TD Child travels significantly farther in the dry ecoregion domain than the humid temperate domain. In addition, for both the ASD and TD Child incidents, subjects traveled farther in urban environments (as measured by "as-the-crow-flies" distances).

While the track offset model was not shown to be significantly different between ASD and TD children, it still holds operational significance for searchers and planners with the ASD 50% quartile track-offset distance of just 9 meters (18 meters total width) versus 14 meters (28 meters total width) for TD Child. This means ASD subjects are much more likely to be found close to a linear feature such as a road, powerline, or hydrological feature. When searchers are assigned to a linear task they should consider searching out to at least the 50% of the track offset. Alternatively, a corridor task may be assigned where the team anchors on the linear feature while the team searches out the 75% track offset distance (46 meters). These may be the only types of tasks possible to search the 75-95% distance annulus.

The find location data indicates a substantial percentage of ASD subjects are found in structures (45-78%), even in more so in urban areas. Search teams should be reminded of the importance of thoroughly searching buildings, out-buildings, yards, and vehicles. In remote areas where no structures are present, subjects have been located in dense foliage, which may represent a proxy for a structure. Searchers, therefore, should also pay particular attention to dense areas that may offer a sense of being enclosed.

Age-specific differences are seen in the prevalence of wandering for both those with ASD and TD children in **Figure 2.** Our findings generally agree with McIlwain and Fournier (2012) who reported ASD three-year-olds as the youngest in their fatality database, even though an early diagnosis of ASD may occur as early as 18 months (Zwaigenbaum et al., 2005). The American Academy of Pediatrics recommends screening all children by age two, yet the median age of Autism diagnosis is 5.7 years (Johnson & Myers, 2007; Shattuck et al., 2009). Therefore, it is both possible that the delayed onset in search incidents among autism may be either a behavioral difference or simply undiagnosed early wandering incorrectly classified as TD children.

Only 7% of the ASD records clearly indicated seeking behavior, although it could be argued that investigative outcomes indicate seeking behavior which would raise the percentage to 27%. This is in contrast to Anderson, et al (2012) who reported that nearly half of all parents reported that the child's wandering/elopement was goal-directed. It is possible that search investigators neglected pursuing possible destinations in ASD incidents

Limitations

This study had several limitations. The ISRID database used a retrospective approach and collected data from numerous different data sources. As a result of the retrospective nature it is quite possible that some of the incidents classified as TD Child may in fact be ASD. Nonetheless, we were able to report statistically significant results even with potentially mislabeled cases. These results are also confounded by different intellectual capabilities within the ASD category. Many of the search records did not mention whether the ASD search subjects were HFA (High Functioning Autism) or LFA (Low Functioning Autism). It is certainly possible that the differences between ASD and TD children seen in this study are more a function of intellectual ability. This distinction may eventually lead to a sub-category within ASD (HFA or LFA) for SAR practitioners based upon future studies. Future studies should compare ASD to children with intellectual disabilities. It would also be appropriate to break ASD into three groups, consisting of of children ages 1-15, unmyelinated young adults ages 16-21, and adults.

Conclusion

The findings of this study have implications for public policy, search and rescue tactics, and a better understanding of the navigational abilities in those who have ASD and TD children. Seven different spatial models provide quantitative data on where those with ASD are located. Those with ASD were 3-4 times more likely to require a search effort, 4.7 times more likely to be involved in a drowning incident, 1.7 times more likely to be evasive, 2.0 times more likely to be found through investigative efforts, and more likely overall to be lost by themselves than TD children (age 1-16).

The study found several statistically significant differences in spatial models used by search and rescue planners. While no differences were seen between the distances traveled by ASD and TD Child in the wilderness, the importance of the ecoregion domain and urban settings was shown. In the urban environment, ASD subjects traveled nearly three times as far as TD Child for all of the quartiles. Differences between ASD and TD Child were shown in decreased distances traveled away from a linear feature (track offset), more likely to be found in the same HUC-12 watershed (67%), and less likely to be found at the IPP (4%) than the TD Child.

This is the first study to look critically at the central premise of lost person behavior categories for ASD and TD Child categories. The data supports the current subject category algorithm of looking at cognitive issues prior to looking at age. The study showed that ASD children and adults are similar while ASD and TD children had several significant differences in spatial models.

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Abbreviations

ANOVA	Analysis of Variance
ASD	Autism Spectrum Disorder
ATV	All-Terrain Vehicle
Avg.	Average (mean)
CARS	Charlottesville-Albemarle Rescue Squad
CEO	Chief Executive Officer
DCJS	Department of Criminal Justice Service
DOA	Dead on Arrival
FEMA	Federal Emergency Management Agency
FOIA	Freedom of Information Act
GIS	Geospatial Information System
HFA	High Functioning Autism
IPP	Initial Planning Point
ISRID	International Search & Rescue Incident Database
KS	Kolmogorov-Smirnov
LFA	Low Functioning Autism
LKP	Last Known Point
n	number (count)
NASA	National Aeronautical Space Administration
NPS	National Park Service
PLS	Place Last Seen
POA	Probability of Area
SD	Standard Deviation
S&T	Science & Technology
TD	Typically Developing
USCG	United States Coast Guard
US DHS	United States Department of Homeland Security

About the Author

Robert J. Koester first joined the Appalachian Search & Rescue Conference in 1981 and since then has participated in hundreds of searches, including over a hundred as Incident Commander. He holds a Ph.D. from the University of Portsmouth in search theory and a MS and BA from the University of Virginia in biology (neurobiology). His contributions to search and rescue include seminal research on search theory and lost person behavior along with creating the International Search and Rescue Incident Database (ISRID). He is an instructor for the Virginia Department of Emergency Management since 1988 and past-president (15 years) of the Virginia Search and Rescue Council, Robert has also worked for the USCG (conducting visual sweep width experiments), NASA (conducting missing aircraft radar research), NPS (responding to major searches and writing the draft NPS *SAR Field Manual*), FEMA (as an instructor and disaster reservist), and SAR Institute of New Zealand (conducting sound and light sweep width experiments). He is currently developing SAR software called FIND, for the US DHS S&T directorate. He also developed courses for DCJS and was a Cardiac Technician for twelve years with CARS. He is the CEO of dbS Productions which provides research, software & publications, and training services. He is also a visiting researcher at the University of Portsmouth. Robert has authored dozens of books and research articles on search and rescue, including *Lost Person Behavior,* and is widely cited.

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