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Capturing talk and proximity in the classroom: Advances in measuring features of young children's friendships

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ABSTRACT

Young children's friendships fuel essential developmental outcomes (e.g., social-emotional competence) and are thought to provide even greater benefits to children with or at-risk for disabilities. Teacher and parent report and sociometric measures are commonly used to measure friendships, and ecobehavioral assessment has been used to capture its features on a momentary basis. In this proof-of-concept study, we use Ubisense, the Language ENvironmental Analysis (LENA) recorder, and advanced speech processing algorithms to capture features of friendship – *child-peer speech* and *proximity within activity areas*. We collected 12,332 1-second speech and location data points. Our preliminary results indicate the focal child at-risk for a disability and each playmate spent time vocalizing near one another across 4 activity areas. Additionally, compared to the Blocks activity area, the children had significantly lower odds of talking while in proximity during Manipulatives and Science. This suggests that the activity areas children occupy may affect their engagement with peers and, in turn, the friendships they development. The proposed approach is a groundbreaking advance to understanding and supporting children's friendships.

1. Introduction

High quality inclusive settings have been deemed the type of classroom best suited to prepare young children with or at-risk for disabilities for kindergarten (Odom, Buysse, & Soukakou, 2011). When children with or at-risk for disabilities are able to observe and interact with socially competent peers in the inclusive classroom, they may learn the skills needed to more appropriately engage in social interactions and, in turn, form friendships (Brown et al., 2008; Buysse, Goldman, & Skinner, 2003; Dietrich, 2005; Odom, 2000). Unfortunately, some children with or at-risk for disabilities can have trouble forming friendships in this setting (Buysse, Goldman, & Skinner, 2002, 2008; Odom et al., 2006). Classroom adults, then, often play a central role in supporting interactions that aid in friendship development between children with or at-risk for disabilities and children with typical development. However, classroom adults can struggle in facilitating this (Buysse, Goldman, & Skinner, 2003). To better understand the relationship between human interactions and development, researchers have begun harnessing sensing tool technology to automate elements of observational measurement (Rehg, 2011; Rehg et al., 2014). These tools offer a means to not only enhance our understanding of features of friendship (child-peer talk and proximity [Buysse, 1993; Buysse et al., 2008]) within different activity areas of the classroom beyond traditional measurement approaches, but could also potentially be used to support early educators' ability to foster them.

Friendships among toddlers are described as a bi-directional relationship in which both children have an interest in spending time or playing together and demonstrate positive affect while engaged in social play (Buysse, 1993; Howes, 1996). This type of relationship follows playmate status, which shares these characteristics but lacks the type of ongoing, complex interactions needed to be considered a friendship (Howes, 2009). For young children, friendships affect numerous critical developmental outcomes, such as language, cognition, and social-emotional competence (Corsaro & Elder, 1990; Hartup, 1992; Kyratzis et al., 2010; Vaughn et al., 2001), as well as later well-being (e.g., Ladd, 2005). Friendships for children with or at-risk for disabilities are even more crucial, given essential skills linked to these developmental outcomes may be stilted or absent (Chang et al., 2016; Guralnick et al., 2007; Meyer

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& Ostrosky, 2014). Of concern, young children who are not able to make friends are at a higher risk for social isolation, depression, and poorer school outcomes (Bukowski et al., 2009; Ladd & Troop-Gordon, Ladd & Troop-Gordon, 2003; Parker & Asher, 1987, 1993).

1.1. Factors affecting friendships in the classroom

Disability status, classroom activity areas, and an educator's ability to support friendships are factors affecting friendship formation in young children. Children with or at-risk for disabilities may be more likely to encounter difficulty with peer relations that lay the foundation for friendships, compared to children who are typically developing (Kemple, 2004; Odom, 2000). Notably, when children with or at-risk for disabilities are able to form friendships, their interactions can change, which may aid in symptom amelioration. For instance, young children with high functioning autism spectrum disorder (ASD) tend to interact with friends in a more socially complex and coordinated manner than non-friends (Bauminger-Zviely et al., 2014).

The classroom space and materials within it affect child-peer talk (Kim et al., 2003; Innocenti et al., 1986; Martin, 2016) and can aid in transforming playmates to friends (Buysse et al., 2008). For example, researchers have reported that children with disabilities tend to have the most peer interactions during art and manipulatives (Kontos, Moore, & Giorgetti, 1998). For young children with ASD in particular, there is evidence that engagement with peers occurs more in books, snacks, large motor activity areas (e.g., swinging, riding tricycles) (Reszka et al., 2012), and pretend play (Hume, Sam, Mokrova, Reszka, & Boyd, 2019).

Early childhood educators often encounter difficulty in determining when and where to support relationships between young children with typical development and children with or at-risk for disabilities (e.g., Harper & McClusky, 2003). This difficulty may stem from a lack of training on how to support peer acceptance of these children in the classroom (Buysse et al., 2008; Favazza et al., 2000). For example, teachers often utilize behavior regulation and environmental arrangement strategies to support friendships for young children with ASD, but rarely attempt to promote interactions with peers (Chang et al., 2016) – even though research suggests this is an effective strategy (e.g., Irvin et al., 2015). Taken together, this work suggests that: (a) having a disability or being at-risk for one may affect peer interactions leading to friendship formation, (b) certain activity areas may help facilitate more peer interactions, and (c) supporting friendships with typically developing peers poses some challenges for educators.

1.2. Measuring friendships and the features of it

Child, parent, and teacher report measures (or some combination of these) are commonly used methods for measuring young children's friendships. Sociometric measures provide a method for assessing children's peer relationships, offering insight into who children self-report as friends (Buysse et al., 2008; Meyer, & Ostrosky, 2014). However, the use of sociometric tools with young children who have disabilities can be challenging (Buysse et al., 2008). Further, the ability to detect changes in the features of children's friendships over time is limited (Hurley, 2012). Although informative, parent and teacher reports can produce unwanted measurement issues (Odom et al., 2008). Parents have been found to over report their child's friendships when compared to teachers, possibly due to a parent's distinct perspective on their child's friendship networks relative to teachers' (Buysse, 1993). Characteristics of teachers (e.g., years of experience) and features of classroom settings (e.g., adult-to-child ratio) are associated with teachers' perceptions of children (Mashburn et al., 2006) and, arguably in turn, children's friendships. Additionally, there is evidence that teachers are less accurate in their identification of young children with disabilities friendships, even though they report more confidence in recognizing these compared to children with typical development (Meyer & Ostrosky, 2018).

Ecobehavioral assessment (live- or offline-video) can also be used to capture observed features of friendship on a momentary basis during activities and routines in natural settings (e.g., Frea et al., 1999); however, this approach is designed more for use among researchers than educators, given it requires training on discrete behaviors, maintaining reliability, as well as data analyses (Irvin, Crutchfield, Greenwood, Simpson, et al., 2017; Odom et al., 2000). Thus, given the limitations of traditional approaches to measuring the friendships of children with or at-risk for disabilities, new techniques are needed that introduce less measurement error, require fewer human resources, and could 1 day be used by teachers.

1.3. Using sensing tools to measure features of friendship

Sensing tools offer an innovative approach to measuring features of friendship and could better inform basic research (e.g., understanding factors that lead to development of friendship) and translational work (e.g., aiding teachers in supporting friendship). Examples of sensing tools include: (a) the use of a point-of-view camera to automatically detect and code eye gaze in young children with ASD (Edmunds et al., 2017), and (b) measuring physiological synchrony between parents and children via electrodermal activity, using noninvasive biosensors worn like a watch (Palumbo et al., 2017). In the early childhood inclusive classroom, a sensing system recently applied to detect talk and time spent in specific activity areas consisted of the Language ENvironmental Analysis (LENA) System and Ubisense (Irvin, Crutchfield, Greenwood, Simpson, et al., 2017). The LENA system is a speech analysis tool that simulates speech-recognition to estimate word count and was originally developed to model Hart and Risley's (1995) measurement of parent-child talk in the home environment. This technology provides full-day recordings of child and adult speech and the surrounding classroom language environment, and is increasingly used with young children with or at-risk for disabilities (e.g., Dykstra et al., 2012; Irvin et al., 2017). Although LENA is a useful tool, when overlapping speech or noise is dominant, the child and adult speech assessment taking place within these instances are not reliable, and therefore do not contribute to core child and adult vocal metrics (Gilkerson & Richards, 2020). Seeking to recover more usable speech from periods of overlapping speech and noise, researchers have recently applied advanced speech-processing algorithms (i.e., combined speech-activity detection and speaker diarization, or Combo-SAD) to early childhood classroom audio to improve speech-activity detection and speaker tagging accuracy in children wearing a LENA recorder (23% child speech error rate) (Hansen et al. 2019). The application of speech-activity detection separates background noise from speech (Ziaei et al., 2015), and speaker diarization categorizes the speech of individual speakers (e.g., who said what and when) (Hansen & Hasan, 2015).

Ubisense is a real time location system that has been validated for use in the early childhood classroom (Irvin et al., 2017). Recently, Messinger et al. (2019) used Ubisense to investigate social interactions and the location and movement of 16 5-year-old participants. Illustrative coordinate mapping revealed the 5-year-old boys and girls congregated in different physical locations within the classroom. This group has also validated LENA and Ubisense as a measure of peer social interaction and have reported it was associated with toddler-age children's friendships (Altman et al., 2020). Our study extends this work by: (a) examining child-playmate talk within activity areas of the classroom, and

(b) using a speech processing approach, that is more tailored to noise and speaker/language diversity in classroom settings.

Sensing tools and systems offer an opportunity to capture continuous, objective measurements without a human observer, and hold the promise of 1 day providing educators with data they can use to respond to these displays (or lack thereof) more immediately. In this proof-of-concept study, we use Ubisense, the Language ENvironmental Analysis (LENA) recorder, and advanced speech processing algorithms (i.e., Combo-SAD) in an attempt to capture friendship features in young children in an inclusive classroom, namely child-playmate proximity and speech. Our research questions were: (1) How much time did a toddler-aged focal child at-risk for a disability spend with playmates in activity areas; (2) How much time did a toddler-aged focal child at-risk for a disability spend vocalizing in activity areas in proximity of playmates, and (3) Is there a relationship between activity area and the likelihood that a toddler-aged focal child at-risk for a disability and his playmates talk more when in proximity?

2. Method

We used secondary data from a study comparing speech processing and Ubisense tools to global classroom measures of quality (i.e., Early Childhood Environment Rating Scale [ECERS], Infant/Toddler Environment Rating Scale [ITERS]) within a center-based program in a large urban community in a Southern state. Participants (teachers and families) consented to the use of de-identified data from the pilot for secondary analysis. In total, the pilot study included 4 lead and 10 assistant teachers across 4 classrooms and 44 children (24 typically developing and 20 with special needs). The classroom used for this proof-of-concept study was made up of the following activity areas: Art, Blocks, Entrance/Cubbies, Cozy Books, Diaper Change, Dramatic Play, Manipulatives, Science, and Sensory. The classroom space measured 7.36 meters (24.15 feet) wide and 7.62 meters (25 feet) in length, with extensions/cutouts for a small kitchen area and bathroom facilities. Teachers were instructed to go about their typical morning activities and routines.

2.1. Participants

In this classroom, we selected 3 of the 8 consented children to participate in the study: Jo (white male; 3 years, 1 month; received occupational therapy and speech language therapy once a week), Kay (white male; 3 years, 0 months) and Dereck (bi-racial male; 2 years, 11 months) (all names are pseudonyms). Jo, who served as the focal child, was at-risk for a disability, while Kay and Dereck were his 2 playmates who were typically developing. The children for this study were selected because they were: (a) included as part of our pilot combo-SAD speech analysis, given this toddler classroom was a less challenging audio environment to contend with relative to the preschool classrooms; (b) reported by the lead teacher to be playmates via the *Playmates and Friends Measure*; and (c) 1 child was at-risk for a disability. The mothers of all 3 children were college educated and none received a childcare subsidy. All 3 participants wore the LENA and Ubisense tag during morning activities and routines (8:52 AM -12:18 PM) on 1 day during winter.

2.2. Measures

2.2.1 Ubisense

This real-time location system uses ultra-wideband radio to provide second or multi-second location estimates simultaneously for multiple individuals in indoor and/or adjacent outdoor environments see www.ubisense.com. The networked sensors and wearable lightweight transponder tag relay data to a networked PC running the Ubisense Location Engine, which creates a digital map and monitors tag movements within the local environment. The system's precision ranges from 15-30 cm (6-12 inches), depending upon local environmental conditions and the number of installed sensors. The reliability and accuracy of the tool has shown to be more than acceptable in industrial (e.g., Phebey et al., 2010) and health-related settings (e.g., Kearns et al., 2016) and, as noted earlier, the early childhood classroom (Irvin, Crutchfield, Greenwood, Kearns, & Buzhardt, 2017).

2.2.2 LENA

This speech-recognition package consists of a digital language processor and speech-recognition software that aggregates total words spoken by adults, adult-child conversational turns, focal child vocalizations and vocalizations from other children (peers). LENA is capable of recording and reporting up to 16 consecutive hours of audio. Note, for this study, we used the LENA as a recorder only.

2.2.3 Playmates & Friends Questionnaire for Teachers – Revised

The Playmates & Friends Questionnaire for Teachers – Revised (*PFQT-R*; Goldman, & Buysse, 2005) captures information about a teacher's perception of a child's playmates, friends, and the time they spend together. The lead teacher of the children's classroom filled out this measure within 2 weeks of LENA and Ubisense data collection.

2.2.4 Demographic survey

The childcare director filled out a standard demographic form on child characteristics (e.g., gender) that was collected at the time of enrollment. This measure also included questions about the families of participating children (e.g., mother's education).

3. Procedures

Ubisense set-up & calibration

We chose Ubisense for this project largely because of the desirable measurement properties described earlier. The system itself requires a number of tasks be completed before it is operational. Key steps to setting up Ubisense include: (a) accurately locating sensors in the 4 corners of the space to provide maximum coverage, (b) networking the sensors via Category 5 cord to a laptop computer, (c) minimizing electronic interference caused by other devices (i.e., Wi-Fi routers), (d) establishing the dimensions of the classroom based on laser distance measurements, and (e) precisely calibrating the real-time location system sensors to their surveyed x, y, z locations, based on laser distance measurements. Following set-up, we used the Geometry feature of Ubisense to create boundaries around individual activity areas in the classroom, which subsequently helped to identify when children wearing a transponder tag were in a specific activity area (e.g., Art, Pretend Play).

Data extraction, cleaning & analysis

With Ubisense set up and calibrated, the scanning rate was set to 1 hertz to increase the manageability of the large amount of data produced by the real-time location system. Location data of children wearing transponder tags were then extracted from the system into an Excel file. Even though Ubisense can provide second-by-second location information, there are times when this information is missing due to a location tag being blocked. We addressed this by filling in the location data at the missing seconds (less than 6%) by interpolating the average value between the time the last coordinates were present. Although not a focus of this study, based on the classroom schedule and an absence of Ubisense data for the three children, ~ 50 mins. (i.e., 24% of the

Table 1
Children and Playmates' Time in Activity Areas (minutes).

	Jo's time in activity areas	Kay's time in activity areas	Dereck's time in activity areas	Jo next to Kay	Jo next to Dereck	Jo, Kay, & Dereck next to each other
Art	12.13	22.45	5.12	0.02	0.28	0.00
Blocks	51.12	94.03	90.57	27.45	11.55	0.00
Dramatic Play	18.88	9.48	10.85	2.83	0.02	0.00
Manipulatives	6.50	11.48	15.18	1.12	0.87	2.12
Science	53.43	15.20	37.45	3.93	18.08	0.05
Sensory	3.20	2.75	2.68	0.07	0.00	0.00
Entrance/Cubbies	6.47	1.55	1.03	0.27	0.10	0.00
Books	4.58	0.40	0.25	0.00	0.00	0.00
Diaper Changing	0.62	0.13	1.13	0.00	0.00	0.00

observation period) were spent outside of the classroom (e.g., gross motor room).

From these individual files, we developed a location-clustering program in MATLAB to determine activity areas the children occupied. Additionally, the Pythagorean theorem Distance Formula (DF) ($d = \text{sqrt}\ [(x1\text{-}x2)^2 + (y1\text{-}y2)^2]$) was used to calculate when two children were within 3 feet of each other within activity areas to ensure they were in close proximity. For determining when all three children were in proximity, the distance between each child was evaluated and coded as in proximity if all distances were less than 3 ft. Our LENA data were shared with speech-processing engineers at the University of Texas at Dallas for the application of Combo-SAD and to place child speech on a 1-second metric. With speech and location analyses completed and on the same metric, we then used SPSS crosstabs to determine when children were in the same activity area and within 3 feet of one another (research question 1) and talking (research question 2).

To address research question 3, we first subset the data to include only observations where dyads or triads of children (i.e., Jo and Kay; Jo and Dereck; Jo, Kay, and Dereck) were in proximity and in the same activity area ($n = 4{,}217$), then created a new binary variable indicating if any child in the dyad or triad was talking during that 1-s interval (0 = no, 1 = yes). We then used logistic regression in R 4.0.3 (*R Core Team, 2020*) to estimate the relationship between an activity area and the likelihood of a child talking, and then converted estimates to odds ratios to increase interpretability. We chose Blocks as the reference group for activity as it was the most frequently observed area where dyads were in proximity.

Results

Time spent in specific activity areas is expressed in minutes and percentage of time. Vocalizations are presented as a rate-per-minute. Because there were areas where children spent little time and presented few vocalizations, we ended up with some vocalizations per minute that were less than 1. Over the approximately 3 hours and 26-minute data collection period (12,332 1- second speech and location data points), Jo spent the most time in Science (53.4 minute, 26%), Blocks (51.1 minute, 25%), and Dramatic Play (18.9 minute, 9%). Jo spent the most time close (i.e., within 3 feet) to Kay in Blocks (27.45 min, 13%) and Dereck in Science (18.1 minute, 9%). The 3 children spent minimal time near one another in all other activity areas – see Table 1 for complete results (time each child spent within an activity area and within 3 feet of a playmate).

All 3 children spent the most time talking per minute in Blocks (Jo = 12.02; Kay = 15.65; Dereck = 18.80), which was followed by Science for Jo (8.98), Manipulatives for Kay (1.60) and Science for Dereck (4.47). Manipulatives was the only activity area that all 3 children were next to one another and talking, and vocalization rates were similar (range 0.22-0.40). When Jo was near Kay or Dereck in Blocks, his vocalization rate was higher than his playmates in Blocks but roughly the same rate as Dereck in Science. While in the Blocks, more of Jo's vocalizations were near Kay (6.03) than Dereck (3.80). Although Science was one of the areas Jo spent the most time with playmates, talk occurred much less frequently with Kay (0.75) and Dereck (1.85). Jo and Kay vocalized near one another in 4 activity areas (Blocks, Dramatic Play, Manipulatives, and Science); Jo also vocalized near Kay in Entrance/Cubbies. Jo vocalized near Dereck in 3 activity areas (Blocks, Manipulatives, and Science), and Dereck near Jo in 4 areas (Art, Blocks, Manipulatives, and Science). See Table 2 for complete results (total talk by child within activity areas and the talk within 3 feet of playmate in same activity areas).

Results of the logistic regression estimating activity area's relation with talking are presented in Table 3. Estimates and odds ratios indicate the increase or decrease in the odds of a child in a dyad or triad talking when that area is compared to the reference group, Blocks. Children had statistically significantly lower odds of talking during Manipulatives (OR = 0.59) and Science (OR = 0.36) when compared to Blocks. Estimates for Sensory, Entrance/Cubbies, Books and Diaper Changing were excluded due to very low rates of occurrence.

5. Discussion

The inclusive classroom can provide a space for friendship development between children, which can benefit young children with or at-risk for disabilities in multiple ways (e.g., increased acceptance among peers, social-emotional skills) (Buysee et al., 2008; Odom et al., 2006). This study used a sensing system to investigate specific child-peer vocalizations and proximity to playmates – 2 essential factors contributing to friendship development. Our results should be interpreted with caution, given the small sample of children and limited audio and location recording time. However, it was compelling that Blocks yielded more talk than Science and Manipulatives when children were in proximity of one another. This suggests that the activity areas children occupy may affect their engagement with peers, which aligns with previous ecobehavioral research (e.g., Reszka et al., 2012), and in all likelihood contributes to the friendships they develop. Importantly, this type of data could be useful for early childhood educators who are attempting to transition children with or at-risk for disabilities who are playmates into friends. More specifically, data on how much time children are spending next to each other and talking with one another may help educators ensure playmates spend more time together in activity areas that yield more vocalizations. Additionally, this type of data could aid teachers in understanding what type of activity areas better facilitate children being near one another and talking – which could prompt changes in the environmental set-up of specific areas to better support friendship development. Further, these types of data allow researchers to consider questions focused on proximity and vocalizing benchmarks that facilitate children's transition from peers to playmates to friends.

Table 2
Target Child & Playmates Vocalizations by Activity Area (per minute).

	Jo vocalizing	Kay vocalizing	Dereck vocalizing	Jo vocalizing next to Kay	Kay vocalizing next to Jo	Jo vocalizing next to Dereck	Dereck vocalizing next to Jo	Jo vocalizing next to Kay & Dereck	Kay vocalizing next to Jo & Dereck	Dereck vocalizing next to Jo & Kay
Art	2.13	1.35	0.87	0.00	0.00	0.00	0.08	0.00	0.00	0.00
Blocks	12.02	15.65	18.80	6.03	4.38	3.80	3.07	0.00	0.00	0.00
Dramatic Play	3.90	1.18	1.65	0.67	0.60	0.00	0.00	0.00	0.00	0.00
Manipulatives	0.98	1.60	2.65	0.07	0.03	0.13	0.02	0.35	0.22	0.40
Science	8.98	1.43	4.47	0.75	0.17	1.85	1.85	0.00	0.00	0.00
Sensory	0.38	0.12	0.32	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Entrance/Cubbies	1.55	0.22	0.08	0.12	0.00	0.00	0.00	0.00	0.00	0.00
Books	0.35	0.05	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Diaper Changing	0.13	0.00	0.12	0.00	0.00	0.00	0.00	0.00	0.00	0.00

Table 3
Logistic Regression Estimates for Relation Between Activity Area and Talking.

				95% Confidence Interval for OR	
Activity Area	Estimate	*SE*	OR	Lower	Upper
Intercept	-0.46***	0.04	0.63	0.58	0.68
Art	-0.49	0.53	0.61	0.20	1.63
Dramatic Play	0.07	0.16	1.07	0.78	1.47
Manipulatives	-0.52***	0.15	0.59	0.44	0.79
Science	-0.94***	0.08	0.39	0.33	0.46

Note. Blocks was the reference group for Activity Area. OR = odds ratio. Sensory, Entrance/Cubbies, Books, and Diaper Changing were excluded due to very low occurrences (<25).
*$p < .05$. **$p < .01$. ***$p < .001$.

Although teacher, parent, and child report, as well as ecobehavioral assessment have furthered our understanding of young children's friendships, each approach comes with limitations. Our sensing system overcomes some of these limitations by allowing for ongoing, simultaneous assessment of features (proximity and speech) of friendship to be captured within activity areas of the classroom without the need for an observer, and in an unobtrusive manner over long periods of time. With researchers recommending the utilization of multiple measures to gain an accurate, comprehensive representation of children's friendships (Buysse, 1993; Hall & McGregor, 2000), our approach shows promise as a new tool to help identify and better understand friendship development in the early childhood classroom.

5.1. Limitations

While this investigation represents an advancement in measuring features of friendship, it has several limitations. First, this study is based on 1 participating toddler at-risk for a disability and 2 of his playmates, and friendships at this age can lack stability. Second, data collection occurred in the morning of 1 school day in the classroom only. Setting up Ubisense across rooms/spaces in an early childhood setting in future studies could result in a more complete understanding of children's interactions with playmates in this context. Although we used a roughly 3-foot perimeter to better ensure participating children were indeed talking to one another, an investigation using live- or offline-video coding is needed to confirm the amount of vocalizations between playmates. Further, our methods do not capture mutual affect such as smiling or sharing toys with one another. Larger samples of friends/playmates and non-friends/non-playmates, recorded over longer time periods are needed to verify and benchmark children's talk and their proximity to friends/playmates. Finally, other teacher (e.g., use friendship strategies) and classroom factors (e.g., curriculum) that could have affected the interactions taking place between these children were beyond the scope of this initial investigation.

5.2. Future directions

5.2.1. Type of disability and friendship

Behaviors linked to specific disabilities can affect engagement with peers in classroom activities (De Schauwer et al., 2009). Externalizing behaviors associated with specific types of conditions (e.g., ASD, emotional-behavior disorders) in particular, have been found to be negatively associated with peer acceptance and friendship (Odom et al., 2006). Alternatively, a disability/delay not significantly influencing a young child's social competence (e.g., speech-language impairment, physical impairment) may have less of an effect on peer acceptance (Odom et al., 2006). With the varying influence of a child's disability on friendships, additional research using these tools is essential to better understand how at-risk/disability status influences friendship development and its associated outcomes (e.g., social skills) over time.

5.2.2. Friendship activities and interventions

Friendship activities are everyday classroom activities that have been modified to promote positive social interactions (e.g., Frea et al., 1999). During these activities, teachers may use praise and rely on socially competent peers to model appropriate behaviors and facilitate discussions about friendship. An example of a friendship activity would be changing a verse to the "Clean-up Song" to *"When all the toys are cleaned up, give a friend a thumbs up"* (Brown et al., 2008). The packaging of these type of activities with other strategies related to raising awareness (e.g., positive posters and books about disability) and acceptance are known as affective interventions (e.g., Meyer, & Ostrosky, 2016). The Making Friends program (Favazza et al., 2015) is a popular affective intervention aimed at increasing positive interactions between children with or at-risk for disabilities and their peers in inclusive settings and, in turn, friendships. Our speech-location measurement system could be used in combination with existing methods to more accurately determine the effectiveness of the individual friendship strategies and affective interventions in facilitating friendships among specific young children with or at-risk for disabilities and peers who are typically developing in the inclusive classroom.

5.2.3. Capturing other features of friendship

Advanced speech-processing algorithms such as laughter and sentiment (Hansen et al., 2017) have been applied to adult speech in controlled (e.g., small meetings) and naturalistic settings (e.g., college courses) but not in early childhood education settings. Further, only recently has key word spotting been applied to audio from early childhood classrooms (Buzhardt et al., 2020). More research is needed that examines these algorithms in this context – both with children and adults. If coupled with Ubisense, we could then begin to see when and where friendship strategies are most effective. Additionally, if these other features of child friendship talk (e.g., affection) could be captured, a more robust measure of friendship may be possible.

6. Conclusion

Young children's friendships are related to numerous developmental outcomes, such as language, cognition, and social-emotional competence, as well as future well-being (Kyratzis et al., 2010; Ladd, 2005; Vaughn et al., 2001) and are particularly important for young children with or at-risk for disabilities (Chang et al., 2016; Guralnick et al., 2007; Meyer & Ostrosky, 2014). While our approach is in the early stages of development, it provides a new opportunity for collecting large amounts of real-time data without the need for a human observer. Importantly, it offers a way to capture features of friendship (child talk and proximity) and enhance our understanding of how young children with or at-risk for disabilities develop and sustain friendships. Lastly, we hope future investigators will join our effort to advance the application of sensing systems in early childhood inclusive classrooms by testing the tools we have explored in combination with others (e.g., gestures captured via video [Rehg et al., 2014]) as they become more readily available for natural settings.

CRediT author statement

Dwight Irvin: Conceptualization, writing, and combined speech and location analysis; *Ying Luo:* Ubisense set-up, data management, creation of Ubisense database, and writing Ubisense methods;

Jonathan Huffman: literature review, writing, and editing; *Nicolette Grasley-Boy:* editing, database management, and statistical analysis; *Beth Rous:* recruitment, writing, reviewing, and editing; and *John Hansen:* speech analysis and writing speech analysis methods.

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