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Benefits of Assessing Linguistic Skills within the Evaluation of Navigational Skills

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Abstract: Good navigational skills are required to find words embedded within the dynamic display of a speech-generating device (SGD). Past research has demonstrated a relationship between navigational and cognitive skills in children and adults. Linguistic skills could also play a role in the navigational process. The goals of this study were to investigate the relationship between navigational and linguistic skills and to determine if the addition of linguistic variables to cognition could offer a better prediction of children's navigational ability. Although receptive language skills were correlated with navigational skills, results revealed that linguistic skills were not among the best predictors. When age, linguistic skills, and cognitive skills were statistically analyzed, cognition alone remained the best predictor of the ability to navigate an SGD with taxonomical organization.

Keywords: Augmentative and Alternative Communication (AAC), Navigation, Speech-Generating Device (SGD), Linguistic skills, Children

Introduction

The ability to access symbols that are not directly visible on the main screen of a speech-generating device (SGD) with a dynamic display is a necessary skill to utilize technology at its fullest capacity (Drager et al. 2004; Light and Drager 2007; Reichle and Drager 2010). The iPad (Apple 2015) and other new technology used for augmentative and alternative communication (AAC) purposes have dynamic displays that maximize access to a large vocabulary in a more independent fashion (Reichle and Drager 2010). A study by Robillard et al. (2013) demonstrated that cognitive skills have an impact on young children's ability to navigate an SGD with taxonomical organization. In fact, it was revealed that 60% of the ability to navigate could be explained by sustained attention (46%), categorization (10%) and fluid reasoning skills (4%) (Robillard et al. 2013). It could be important to explore the role that linguistic skills might play within the ability to navigate; especially since the linguistic skills of children who have complex communication needs are at risk of developing poorly (Drager, Light, and McNaughton 2010). In order to better understand the skills needed for children to navigate an SGD with a dynamic display and taxonomical organization, the present study explored whether linguistic skills could further explain the ability to predict navigational skills. The goals of this study were to analyze the relationship between navigational and linguistic skills and to determine if linguistic skills could predict navigational skills. Ultimately, the purpose was to determine if a combination of linguistic and cognitive skills could offer a more precise prediction of navigational skills than cognition alone.

Children who have complex communication needs and who need to use an SGD to communicate may have varying levels of language skills and may have a language impairment. Indeed, "children who have complex communication needs form a heterogeneous group that varies significantly with respect to motor, sensory, perceptual, cognitive and linguistic skills, socioeconomic and cultural background, and environmental factors (e.g., communication partners, participation in instructional activities)" (Drager, Light, and McNaughton 2010, 304). Linguistic skills were therefore judged to be an important variable to add within the study of children's navigational skills.

Linguistic Skills

A child who has a language impairment essentially has difficulty learning language (Leonard 1998). It is estimated that 7% of school-aged children have a language impairment (Tomblin et al. 1997). According to Kohnert (2010), language impairments are due to innate factors that negatively interact with the demands of language learning. Some of the reported clinical markers of language impairments are limited vocabulary (e.g. Gray 2004; Rescorla 2005), difficulties with morphology and syntax (e.g. Bedore and Leonard 2001; Cleave and Rice 1997), shorter and less complex narrative discourse (e.g. Mayer-Crittenden 2013; Scott and Windsor 2000) and difficulties with social language (Fujiki et al. 1999). Until recently, children with a language impairment were thought to have intact cognitive skills (Leonard 1998). We now know that children who have a language impairment may have limited general processing capacities, which lead to a reduced performance in both the verbal and nonverbal areas (Leonard et al. 2007; Miller et al. 2001). They may also have poor performances in cognitive non-linguistic areas. Attention, working memory and processing speed are examples of functions that would be affected in children with a language impairment (Archibald and Gathercole 2007; Bishop and Norbury 2005; Gathercole 2006; Hoffman and Gillam 2004; Kohnert and Windsor 2004; Miller et al. 2001; Montgomery 2008).

Studies conducted in Quebec, Canada, by Thordardottir (2011) and in Ontario, Canada, by Mayer-Crittenden et al. (2014) revealed that language-impaired francophone children demonstrated difficulties in all linguistic domains: lexical, morphosyntax, syntax and narrative. With respect to children who have complex communication needs, Blockberger and Johnston (2003) reported difficulties with the acquisition of grammatical morphemes, which could be caused by the lack of opportunities for verbal output in language learning.

Linguistic and Cognitive Skills

According to numerous studies, processing speed, sustained attention and working memory are all correlated with linguistic skills (e.g. Archibald and Gathercole 2007; Bishop and Norbury 2005; Gathercole 2006; Hoffman and Gillman 2004; Kohnert and Windsor 2004; Miller et al. 2001; Montgomery 2008). Indeed, learning language without sufficient cognitive skills could prove to be difficult (e.g. Kohnert 2010). Researchers now recognize that cognitively demanding tasks such as learning language can modulate the development of the brain, and, in turn modify cognition (e.g. Green and Bavelier 2003; Maguire et al. 2000; Polk and Farah 1998). Please refer to Table 1 for a description of the cognitive and linguistic factors.

Previous Studies on Navigation

A study by Wallace, Hux, and Beukelman (2010) discovered a relationship between cognitive flexibility and navigational skills in adults who had experienced a traumatic brain injury (TBI). The Symbol Trails subtest of the Cognitive Linguistic Quick Test (CLQT) (Helm-Estabrooks 2001) was used to measure cognitive flexibility. This subtest was found to predict the level of training needed to master the navigation of an SGD and demonstrated the importance of cognitive flexibility for this population.

In young children, a study by Robillard et al. (2013) observed a relationship between navigational skills and several cognitive factors: sustained attention, categorization, fluid reasoning, visual spatial working memory and verbal working memory. Cognitive factors were assessed using the Leiter International Performance Scale-Revised (Leiter-R) (Roid and Miller 1997), and the Automated Working Memory Assessment (AWMA) (Alloway 2007). This same study determined that sustained attention, categorization and fluid reasoning were the best predictors of navigational skills in children. Although age was correlated with the ability to

navigate, (6-year-olds performed better than 5 and 4-year-olds, and 5-year-olds performed better than 4-year-olds), it was not among the best predictors of navigational skills.

The relationship between navigational and linguistic skills has not yet been empirically studied or reported. Since the ability to use and understand language is a variable that does fluctuate among children with complex communication needs, it could also be an important factor in navigation. In many devices, vocabulary is organized taxonomically. Therefore, it is possible that children who have difficulty understanding and classifying vocabulary may also have difficulty navigating within an SGD having this type of organization. Several authors argue that children who have a language impairment also have a reduced performance on cognitive tasks (e.g. Archibald and Gathercole 2007; Bishop and Norbury 2005; Gathercole 2006; Hoffman and Gillman 2004; Im-Bolter, Johnson, and Pascale-Leone 2006; Ellis Weismer et al. 2005). Since it has already been demonstrated that cognition plays a role in navigational skills (Robillard et al. 2013; Wallace, Hux, and Beukelman 2010) it is now important to also analyze the role of linguistic abilities within navigational skills.

Predicting children's ability to navigate an SGD with a dynamic display could be important to help clinicians select the appropriate device for maximum communicative success. For children who have difficulty navigating between pages of a dynamic screen, demands could be decreased by limiting the number of symbols per page and by using a different vocabulary layout or organizational method (Wilkinson and Hennig 2007). Indeed, since a study by Drager et al. (2004) established that 3-year-olds were less accurate in finding vocabulary when navigating an SGD with taxonomic grids compared to one with visual scene displays, the latter organizational method could be used in children who have difficulty navigating. The use of a consistent core vocabulary with consistent symbol location could also be used to tap into motor learning and increase automaticity (Van Tatenhove 2009).

Since cognitive and linguistic skills are interconnected, it was hypothesized that the addition of linguistic variables to cognitive variables and age would allow for an even more accurate prediction of navigational skills. The specific research questions for this study were: (a) Are navigational skills correlated with linguistic skills?; (b) Can linguistic abilities predict the ability to navigate an SGD with a dynamic display that uses a taxonomic organization?; and (c) Does the combination of linguistic skills, cognitive skills and age increase the ability to predict navigational skills in children?

Method

Participants

Thirty-nine children aged 48 to 77 months ($M = 65.82$, $SD = 7.64$) participated in this study. Twenty were girls and 19 were boys. None of them had complex communication needs. Seventeen of the children were enrolled in junior kindergarten (JK) and 20 were enrolled in senior kindergarten (SK). In Ontario, JK represents the first year of school when children must be 4 years of age by December 31st, and SK the second year, where children must be aged 5 years by December 31st. School entry happens when children are aged between 3;9 and 4;8 years. The children attended eight different French language schools within the City of Greater Sudbury, in Ontario, Canada, a community where French is a minority language and English is the majority language. In order to participate in this study, the children's dominant language had to be French. The children who participated in this study were the same as those who participated in a study on navigation and cognition conducted by Robillard et al. (2013), with the exclusion of the English dominant children because their poorer performance on the French language tests could have been attributed to their level of bilingualism. Hearing impairment was ruled out using earphones and a web-based hearing test (www.digital-recordings.com) conducted by research assistants. Participants all passed the screening at 10db HL, with some exceptions at 500 Hz because the test

was not conducted in a soundproof booth and some background noise was present. Vision problems were ruled out via a questionnaire completed by the parents. Some children wore corrective glasses. Before the study was conducted, ethics' approval was received by the Laurentian University Research Ethics Board and only children for whom informed parents signed the consent form participated in this study.

Setting

The children were assessed in a private room at their respective school or at the Laurentian University Speech-Language Pathology Clinic. The distraction levels within these two settings were judged to be similar since only the child and research assistant were present in the room. In order to reduce the impact of possible fatigue, the tests were not all administered at one time. To control for the practice element on the subtests that were last completed, navigational task and subtests were randomly administered. The number of sessions needed to accomplish all of the cognitive and navigational tasks varied per child, from four to six sessions, which ranged from 30 minutes to two hours each. To complete the linguistic tasks, two to three sessions varying from 30 minutes to two hours were needed.

Materials

Navigation

As in the study conducted by Robillard et al. (2013), in order to measure navigational skills, the iPad2 (Apple 2015) and the application Proloquo2Go (AssistiveWare 2015) were used. Since a study by Light et al. (2004) has demonstrated that 4 and 5-year-olds were successful with a layout of 12 to 20 symbols per page, a 16-location grid was selected. Pilot testing on six children with typical development aged 4 to 6 years confirmed that this number of symbols per page could be used successfully. The total number of target words for the experimental navigational task was also determined through pilot testing and was based on the number of items that the children could reasonably complete within a single session without requiring a break. Although young children may be more apt to use schematic organization (grouping by event contexts), the preloaded taxonomical organization (grouping by hierarchical categories) was chosen to research its impact on navigation. The symbols, which were preloaded, were SymbolStix (N2Y Inc. 2015).

The words chosen for the navigational task were judged to be familiar for most children aged 4 to 6 years. They were selected from the younger age groups of receptive vocabulary tests, such as the PPVT-4 (Peabody Picture Vocabulary Test – 4th Edition) (Dunn and Dunn 2007) and the ÉVIP (Échelle du Vocabulaire en Images Peabody) (Dunn, Thériault-Whalen, and Dunn 1993). They were concrete nouns representing objects, animals or people. The practice portion involved the retrieval of six words and for the formal navigational task, the retrieval of 25 words. A list of the target words can be found in Appendix A. The only word added was *BABY*, under the *PEOPLE* category since it was not part of the preprogrammed vocabulary. For the first portion of the task, the words could be found within the same categories as the practice words. However, as the task progressed, the symbols that needed to be retrieved could be found under new categories. Some symbols were retrieved under three levels and others that were found under sub-categories were retrieved under four levels. The order of presentation of the words was determined through pilot testing. In order to avoid discouraging the children who had difficulty navigating, the most difficult words to retrieve were placed at the end of the task and were often not administered to the children who attained the ceiling of eight consecutive errors. More information regarding the navigational task can be found in Robillard et al. (2013) and Robillard et al. (2015).

Linguistic Competence

The tests used to measure linguistic skills were administered within the framework of a study on bilingualism led by the second author (Mayer-Crittenden et al. 2014) and conducted at the same time as this study, with the same participants. Following approval by the Laurentian University Ethics Board, the results of those evaluations became available for this study. Form A of the Échelle de Vocabulaire en Images Peabody (ÉVIP) (Dunn, Thériault-Whalen, and Dunn 1993) was used to measure receptive vocabulary. This French version of the PPVT-4 (Dunn and Dunn 2007) was adopted and standardized for the Canadian francophone population and measures the comprehension of isolated words. In this task, the children were required to point to the images that correspond to the words presented verbally. Raw scores can be converted to standardized scores for children aged 2;6 to 18 years. Internal consistency reliability for form A of the ÉVIP varied from .78 to .88 for children aged 4 to 6. The Carrow (l'Épreuve de Compréhension de Carrow-Woolfolk, Groupe Coopératif en Orthophonie 1999) was used to measure language comprehension. This test is a French adaptation of the Test for Auditory Comprehension of Language-Revised (TACL-R) (Carrow-Woolfolk 1985) and was standardized with francophone children from Quebec. It contains three subtests in which the child must point to an image that corresponds to the word or sentence recited by the administrator. The first subtest, *Classes de Mots et Relations* (Word Classes and Relations), measures the comprehension of vocabulary and concepts; the second, *Morphèmes Grammaticaux* (Grammatical Morphemes), measures the comprehension of grammatical morphemes; and the third, *Phrases Complexes* (Elaborated Phrases and Sentences), measures the comprehension of complex sentences. The scores for the three subtests can be combined in order to obtain a composite score. A spontaneous language sample was obtained in French, in accordance with the study by Leadholm and Miller (1995), in order to calculate the mean length of utterances. A French (Québec) adaptation (Thordardottir and Gagné 2006; Gagné and Thordardottir 2006) of the Edmonton Narrative Norms Instrument (ENNI) (Schneider, Dubé and Hayward 2002–2006) was used to measure narrative skills. For this test, children are required to tell a story from a picture book that does not contain words. A French (Québec) adaptation (Royle and Thordardottir 2003) of a subtest from the Clinical Evaluation of Language Fundamentals-Preschool (CELF-P) (Semel, Wiig and Secord 1992) for sentence repetition was used to measure sentence recall. The children were required to repeat sentences while listening to a story (*Le grand démenagement*) as told by the administrator. Finally, the subtest *Concepts et Exécution de Directives* (Concepts and Following Directions) from the CELF Canadien Français (French Canadian) (Wiig et al. 2009) was used to evaluate the child's ability to interpret and carry out commands which contain basic concepts that increase in length and complexity. Following a verbal command, the child is required to identify the corresponding images. The internal consistency reliability for this subtest ranges from .92 to .95 for children aged 4 to 6 years. Please refer to Table 1 for a summary of all of the linguistic measures used within this study.

Table 1: Summary of Linguistic Measures Used in This Study

Name of test/task	Implementation	Measurement
CELF (concepts et exécution de directives/Concepts and Following Directions)	Identifying a sequence of images following a direction presented orally.	Receptive language
ÉVIP	Selecting a target word among four pictures	Receptive vocabulary
Carrow	Selecting a target word or sentence among three pictures	Receptive language
CELF CDN-F (imitation de phrases)	Recalling sentences presented orally within the framework of a story that increase in length and complexity.	Expressive language
ENNI	Telling a story from a wordless story book	Narrative abilities
Spontaneous language sample	Structured play for 15–20 minutes to collect a language sample	Expressive language

Cognition

The cognitive measures used were: the Leiter International Performance Scale-Revised (Leiter-R) (Roid and Miller 1997) and the Automated Working Memory Assessment (AWMA) (Alloway 2007). The Leiter-R is a non-verbal test standardized for ages 2 to 20;11 years; during the administration of this test, neither the child nor clinician need to speak. Table 1 presents a summary of the cognitive subtests. Its internal consistency reliability varies between .75 and .90 for the subtests used (Roid and Miller 1997). The AWMA is a computerized test of visual-spatial and verbal working memory for children aged 4 to 22;11 years. Correlation coefficients for test-retest reliability varies between .83 and .90 (Alloway 2007) for the subtest used within this study. Please refer to Robillard et al. (2013) for a more detailed description of the cognitive subtests that were administered.

Procedure

Navigation

Only one trained research assistant administered the experimental navigational task. The research assistant described and demonstrated how to use the Proloquo2Go (AssistiveWare 2013) application on the iPad2 (Apple 2015) and how to find words within the levels, which took an average of 5 to 10 minutes. This was a generic explanation of the symbols, taxonomic organization and device operation. For example, it was explained that words could be found under folders representing categories, that the home button linked to the first page and that the back button linked to the previous page. Because Proloquo2Go was not available with a French speech synthesizer, the volume was turned off to control for the participants' varying levels of English skills. The research assistant confirmed the retrieval of symbols by verbalizing the words in French.

Practice Portion

For the practice portion, the children were asked to retrieve six practice words on the iPad2. To control for the children's ability to correspond the symbol to the referent and to ensure that only navigation was being measured, the symbols were presented in a booklet, alone on one page, at the same time as the word was said aloud. The booklet remained open, displaying the target symbol, while the children navigated within the pages of the iPad2 to find symbols. During the practice portion, the research assistant gave the children prompts if they were unable to find a word, for example "What category does that word belong to?" or "You can use the home button to return to the first page." These six words all had to be successfully retrieved (with or without prompting) before starting the formal task. If practice words were not retrieved independently, the research assistant modeled the correct path to teach the navigation needed to find the symbol. The formal navigational task then began.

Formal Task

The children were then asked to retrieve 25 words within the dynamic pages of Proloquo2Go using the iPad2. The procedure was identical to the practice portion with the exception that prompts were not given. As in the practice portion, symbols were always presented in a separate booklet at the same time as the research assistant verbalized the words. The booklet remained open in front of the child, displaying the symbol, during the entire navigational task. The child could look at the symbol at anytime to ensure proper symbol selection. This was done in order to ensure that navigation was truly being measured and not representation. The child was instructed that if a symbol could not be retrieved, the page of the image booklet could be turned in order to skip that symbol.

One point was awarded if the child correctly retrieved the word. No point was given for that item if the word could not be retrieved, was incorrectly retrieved or was skipped. The test ended once all of the 25 items were presented or after the child reached the ceiling of failing to retrieve eight consecutive symbols. The items that were not administered were given a score of 0. They were not omitted from the analysis. The total of correct answers from those 25 items was used to calculate the percentage of words correctly retrieved and represented the navigational score.

Procedural and Inter-Rater Reliability

The sessions were all videotaped with parent consent. To ensure procedural reliability, another a second research assistant viewed the videos and coded the children's answers for a sample of 20% of the participants (8 of 39 children) who were randomly selected. The second assistant coded the children's answers to calculate inter-rater agreement. Both procedural and item-by-item inter-rater reliability were 100%. An inter-rater reliability analysis using the Cohen's Kappa statistic was also performed to determine consistency among raters. The inter-rater reliability for the raters was found to be $Kappa = 1.00$ ($p < .001$).

Linguistic and Cognitive Tests

Trained research assistants administered the linguistic and cognitive tests. Each subtest or task took, on average, 10 to 30 minutes to administer. As per standard administration, the Leiter-R was administered without verbal instructions. A portable computer with a 15-inch screen was used to administer the AWMA. Because the AWMA is an English program, the sound was turned off and the instructions were given in French by the research assistants.

Results

Navigational and Linguistic Skills

Navigation scores varied from 12 to 100 percent success ($M = 64.15$, $SD = 26.02$). Raw scores for all of the linguistic and cognitive tests were used in the analyses.

Correlation

The correlations between navigation and the results of the linguistic competence tests were then examined. Table 2 presents the correlation between the variables as well as the mean and the standard deviation for each test or subtest. Positive correlations between navigation and six of the 12 language measures were found. The higher the score on the ÉVIP, the Carrow (total and all three subtests) and the CELF-CDN-F subtest Concepts et Exécution de Directives (Concepts & Following Directions), the higher was the score on the navigational task. Navigation was not significantly correlated with the sentence repetition subtest of the CELF-P, the ENNI (narration task), nor the mean length of utterances (words and morphemes).

Table 2: Correlations, Means and Standard Deviations of Navigation, Age and the Linguistic Measures (in French)

Variables	1	2	3	4	5	6	7	8	9	10	11	12	13	14
1. Navigation	--	.61*	.34*	.60*	.36*	.43*	.50*	.53*	.21	.23	.33	.17	.05	.10
2. Age		--	.39*	.57*	.37*	.51*	.36*	.47*	.49*	.48*	.45*	.16	.23	.26
3. ÉVIP			--	.57*	.56*	.39*	.38*	.49*	.61*	.45*	.40*	.49*	.47*	.53*
4. Carrow (total)				--	.68*	.80*	.05*	.57*	.52*	.53*	.37*	.38*	.09	.16
5. Carrow (classes de mots et relations)					--	.33*	.26	.47*	.34*	.37*	.34*	.35*	.19	.25
6. Carrow (morphemes grammaticaux)						--	.40*	.42*	.48*	.49*	.40*	.37*	.06	.13
7. Carrow (phrases complexes)							--	.39*	.32*	.30	.08	.12	-.04	.02
8. CELF (concepts et exécution de directives)								--	.63*	.67*	.59*	.56*	.37*	.43*
9. CELF-P (sentence repetition, in order)									--	.99	.58*	.50*	.43*	.52*
10. CELF-P (sentence repetition, no order)										--	.59*	.67*	.41*	.47*
11. ENNI (grammar)											--	.65*	.43*	.48*
12. ENNI												--	.50*	.57*
13. MLU (words)													--	.98*
14. MLU (morphemes)														--
<i>M</i>	64.15	65.82	41.21	60.28	27.92	18.49	13.64	19.26	66.69	70.08	14.19	13.08	3.92	4.98
<i>SD</i>	26.02	7.64	14.16	15.26	6.35	7.39	6.79	7.80	20.48	19.51	7.05	4.01	0.72	1.03

*p < .05

Prediction of Navigation According to Linguistic Skills

The ability to predict navigational skills with the use of linguistic measures was examined. The object of this analysis was to find the most pragmatic set of linguistic factors that could best predict navigational skills. That is, the best prediction possible with the least amount of linguistic factors. Since no theoretical reason would suggest an order in which variables should be included, a stepwise linear regression was a relevant statistical choice in this case (Tabachnick and Fidell 2013). This statistical analysis started out empty, and then independent variables were added one at a time if they met statistical criteria for inclusion, but were deleted at any step if they no longer contributed in a significant manner to the regression (Tabachnick and Fidell 2013). The final results contained the variables that made the most important contribution to the regression model. The only variable included in the model was the total score on a measure of language comprehension, the Carrow test. This test explained 37% of the variance ($F(1;33) = 19.20$). None of the other variables were retained in the equation.

Prediction of Navigation According to Age, Linguistic and Cognitive Skills

The final analysis was based on the prediction of navigation from the combination of linguistic and cognitive tests, with the addition of the age factor. The goal of this analysis was to find the set of cognitive and linguistic tests that could better predict navigational skills. Once again, a stepwise logistic regression was performed, using the navigation score as the dependent variable. The independent variables that were included were age in months, raw scores from the language tests used in the previous analysis and raw scores from the seven subtests of the Leiter International Performance Scale-Revised (Leiter-R) (Roid and Miller 1997), as well as raw score from seven subtests of the Automated Working Memory Assessment (AWMA) (Alloway 2007) (subtests are listed in Table 1). The Attention Sustained subtest was the first to be inserted into the model. This subtest explained 57% of the variance ($F(1;33) = 42.86$). The Picture Context Subtest was then entered into the equation, explaining 9% of the variance ($F(1;32) = 11.52$). These two factors alone explained 66% of young children's navigational skills. None of the other variables were included in the model.

Discussion

The object of this study was to explore the influence of linguistic skills on young children's navigational skills. It was predicted that the addition of linguistic variables to the cognitive factors and age would offer a better prediction of navigational skills than cognition alone.

Linguistic Skills

Several language tests and subtests were significantly correlated with navigation; these tests and subtests all measured receptive linguistic abilities. The better the child's understanding of language, the better the ability to navigate an SGD with a dynamic display and taxonomical organization. The same could not be said for expressive linguistic skills. Better expressive language skills did not increase the ability to navigate an SGD. The strength of the bond between receptive linguistic skills and navigation decreased once it was observed that these subtests were significantly correlated with seven cognitive subtests (Leiter-R: Attention Sustained, Leiter-R: Classification, AWMA: Digit Recall, AWMA: Odd One Out, AWMA: Counting Recall, AWMA: Block Recall, and AWMA: Backwards Digit Recall). It has been demonstrated that in addition to linguistic competencies, language tests require attention and memory (Leonard et al. 2007). For this reason, the contribution of the cognitive component to linguistic tests could be the source of significant correlations with navigation. Moreover, according to Leonard et al. (2007), cognitive factors may contribute to the prediction of linguistic test results.

The total score of the Carrow test (measures language comprehension) contributed solely to the regression model, and was the only linguistic test that could be part of a subset that allows for the best prediction of navigational skills. One could hypothesize that this is due to the fact that children with poorer receptive language skills also have poorer categorization skills, which according to the present study, is one of the better predictors of the ability to navigate an SGD with taxonomical organization. Indeed, the Carrow test was significantly correlated with the Picture Context subtest of the Leiter-R ($r(37) = .31, p < .05$) and the Classification subtest ($r(37) = .43, p < .001$) of the Leiter-R, which are both measures of categorization. Finally, the Attention Sustained subtest of the Leiter-R was also significantly correlated with the Carrow test ($r(37) = .58; p < .001$).

Linguistic Skills, Cognitive Skills, and Age

When the cognitive and linguistic factors were combined with the age of the participants, the Attention Sustained (measures sustained attention) and Picture Context (measures categorization) were the best predictors of navigational skills. These results were similar to those found by Robillard et al. (2013), except for the exclusion of the Sequential Order subtest which measures fluid reasoning skills. Thus, the Carrow, the linguistic test that was the best predictor of navigational skills among the linguistic variables before the addition of the cognitive factors and age, was no longer an important predictive factor. Cognitive flexibility, which was reported to have a predictive value of the navigational skills of adults who experienced a traumatic injury by Wallace, Hux, and Beukelman (2010, 251), was not correlated with the navigational skills of young children with a typical development (measured using the Figure Ground subtest of the Leiter-R). A different cognitive flexibility task could reveal different results.

Since the Attention Sustained subtest scores and the Carrow scores were correlated, a linear regression was performed between these two variables in order to attempt to explain this phenomenon. Indeed, the Attention Sustained subtest could predict the scores on the Carrow test, explaining 32% of the variance ($F(1;63) = 31.48$). With the addition of the cognitive factors, the Carrow's contribution to the prediction of navigational skills disappeared. Since the only linguistic measure that could predict the ability to navigate could be estimated from the children's attention level, the contribution of the linguistic component disappeared when all these factors were combined.

Limitations

As in the previous study by Robillard et al. (2013), it is unknown whether the same factors would impact navigation among children who have complex communication needs. Procedural limits of this study include the variation in settings and in the number of assessment sessions per child. Future studies should incorporate formal testing of vision and representational skills. The varying levels of French language skills and the different levels of exposure to English could have impacted the results on the linguistic assessments. It is also unknown whether children belonging to different age groups would obtain similar results.

The experimental navigational task for this study required finding single words only. A navigational task requiring the sequencing of symbols could require higher linguistic and cognitive skills. The fact that the iPad volume was turned off may also have negatively impacted the results. The validity of the linguistic and cognitive measures could be questioned since these skills are difficult to isolate. Results should be interpreted with caution since the sample was small for the use of a stepwise linear regression (Tabachnick and Fidell 2013). A larger number of participants would also be needed to be able to generalize the results.

Future Research

Further navigational studies are needed with children who have complex communication needs. These studies should assess particular populations of children who often use SGDs, for example children with autism. It would also be beneficial to examine young children's ability to navigate a SGD with a dynamic display using taxonomical organization versus schematic organization or visual scene displays. Moreover, new variables need to be explored in order to better understand young children's navigational skills. Finally, in order to benefit a greater number of children who need technology to communicate, future research is needed to determine how SGDs should be programmed to reduce the attention and categorization demands.

Conclusion

This study demonstrated that linguistic skills could influence navigational skills in young children. Indeed, many receptive linguistic tests were significantly correlated with navigation, but among those, only the Carrow was needed to best predict navigational skills. However, when cognitive factors and age were added to the analysis, the predictive value of the Carrow disappeared. Although linguistic skills were important for navigation, they were not as important as cognition. The factors that remained the best predictors of young children's navigational skills were Attention Sustained, a subtest of the Leiter-R that measures sustained attention, and Picture Context, a subtest of the Leiter-R that measures categorization skills. Together, these two factors explained 66% of navigational skills.

Contrary to what was anticipated, the addition of linguistic skills to cognitive skills and age did not offer a better prediction of navigational skills. According to the results of this study, cognitive skills, or more precisely sustained attention and categorization skills, remained the best predictors of navigational skills. These results were similar to those found in the previous study by Robillard et al. (2013), which revealed that sustained attention, categorization and fluid reasoning skills were the best predictors of navigation. Further research is needed in order to better understand navigational skills among young children. More variables need to be explored in order to better understand the skills needed to find words within an SGD with a dynamic display and taxonomical organization.

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