A Natural History of Repetition

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Abstract: The purpose of this study was to understand typically developing children's repetitive behavior in a free-play, daycare setting. By studying repetition in a non-Montessori setting, we tested the assumption that repetition is a characteristic behavior of all young children and not limited to the Montessori environment. Although Maria Montessori identified repetition during her observations, there is little empirical evidence to support her claim: most research has considered repetition in terms of psychopathology. We collected naturalistic observational data on 31 3- to 6-year-old children for a total of 101 hours to investigate the frequency, contexts, and structure of repetitive bouts. Multilevel model results suggest the ubiquity of repetition, as all children in the study engaged in motor repetition. Furthermore, repetition occurred throughout all free-play activities (construction, animation, fantasy play, rough-and-tumble play, and undirected activity), although repetition was not equally distributed across activities. Motor repetition was not equal across ages either; younger children engaged in more motor repetition than did older children. To understand the structure of repetition, our study also looked at the length of repetition bouts, which ranged from 2 to 19 repetitions and averaged 2.86 repetitions per bout. This natural history of repetition is an influential starting point for understanding the role of repetition in development and is informative to both Montessori and non-Montessori early childhood educators.

Scientific Origins of the Montessori Method

Montessori education presents a distinct alternative to mainstream education programs and is known for its multiage classrooms, provision of developmentally appropriate learning materials (M. Montessori, 1966; M. Montessori, 1948/2007b), emphasis on developing children's ability to learn independently (M. Montessori, 1948/2007b), freedom to choose and engage with work at children's own pace (M. Montessori, 1918/2007a; M. Montessori, 1948/2007b), and acquisition of the social skills needed to cooperate and coordinate with others (M. Montessori, 1967/1995; M. Montessori, 1972/2007c).

These components of child-centered education are advertised on Montessori websites, along with the claim that Montessori education is scientifically supported (Montessori Alberta, n.d.; Montessori & Me Private Schools of Edmonton, n.d.; Mosaic Montessori Academy, n.d.; Montessori School of Calgary, n.d.); emphasizing that Maria Montessori was a scientist (Montessori Alberta, n.d.; Montessori Children's House Academy, 2019; Montessori Children's House, 2019; Rising Scholars Montessori, n.d.; One World Montessori School, n.d.; Sunflowers Bilingual Montessori Centre, n.d.).

Such claims of Montessori education's scientific origins are not new; Dr. Montessori herself, who began developing her educational Method in the early 1900s, promoted her work as scientifically based. Specifically, Dr. Montessori posited that, unlike previous pedagogies that were based on the "good sense" (M. Montessori, 1918/2007a, p. 57) of instructors, her new pedagogy belonged in the realm of modern science:

> The "method," which informs [this new pedagogy]—namely experiment, observation, evidence or proof, the recognition of new phenomena, their reproduction and utilization—undoubtedly places it among the experimental sciences. (M. Montessori, 1918/2007a, p. 58)

Dr. Montessori's pedagogy was founded on the idea that children, directed by internal impulses, seek out activities that satisfy their developmental needs (M. Montessori, 1967/1995; M. Montessori, 1918/2007a). Developmentally appropriate activities could be identified by observing children's behavior; tasks that children tended to repeat and that elicited high levels of concentration were considered to fulfill a developmental need. Dr. Montessori adopted this view after observing a young girl in the original Children's House in the San Lorenzo quarter of Rome (1918/Montessori 2007a). The girl, around three years of age, was working with the learning material known as the Cylinder Block (i.e., a wooden block with cylinder cutouts of varying size). The girl was repeating her work with the blocks—removing the cutouts and replacing them in the block—with intense concentration. Dr. Montessori counted the number of times the girl repeated the task while also attempting to distract the child by recruiting other children to march around the girl as she worked. When this was unsuccessful, Dr. Montessori picked up both the girl and her chair. This distraction attempt was also ineffectual; the girl clutched the materials on her lap and continued working. When the girl finally stopped working on the task of her own accord, "she looked round with a satisfied air, almost as if awaking from a refreshing nap" (M. Montessori, 1918/2007a, p. 54). By the time the child had finished, Dr. Montessori had counted 44 repetitions.

This anecdote is part of the narrative recounting the origins of the Montessori Method and describes how repetition first came to Dr. Montessori's attention. After her original observation, she began to notice that repetition was "common to all and nearly constant in all their actions" (M. Montessori, 1966, p. 120). Repetition was thus installed as a central concept in Montessori theory and was later classified as a human tendency by her son, Mario Montessori (M. M. Montessori, 1956). Dr. Montessori claimed that the tendency to repeat was driven by nature and occurred spontaneously because of a powerful and irresistible energy (M. Montessori, 1918/2007a; Standing, 1957/1998). Unlike other educational theories of the time that proposed that children needed to be molded into respectable adults (M. Montessori, 1918/2007a), Montessori theory advocated that children's inherent nature be the guide: there is a natural plan to development that unfolds when children are given the opportunity to develop without interference (M. Montessori, 1966). The adult's role, therefore, is to observe and present children with developmentally appropriate materials (M. Montessori, 1918/2007a; M. Montessori, 1948/2007b).

Dr. Montessori described the material-selection process as "psychical" (M. Montessori, 1918/2007a, p. 59) experimentation. Materials of "every kind of quality" (M. Montessori, 1918/2007a, p. 58) were presented to children; only variations in color and size were mentioned specifically. The developmental usefulness of a material was assessed by children's reactions to it; to be included in the learning environment, the material needed to elicit concentration and repetition (M. Montessori, 1918/2007a).

Despite describing her experimental process as "laborious, prolonged, and exact" (M. Montessori, 1918/2007a, p. 57), Dr. Montessori did not provide detailed methods of how she collected her data. To our knowledge, there is no operational definition of concentration, which is necessary for others to replicate her work, nor is there any indication of the number of repetitions needed for an activity to be considered developmentally advantageous. There is also no information on how many children were tested; Dr. Montessori reported simply that there were "a number of children" (M. Montessori, 1918/2007a, p. 58). Finally, Dr. Montessori did not explain the process of varying material qualities other than providing a single example; she described varying the size of the Geometric

Solids (i.e., 10 blue, wooden, three-dimensional shapes intended to refine tactile awareness) to determine which set children found most attractive. Thus, not only are procedural details scanty but empirical results are completely absent. Readers have access only to Dr. Montessori's interpretation of her findings. Granted, today's expectations for empirical evidence differ from those of the early 1900s when Dr. Montessori conducted her research; however, as Montessori advocates claim the Montessori Method is scientifically supported, it is necessary to test her findings according to today's scientific requirements. This is the case not only for the material-selection process but for all aspects of Dr. Montessori's developmental theory.

During Dr. Montessori's early observations, which ultimately led to the establishment of her Method, she observed behavior not typically attributed to young children (Standing, 1957/1998). In addition to repetition and concentration, she observed children's capability to choose, discipline, love of work, love of silence, indifference to reward and punishment, and sense of dignity (M. Montessori, 1966; Standing, 1957/1998). She concluded that children engaging in these behaviors were expressing their true natures. As with her descriptions of learning-material selection, however, no evidence is available indicating how often these behaviors occurred or whether they were spontaneous.

All of the behaviors that Dr. Montessori identified as expressions of children's true nature thus require empirical study, but repetition is a reasonable starting point because of its importance in Montessori theory. Repetition is a frequently reported characteristic of children's nature or, at least, it is often recounted as such because it is inextricably tied to the origin of the Montessori Method (M. Montessori, 1966; M. Montessori, 1918/2007a; Standing, 1957/1998). Its importance in day-to-day practice also makes repetition an important topic for scientific investigation. In the Montessori Primary training of one of the authors, repetition was said to foster skill acquisition across the Primary learning activities.[1] Repetition thus serves a functional purpose in the Montessori environment and has a considerable impact on children's learning and development.

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[1] All cited curriculum material is from Association Montessori Internationale Primary Training.

Repetition Research

Current research does little to support the argument that repetition is a natural tendency, which may be caused by the focus of repetition research on atypical rather than typical development. Although we did not perform a systematic review of the repetition literature, we conducted an informal search of a number of psychology databases, discovering that the majority of literature focuses on cases of psychopathology, such as obsessive-compulsive disorder (Eilam, 2015; Radomsky, Dugas, Alcolado, & Lavoie, 2014) and autism spectrum disorder (Bodfish, Symons, Parker, & Lewis, 2000; Honey, Leekam, Turner, & McConachie, 2007; Mooney, Gray, & Tonge, 2006; Turner, 1999). Research on typically developing children, however, is limited, and what is available concerns mostly repetition during infancy. For example, Piaget (1952) commented on repetitive motor behavior in infants, which was later empirically supported by Thelen (1979, 1980, 1981), who identified 47 motor patterns involving legs, feet, arms, hands, fingers, head, and torso in infants. To our knowledge, repetition among typically developing children is limited to a survey conducted by Evans et al. (1997), which asked parents about their typically developing children's compulsive-like behavior (including repetition) in infancy and preschool. Parents reported repetitive behavior in their children's daily activities, with repetition peaking between 12 and 47 months of age. Although this study is based on parental reports rather than researchers' observations of children's repetition, it does provide a starting point for the study of repetition as characteristic preschool behavior, in other words, empirical evidence for the age groups most prone to repeat tasks, which is unavailable in Montessori theory.

Dr. Montessori's original research does not provide the procedural details and empirical support required by today's scientific standards. It would be unfair, however, to expect the same level of scientific rigor that we see today; scientific reporting and research techniques from the 1900s differ from those that are commonplace today. For example, the academic journal *Child Development* recently published methodological recommendations for high-quality, reproducible research, recommending that sample recruitment and selection, data collection and coding, descriptive statistical information, and model specification be included in empirical research papers (Coll, n.d.). Although these contemporary

expectations for scientific reporting are not present in Dr. Montessori's research, she was not alone in the way she reported on her methods. Piaget similarly provided scant procedural details in his classic work (Bond & Tryphon, 2009). Today, such details are obligatory: all methods and procedure must be reported so other researchers can evaluate them and try to replicate them in their own studies. With respect to the kinds of observational techniques Dr. Montessori employed, it was not until the late 1960s that ethologists (i.e., scientists who study behavior in naturalistic settings) developed methods for systematic observation that were able to address concerns about time sampling and reliability (Smith & Connolly, 1980). It is also important to note that Dr. Montessori's main goal in observing children's behavior was not research, but rather to inform practical application in a classroom setting (M. Montessori, 1918/2007a).

Thus, while it is inappropriate to criticize Dr. Montessori's research by applying current scientific standards, it is still necessary to address whether her educational and developmental claims stand up to scientific scrutiny. As already noted, Montessori proponents claim that Montessori education is based on scientific study, and it is promoted as an evidence-based approach to schooling. As we have seen, however, Dr. Montessori's original work provided anecdotes of children's so-called characteristic behaviors but did not provide measures of variation in behavior or of the frequency and contexts in which behavior occurs. Consequently, Montessori guides (particularly new guides with less experience) have little guidance on the amount of repetitive behavior to expect. For example, in the Montessori Primary education training of one of the authors, future guides were taught that developing refined movement required "prolonged repetition."[2] This lack of specificity can be considered advantageous as it allows guides to make judgments on a case-by-case basis; again, in the same author's training, it was acknowledged that some work does not elicit as much repetition as others (for example, the Teen Boards). The problem, however, is that the expectation of repetition rests on anecdotes; in other words, we currently have no idea whether repetition is, in fact, characteristic behavior of young children. This, in turn, means that we have no idea whether Montessori education simply capitalizes on

children's tendency to repeat actions as a way to enhance learning or whether the use of repetition represents the application of a particular kind of pedagogy in the Montessori classroom. A more-detailed, scientific understanding of central concepts like repetition and concentration can provide Montessori guides with valuable information on prevalence and variability within and between children and determine whether intense repetition is, in fact, a spontaneous feature of children's engagement with learning materials.

Furthermore, current academic literature on repetition is limited, focusing almost exclusively on repetition as a psychopathological behavior. Pathological studies of repetition report repetition as nonfunctional, or even detrimental, differing from the type of repetition Dr. Montessori described. In the Montessori context, repetition is considered typical (as opposed to psychopathological) and developmentally advantageous. It is necessary to differentiate types of repetition, first by determining whether observable differences exist. Not only would differentiating repetition types benefit child educators, but recognizing structural differences between pathological and developmentally typical repetition may improve psychologists' ability to accurately diagnose autism spectrum disorder and obsessive-compulsive disorder. Recognizing structural differences between types of repetition can then lead to studying the functional aspects of repetition, such as whether developmentally typical repetition facilitates skill development.

Aims of the Present Study
The aim of the current study was to gather data on the natural history of repetition—an account of spontaneously occurring repetition among children. To do so, we conducted an exploratory observational study of children in a non-Montessori, free-play daycare setting as a means of answering questions concerning children's spontaneous repetitive behavior and how it compares to Dr. Montessori's famous anecdote. By conducting our study at a free-play daycare rather than in a Montessori environment, we could address the assumption that repetition is characteristic behavior in all young children; if it is a natural tendency, we can expect repetition to occur outside of the Montessori environment. Free-play daycare provides an appropriate environment to test this assumption as children's activities are unguided during

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[2] Curriculum material from Association Montessori Internationale Primary Training.

free-play periods. During such periods, children are free to engage with any of the classroom materials and to decide how to engage with the materials, (i.e., materials do not have a prespecified use or learning goal; Santer, Griffiths, & Goodall, 2007). This is in contrast to Montessori environments, in which each set of materials has a purpose. Furthermore, Montessori guides demonstrate how to use the materials, and children can engage only with materials that the guide has presented them.

Conducting our research in a free-play environment allowed us to examine the spontaneous nature of repetition by observing children when there were few restrictions on their behavior. We first predicted that all children would engage in repetition (Prediction 1). This prediction is supported by Dr. Montessori's claim that repetition was "common to all," (M. Montessori, 1966, p. 120) as well as by her concept of developmental planes. Montessori theory posits that individuals within the same developmental period (i.e., plane) exhibit the same characteristic behaviors (M. Montessori, 1967/1995). As all children in the current study were in the second phase of the first developmental plane, we expected all children to engage in repetition if it is, in fact, a natural tendency of this age group. We further predicted that repetitive behavior would be found across all activities observed in free play (Prediction 2). Prediction 2 is grounded in Dr. Montessori's claim that repetition was "nearly constant in all [the children's] actions" (M. Montessori, 1966, p. 120). To determine whether there were frequency differences across children, we also predicted that children 47 months and younger would engage in more repetition than older children (Prediction 3), based on Evans et al.'s (1997) study. Finally, to better understand the structure of repetitive bouts, we predicted that bouts of repetition would be of a comparable length (i.e., approximately 40 repetitions) to those described by Dr. Montessori (Prediction 4; M. Montessori, 1966).

Methods

Study Site

Data were collected at a not-for-profit daycare center in a Canadian city. The center accommodated 84 children ranging from 12 to 72 months in age and employs 18 full-time staff members. The daycare had a free-play philosophy and differed from Montessori environments in both daily routine and classroom-age composition. Unlike Montessori education's uninterrupted work periods, morning and afternoon play sessions at the daycare were interjected by transition periods (e.g., indoor to outdoor play), snack and nap times, or group activities (see Appendix A for full schedule). Also unlike Montessori education, the daycare segregated classrooms by age. Classrooms observed in this study are given in Table 1 with the corresponding age ranges.

A researcher ("AJ") conducted observations in both the classrooms and a shared outdoor area. Each classroom (Figures 1 through 4) differed in spatial layout but consisted of similar play areas. Children from all four classrooms shared a single outdoor area (Figure 5). The toddler area was fenced off and not accessible to the children participating in the study. Occasionally, children were given the opportunity to play with chalk and bikes or scooters on the deck.

Participants

Thirty-one children, ranging in age from 33 to 72 months ($M = 50.94$; $SD = 11.56$), participated in the study. Children had exclusive membership to one age-based classroom (i.e., Jr.1, Jr.2, Senior, Kinder). Children were randomly selected for focal sampling (i.e., consent was general, but only a sample of children were included in the study). There were some limitations to random selection, however; children who were not available for the entire study period, as indicated by the daycare

Table 1
Classroom, Adult–Child Ratio, Age Range, and Number of Children

Classroom	Adult–child ratio	Age range (months)	n
Jr.1	1:5	33–40	10
Jr.2	1:7	41–49	14
Senior	1:8	50–60	16
Kinder	1:10	61–72	20

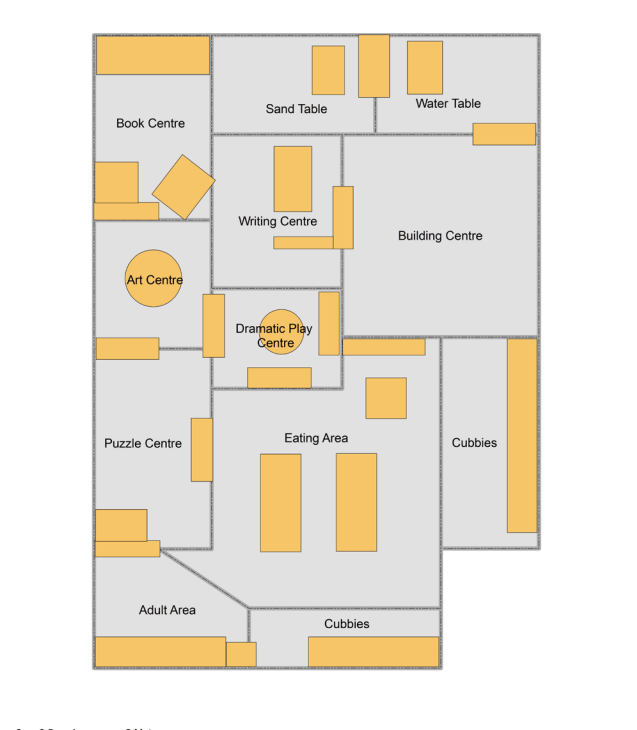*Figure 1.* Layout of Jr.1 classroom.

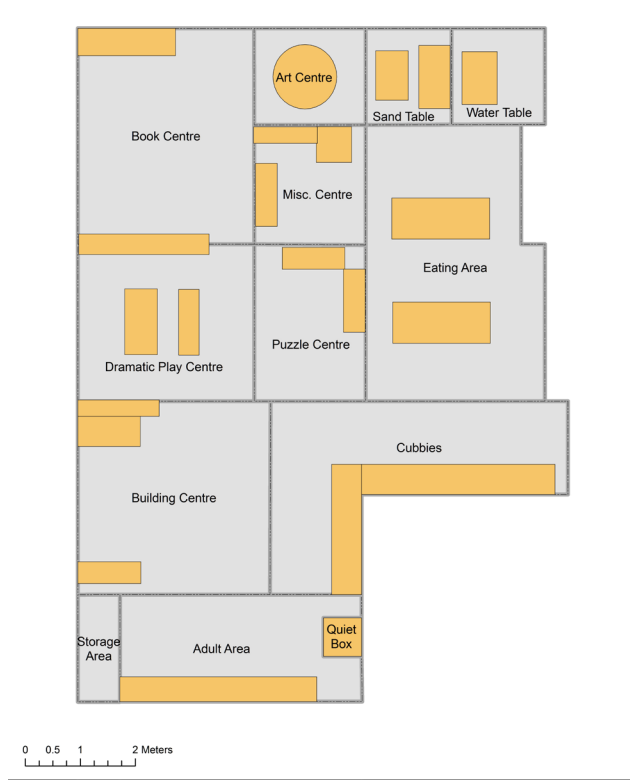

Figure 3. Layout of Senior classroom.

Figure 2. Layout of Jr.2 classroom.

Figure 4. Layout of Kinder classroom.

Figure 5. Layout of outdoor play area.

director, were not included in the sampling pool. Two children were excluded from analysis because they changed classrooms during the study.

Data Collection Procedure

Naturalistic observational data were collected during free play over 8 weeks, for a total of 101 hours. Free play was considered to occur any time children freely chose to engage in play activities; that is, the child chose the activity, how to engage with it, and for how long. Thus, free play did not have external goals put in place by childcare workers but was child led (Santer et al., 2007). Data were not collected during activities such as circle time, snack time, and designated craft time. However, optional, nondirected activities set out by adults, featuring materials such as play dough or coloring sheets, were included as free play since participation was not mandatory.

Pilot data were collected over a 7-day habituation period. The purpose of this period was to accustom the children to a researcher in the classroom. The researcher sat unobtrusively out of direct traffic but in view of the child under observation (i.e., *focal child*), changing locations if the focal child moved out of view.

By the end of the habituation period, the children no longer seemed interested in the researcher's presence since they stopped attempting to interact with her. The short habituation period may be the result of practicum students and support workers often observing children in the classroom. However, the researcher still attempted to observe the children inconspicuously by glancing rather than fixating her gaze on the focal child.

During each *focal follow* (i.e., observation period in which one child was continuously observed), detailed action descriptions were recorded on an iPhone 4 using a Microsoft Excel spreadsheet designed for data collection (see Appendix B). An example action-description sequence for a child during outdoor play may be: scoop rocks from path with shovel; dump rocks into bucket; run to slide; dump rocks out of bucket; go down slide. This example action sequence would be a portion of a longer observation period, or focal follow. Location (i.e., indoor or outdoor) and companions (Table 2) were recorded for each action description.

Focal follows lasted 20 minutes, but it was common for children to leave the observation area during follows. If a child left during the focal follow, data collection was paused for a maximum of 10 minutes. If the child did not return within the 10-minute period, the focal follow ended and a new focal follow of a different child began. Focal follows under 5 minutes were excluded from analysis. Mean duration of focal follows was 18.8 minutes, with a standard deviation of 6.6 minutes. Total observation times per child ranged from 157 to 210 minutes.

Coding Procedure

Following observation sessions, action descriptions were coded according to operational definitions (see Appendix C). A second researcher later coded 20% of the action descriptions. Interobserver reliability was found to be 87% (i.e., the number of agreed codes/total codes × 100). Action codes were then classified according to the kind of play activity involved; each action was therefore part of a higher level of organization called an *event* (see Appendix D). *Undirected* events included random manipulation of objects. *Construction* events involved building a structure from multiple parts, such as art activities or block/ puzzle building. *Fantasy play* involved as-if, pretend-play scenarios, such as playing house. *Animation* involved animating inanimate objects, such as pretending figurines

Table 2
Companion Categories

Category	Criteria
Alone	No other children or adults in play area
Child–child pair	One other child in play area
Adult–child pair	Adult in play area
Small child subgroup	≤2 other children in play area
Large child subgroup	≥3 other children in play area
Small adult–child subgroup	Adult and ≤2 other children in play area
Large adult–child subgroup	Adult and ≥3 children in play area

or stuffed animals were alive. As we were interested in differences between motor and object-manipulation repetition, animation events, which necessitate object use, were coded separately from fantasy play events. *Rough-and-tumble play* was social play involving nonaggressive physical contact, such as grappling or wrestling. A second coder coded 20% of the original data. Reliability between the researcher and the independent coder was 89% (i.e., the number of agreed codes/total codes × 100) for events.

Although all action descriptions were recorded and coded, only movement actions were included in analysis: object-manipulation actions, which were defined as movements involving objects, and motor actions, which were defined as movements without objects. We limited our study to movement repetition, as that type of repetition was featured in Dr. Montessori's anecdote of the Cylinder Block. Object manipulation and motor repetitions were treated as separate categories to account for repetition differences that may result from learning to deal with objects versus learning to deal with oneself. Action descriptions that did not fall into these categories (e.g., observation, social actions, inactive) were not included in analysis.

Repetition Coding
Repetitive sequences, referred to as *repetition bouts*, were extracted from the data using a VBA macro in Microsoft Excel. Repetitions were recorded when an object manipulation or motor action code was repeated within two actions. The occurrence of three or more nonrepetitive actions was considered an interruption to the repetitive sequence and ended the bout. The researcher reviewed the macro output to ensure that

bouts met repetition criteria; all motor and object-manipulation actions were included except actions that were necessary for moving and engaging with objects (e.g., walk, run, pick up, put down). Postural repetitions (e.g., lie, kneel, reposition, sit, stand) also were excluded.

Statistical Analysis
Multilevel models were used for all analyses and were run using the *lme4* package (Bates, Maechler, Bolker, & Walker, 2015) in R version 3.4.0 (R Core Team, 2017). R^2 marginal values were used to assess main effects (i.e., how much of the variance in behavior identified as the dependent variable can be explained by the independent variables), and R^2 conditional values were used to estimate the effect of the full models (i.e., how much of the variance in the dependent variable can be explained by main and random effects). R^2 marginal and R^2 conditional values were generated by the *MuMIn* package (Bartoń, 2016). For more details on multilevel models, see Appendix E.

Distribution of repetition over events
A linear multilevel model (i.e., a multilevel model that assumes a Gaussian distribution) was run to test Prediction 2 (i.e., that repetition would occur across all play events). The dependent variable was actions per minute. Main effects were event, age, and setting. We specified a random effect of "child nested in classroom." Residuals were tested for the assumption of normality using QQ plots, which showed some deviation from normality. Subsequent modeling using a truncated beta distribution suggested no qualitative difference from the Gaussian model; therefore, we report results from the Gaussian model.

Number of repetitive bouts

A Poisson generalized linear multilevel model (i.e., a multilevel model used to deal with count data), was run to test Prediction 3 (i.e., that there would be a difference in the amount of repetition by age). Number of repetitive bouts per focal follow was the dependent variable. The model included follow duration (in minutes), age, setting, and repetition type (motor or object manipulation) as main effects. To allow for the possibility that children of different ages react differently to changes in setting with either object manipulation or motor repetition, a three-way interaction between, age, setting, and repetition type was included in the model. We specified "follow ID nested in child, nested in class" as the random effect. The model did not converge with the default optimization algorithm for *lmer* (nelder-mead); therefore, the bobyqa optimizer (Ypma, 2014) was used to allow convergence. The *DHARMa* package in R was used to test residual assumptions (Hartig, 2017), and revealed overdispersion and zero inflation in the data (for more information, see Appendix F). Overdispersion and zero inflation were removed by creating observation-level random effects, in other words, giving each data point a unique ID that could be included in a new grouping variable (Harrison, 2014).

This full model was compared to a partial, spontaneous repetition-bout model in which only spontaneous, repetitive bouts were included in the dependent variable. Repetitive bouts were coded as spontaneous if there was no observable outcome beyond the repetitive actions themselves or if the outcome did not require repeated action (see Appendix G for coding criteria). The purpose of the partial model was to determine whether there were differences by repetitive-bout type, in other words, differences between activities that require repetition (e.g., filling a bucket) and activities that need to be done only once for completion (e.g., going down a slide). There was no difference between the full and partial model; therefore, the full model is reported in the results (see partial model in Appendix G).

Results

Of 321 focal follows, 265, or 82.6%, contained repetitive activity (either object manipulation or motor repetition or both). The average rate of total repetition per focal follow was 0.08 bouts per minute (i.e., one repetition

bout every 12.5 minutes). The average rate of object-manipulation repetition per focal follow was 0.14 bouts per minute (i.e., one object-manipulation repetition bout every 7 minutes). The average rate of motor repetition per focal follow was 0.02 bouts per minute (i.e., one motor repetition bout every 50 minutes). Other relevant descriptive statistics can be found in the Methods section.

Prediction 1: Repetition Across Children

All children engaged in at least one form of repetition (Figure 6). All children performed object manipulation, the most frequently occurring type of repetition (Figure 7). Not all children, however, engaged in motor repetition (Figure 8); four children in total (two Jr.2 children and two Senior children) did not engage in any motor repetition during the study period. This is not surprising, however, as the overall frequency of motor repetition was low.
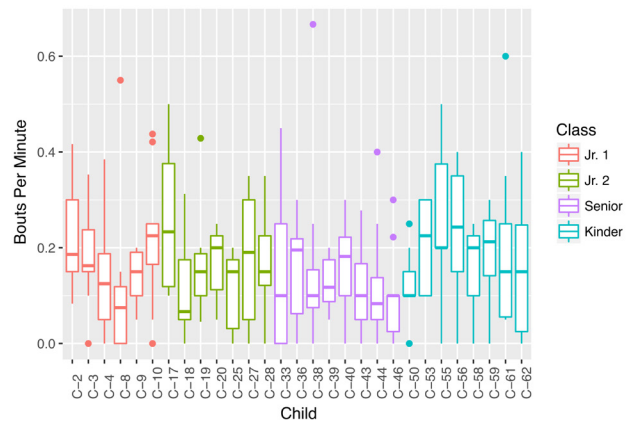

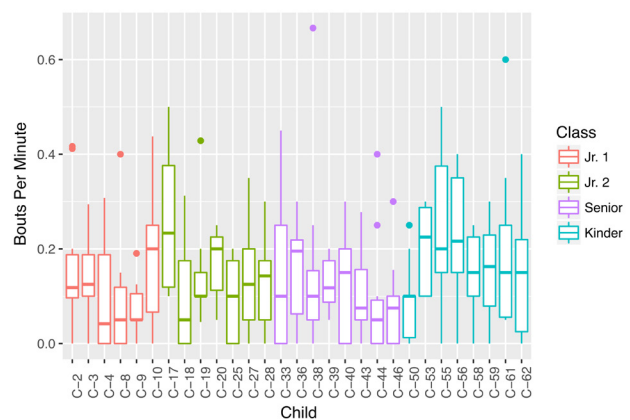*Figure 6.* Total number of repetitive bouts per minute.

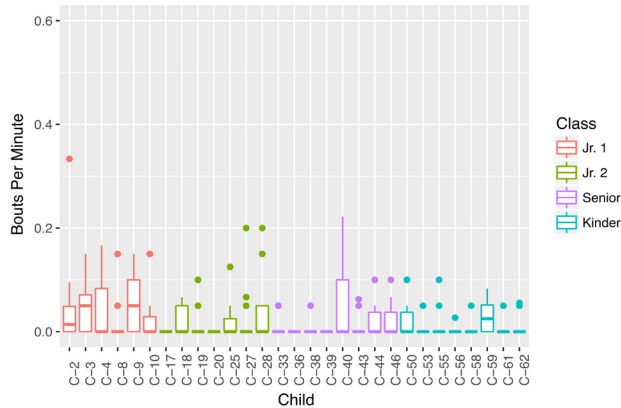*Figure 7.* Number of object-manipulation repetitive bouts per minute

Figure 8. Number of motor repetitive bouts per minute.

Prediction 2: Distribution of Repetition Over Events

In line with our prediction, we found that children engaged in repetitive activity across all events (undirected, construction, animation, fantasy play, and rough-and-tumble play; see Figure 9); however, modeling the amount of repetitive activity by event demonstrated that repetitive activity was not equal across events. This is to be expected as overall activity in each event differed (events also differed in the amount of nonrepetitive actions; Figure 10), but even when taking the proportion of repetitive activity (repetitive actions/total actions) in each event into account, repetitive activity was not equal over events (Figure 11); that is, there were higher frequencies of repetition in some events over others.

Construction and animation had the highest proportions of repetitive activity. Repetition occurred for 31.6% (*SE* = 3.0%) of total actions in construction and 26.4% (*SE* = 8.7%) of total actions in animation (see Table 3). Less repetition was observed in fantasy play and
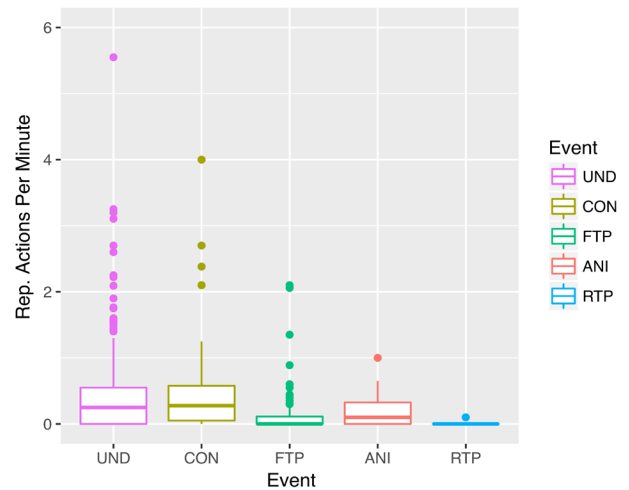

Figure 9. Repetition actions per minute by event.
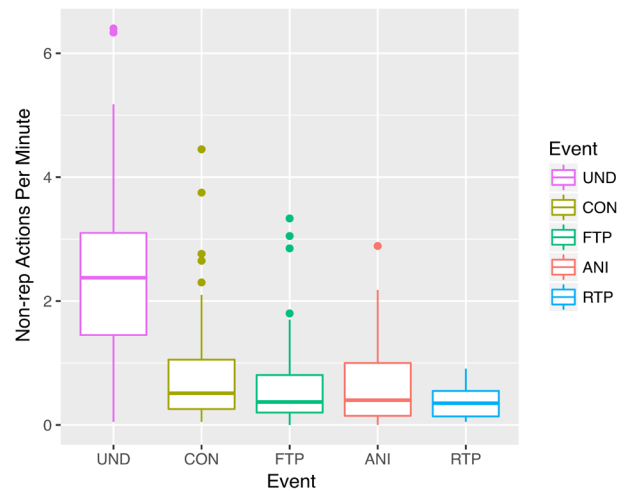
Figure 10. Nonrepetition actions per minute by event

Table 3
Events Linear Multilevel Model Main Effects

Main effects	ß value	*SE*	*t* value	*p* value
Intercept (REF:Animation)	0.26	0.09	3.04	.03
Age	-0.00	0.00	-0.27	.80
Setting (REF:indoors)	0.04	0.02	1.77	.08
Undirected	-0.12	0.03	-4.12	< .01
Construction	0.05	0.03	1.74	.08
Fantasy play	-0.10	0.03	-3.05	< .01

Note. REF = reference

Figure 11. Proportion of repetitive actions to total actions.

undirected activity, where repetition accounted for 16.9% (*SE* = 3.1%) of total actions in fantasy play. The least amount of repetition occurred in undirected activity, at 14.8% (*SE* = 2.8%) of total actions being repetitive). Rough-and-tumble play was excluded from statistical analysis as there was only one incident of repetition in that event.

Overall, the model explained 18% of the variance (Tables 3 and 4). The random effect of child nested in class accounted for 6% of that variance (R^2 marginal value = .12; R^2 conditional value = .18).

Prediction 3: Number of Repetitive Bouts
Model comparison demonstrated no qualitative differences between the full number of bouts model and the spontaneous number of bouts model (see Appendix D for spontaneous bout model). Therefore, we used the full model in our analysis. The full model is displayed in Table 5 (main effects) and Table 6 (random effects). As predicted, there was a small, negative effect of age: younger children engaged in more repetitive activity than older children in both the indoor and outdoor setting, but the effect of age was found only for motor repetition (see Figure 12 for a visual representation of this interaction term). The random effects (Table 6) did not account for any additional variance beyond that explained by the main effects, but the full model was able to explain 53% of the variance in the number of repetitive bouts (R^2 marginal value = .53; R^2 conditional value = .53).

Table 4
Events Linear Multilevel Model Random Effects

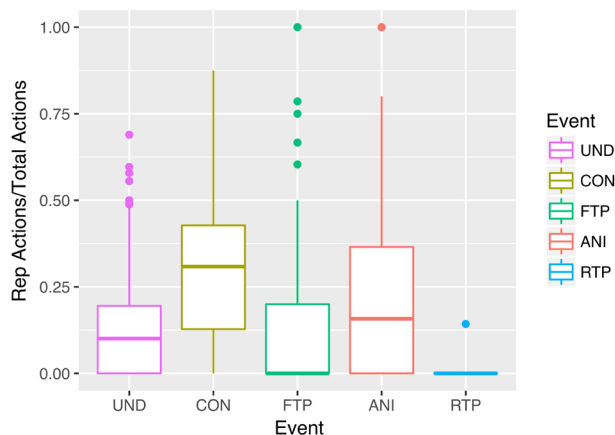| Random effects	Variance	SD
Child:class (Intercept)	< 0.01	0.03
Class (Intercept)	< 0.01	0.04
Residual	0.03	0.18

Table 5
Number of Repetition Bouts per Focal Follow: Poisson Generalized Linear Multilevel Model Main Effects

Main effects	ß value	SE	z value	p value
Intercept	-1.52	0.14	-10.52	< .01
Follow duration	0.31	0.05	6.77	< .01
Age	-0.53	0.13	-3.95	< .01
Setting (REF: indoor)	0.57	0.25	2.28	.02
Rep. type (REF: motor)	2.35	0.15	15.63	< .01
Age*Setting	0.08	0.25	0.32	.75
Age*Rep. type	0.61	0.15	4.20	< .01
Setting*Rep. type	-0.89	0.28	-3.18	< .01
Age*Setting*Rep. type	-0.08	0.28	-0.29	.77

Note. REF = reference; Rep. = repetition.

Table 6

Number of Repetition Bouts per Focal Follow: Poisson Generalized Linear Multilevel Model Random Effects

Random effects	Variance	SD
Number of observations	0.37	0.61
FollowID:ChildID:Class	< 0.01	< 0.01
ChildID:Class	< 0.01	< 0.01
Class	< 0.01	< 0.01
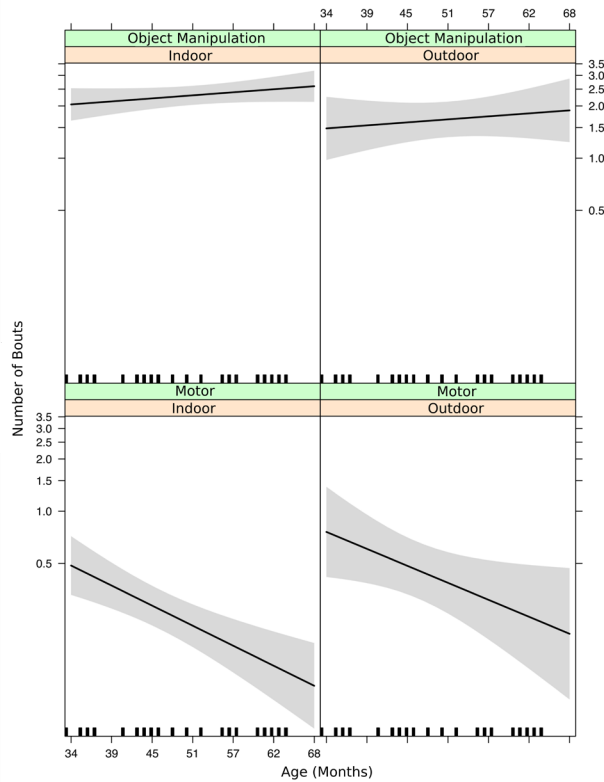
Figure 12. Interaction plot for age, setting, and type of repetition.

Figure 13. Frequency of repetition-bout length.
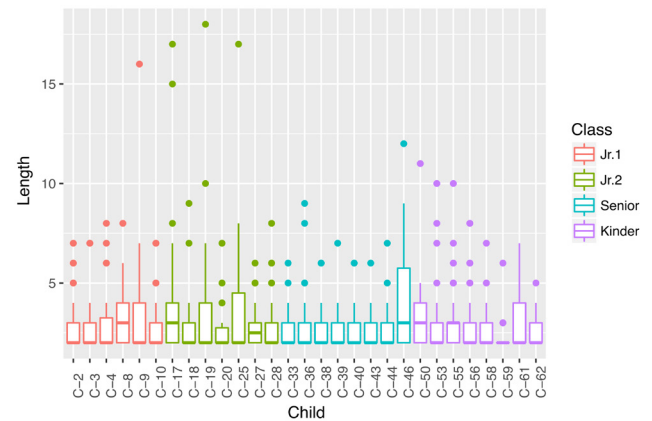
Figure 14. Repetition-bout length by child.

Prediction 4: Repetition-Bout Length

Repetition bouts tended to be short rather than long ($M = 2.97$ actions; $SD = 1.82$ actions) and ranged from two to 18 repeating segments (Figure 13). Bout lengths were similar across ages (Figure 14).

Discussion

This study provides empirical support to Dr. Montessori's assertion that repetition is characteristic behavior in preschool-aged children. Predictions 1 and 2, which addressed general statements Dr. Montessori made

about repetition, were confirmed. First, as predicted, all children engaged in repetition. Not all children, however, engaged in both types of repetition; while all children engaged in object manipulation (i.e., the most common type of repetition), four (two Jr.2 children and two Senior children) of the 28 children did not engage in any form of motor repetition. Considering the overall low level of

motor repetition, however, it is not surprising that some children did not engage in it during the study period. Although we were interested in possible differences between motor and object-manipulation repetition, Dr. Montessori did not refer to any particular form of repetition, and, consequently, we did not specify repetition type in our prediction. Therefore, our prediction that all children would engage in repetition was confirmed.

Our intent with differentiating between repetition types was to establish whether there was a difference in repetition for learning to deal with objects versus learning to deal with one's body. There was a clear difference in the frequency of repetition types, in which object manipulation made up the majority of overall repetition. When considering the role that repetition may play in skill development, the low level of motor repetition may be due to object-manipulation repetition fulfilling skill development in both of these areas. That is, one could hypothesize that object-manipulation repetition develops both the gross and fine motor skill required for manipulative and nonmanipulative motor activity.

Prediction 2, which hypothesized that children would engage in repetition in all events, was based on Dr. Montessori's claim that repetition was "nearly constant in all [the children's] actions" (M. Montessori, 1966, p. 120). We found that children engaged in repetition during all five event categories we considered (i.e., undirected, construction, animation, fantasy play, rough-and-tumble play). There was only one instance of repetition in rough-and-tumble play, however. Rough-and-tumble play is a social activity involving repeated physical contact, and it is expected that repetitions in this event category would largely be social repetitions. As our study recorded only motor and object-manipulation repetition, it is not surprising that we observed just one repetition during rough-and-tumble play. Future work is needed to describe possible types of repetition not included in the current study.

Our study suggests that future work is also needed for understanding how different contexts can affect repetition. Although repetition occurred in all events, we found that the proportion of repetition (i.e., number of repetition actions/total actions) was not equal across events; construction and animation had higher proportions of repetition than fantasy play and undirected events. Therefore, it seems as though some feature of construction and animation elicits more repetition than the characteristics of fantasy and undirected play. In terms of skill development, the difference in object manipulation and motor repetition across contexts may be explained by two possibilities. First, it may be that some skills (e.g., coordination skills required for stacking blocks) are better acquired through repetition, thus increasing the amount of repetition in events that feature that type of skill development. Second, low levels of repetition may be explained by certain skills not requiring as much repetition as others to gain mastery. Consequently, repetition is lower in events that feature that type of skill.

Prediction 3 hypothesized that the younger children in the study would engage in more repetition than the older children. Model comparison was used to determine whether there was a difference between outcome-oriented and spontaneous repetition bouts that required them to be analyzed separately; in other words, outcome-oriented and spontaneous repetition could not be considered a single category. After all, it could be argued that since outcome-oriented repetition tasks necessitate repeated action (i.e., repetition is motivated by the nature of the task) outcome-oriented repetition qualitatively differs from spontaneous repetition, which may better represent repetition for the purpose of skill development. As the model comparison found no difference between the full and spontaneous models, however, all repetition bouts were included in final analysis.

The results supported our prediction that younger children would engage in more repetition than older children; however, the age effect was present only for motor repetition. This suggests an interesting difference in the type of activities that children repeat, particularly when considering repetition for the purpose of skill development. All children in our study displayed equal frequencies of repetition with respect to object manipulation. In terms of motor repetition, however, younger children had higher frequencies. It may be that younger, but not older, children are developing motor skills that require repetition. These results highlight a potentially important difference in how children of various ages use repetition to develop specific skills.

Although there was an effect of age in motor repetition, the effect was small. From a Montessori perspective, this may be explained by developmental plane. Dr. Montessori proposed a stage-like theory of development, which describes distinct periods of mental and physical growth (M. Montessori, 1967/1995). She based her theory of developmental planes on the observation that as children age, they undergo qualitative, rather than quantitative, changes, in other words, changes in kind rather than degree. Dr. Montessori (1967/1995) posited that the characteristics of each plane are fundamentally different from other planes, to the extent that progressing from one plane to the next can be described as a rebirth. Within each phase, children engage in the same behaviors and undergo similar developmental achievements that are unique to that stage. Children between the ages of 3 and 6 are in the second plane of development; during this plane, they are constantly acting on the environment as a means of self-construction or, as Dr. Montessori (1967/1995) expressed it, internalizing their outward experience. As children in this study were all in the same developmental plane, we would expect to observe characteristic behaviors of this age group behavior across all children. This does not mean, however, that frequency differences do not occur. After all, the theory of developmental planes suggests qualitative rather than quantitative changes within a stage.

Prediction 4 hypothesized that repetition bouts would be comparable to the long bouts described in Dr. Montessori's Cylinder Block anecdote (M. Montessori, 1966; M. Montessori, 1918/2007a). Against prediction, repetition bouts tended to be short rather than long, with an average bout length of 2.97. Even the longest bout of 18 repetitions did not approach the 40 repetitions described by Dr. Montessori. Although these results did not match the bout length described in the anecdote, short bouts of repetition are consistent with practice research, which suggests that short, distributed intervals are better for long-term learning than massed practice (Gerbier & Toppino, 2015; Lee & Genovese, 1988; Schutte et al., 2015). If repetition is a self-initiated strategy for learning, it is reasonable to suppose that repetition would be similar to practice patterns known to aid learning. Future work could further examine repetition-bout structure and compare it to other practice patterns known to aid learning, such as practice variability.

Our results may have differed from bout length in the Cylinder Block anecdote due to differences between Montessori and free-play environments. First, there is a fundamental difference between the work done in Montessori classrooms and the activities in free-play environments. Unlike free-play environments, where freedom to choose how to engage with materials is one of its defining features, Montessori work involves sets of materials with specific uses and learning goals.[3] For example, the purpose of the Cylinder Block is to teach children how to discriminate size. Additionally, the Montessori guide introduces each activity by demonstrating the series of steps the child is expected to perform, which may affect the length of repetitive bouts, as well as other structural aspects of repetition. For example, repetition in Montessori environments may be event-like, in which a whole sequence of activities is repeated, whereas free-play daycare repetition may feature shorter, individual action repetitions (as recorded in this study).

Another possible reason the repetitive activity we observed differed from the Cylinder Block anecdote is an absence of prolonged concentration among children in the free-play environment. Dr. Montessori described the young girl to be in deep concentration while repeating the Cylinder Block activity, to the extent that she could not be distracted (M. Montessori, 1966; M. Montessori, 1918/2007a). It is possible that long bouts of repetition occur only when high concentration is also present. Thus, it is possible that long bouts of repetition are rare in daycare settings because high levels of concentration are also rare. Most free-play environments do not actively work to develop children's concentration, whereas it is a priority in Montessori education; developing concentration is facilitated through uninterrupted work periods and allowing children to work without social interference.[4] The absence of long repetitions in the daycare setting leads to the question of whether repetition and concentration are truly natural tendencies or behaviors elicited by particular learning environments. To verify that repetition and concentration are, in fact, natural tendencies, these behaviors must be observed across settings and under varying circumstances.

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[3] Curriculum material from Association Montessori Internationale Primary Training.
[4] Curriculum material from Association Montessori Internationale Primary Training.

Refuting the prediction that bout length would be similar to the bout in the Cylinder Block anecdote does not disprove Dr. Montessori's theory of repetition. Rather, it demonstrates that her classic repetition anecdote was not a typical case of repetition; she likely used this anecdote as an illustrative example rather than a prototypical one. Although the anecdote is striking, practitioners need accurate representations of day-to-day repetition. Knowing the frequency, contexts, and structure of repetition is particularly necessary for new Montessori guides, who have limited practical experience on which to base their understanding of repetition.

The results of this study are informative to both Montessori guides and other early childhood educators. Although repetition is commonly viewed as pathological, our results suggest that repetition is not exclusively a feature of psychopathology, as it is also common in typically developing children. Differences between developmentally typical and psychopathological repetition are likely, however. Whereas pathological repetition is described as purposeless and stereotyped, typical repetition may be more variable if it is performed for the purpose of skill development. Research examining motor-skill acquisition suggests that early movements vary highly but become more stable as skill develops (Barbado Murillo, Caballero Sánchez, Moreside, Vera-García, & Moreno, 2017). Identifying differences in variability between pathological and typical instances of repetition would not only help distinguish between the two types of repetition, but also recognize when and how repetition aids skill development. As the progression from variable to stable movements would indicate the shift from novice to expert, it could help educators recognize if mastery has been achieved and when a child is ready to move on to the next activity.

Limitations and Implications

The current study provides useful information on the context of repetition, who engages in repetition, and the structure of repetition bouts—none of which is currently adequately described in Montessori theory. Continued caution is warranted, however, as the present study is only a single study on a small sample, and its findings need to be replicated. Additionally, there are aspects of the environment in the current study that may have created a natural history of repetition unique to the free-play environment. Therefore, future research could include a comparison to a Montessori environment to determine how repetition looks under these conditions. Differences in types of activities may cause repetition to differ between Montessori and free-play environments. For example, while free-play activities do not have set start and end points, Montessori activities follow a set sequence. Therefore, repetition in free play may comprise individual actions (as recorded in the current study), whereas repetition in the Montessori environment may be more event-like, including a whole sequence of events. Additionally, the schedules between Montessori and free-play environments differ. Montessori environments have an uninterrupted, 3-hour work period, whereas free-play environments have many transition times during the morning and afternoon periods. It may be that longer work periods are more conducive to repetition, as children's activities are not interrupted.

Nonetheless, the current study provides some empirical backing for Dr. Montessori's original claims. Future work can continue to improve descriptions of repetition structure, such as event-like versus individual action repetitions, whether there is a difference between variable and stereotyped repetition, and how repetition is performed under different contexts. The second step in investigating whether repetition is a natural tendency is to establish whether repetition contributes to development and learning. For example, does object-manipulation repetition develop both gross and fine motor skills? And is social repetition a separate category of repetition that develops social skills? An extensive description and thorough investigation into the function of repetition are necessary for determining whether repetition is a natural tendency among young children.

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Appendix A: Daycare Schedule

Time	Activity
07:30	Daycare opens and child drop-off begins; all children begin with free play in Jr.2 classroom
08:00	Children transition to their own classrooms for free play
09:00	Morning snack; children continue free play once snack is finished, i.e., overlaps with free play
10:00	Snack ends; free play continues
10:30	Children transition from indoor to outdoor free play
11:30	Children transition from outdoors to indoors for lunch
12:00	Lunch
13:00	Nap time for Jr.1 and Jr.2; free play for Senior and Kinder
15:00	Afternoon snack/free play; child pick-up begins
15:30	Children transition from indoor to outdoor play
18:00	Daycare closes

Appendix B: Data Collection Spreadsheet

Table B1

Type of Data Collected and Recorded in Spreadsheet

Data type	Explanation
Follow ID	Number
Child ID	Number
Sex	Male or female
Class	Jr.1, Jr.2, Senior, Kinder
Age	Number of months
Time	24-hour clock
Location	Name of center (later used to categorize location as outdoor or indoor)
Companion	See Table 2
Action description	What the child is doing (e.g., scooping rocks from path with shovel)

Figure B1. Example of data collection spreadsheet.

	A	B	C	D	E	F	G	H	I
1	Follow ID	ChildID	Sex	Class	Age (months)	Time block	Location	Companion	Action description
2	1	Child-1	Female	Jr.1	36	9:00	Building centre	Alone	Pick up block
3	1	Child-1	Female	Jr.1	36	9:00	Building centre	Alone	Place block on tower
4	1	Child-1	Female	Jr.1	36	9:00	Building centre	Alone	Pick up block
5	1	Child-1	Female	Jr.1	36	9:00	Building centre	Alone	Place block on tower
6	1	Child-1	Female	Jr.1	36	9:00	Building centre	Alone	Knock tower to ground
7	1	Child-1	Female	Jr.1	36	9:00	In transit	Alone	Walk to art centre
8	1	Child-1	Female	Jr.1	36	9:00	Art centre	Small child subgroup	Sit at table
9	1	Child-1	Female	Jr.1	36	9:00	Art centre	Small child subgroup	Pick up crayon
10	1	Child-1	Female	Jr.1	36	9:00	Art centre	Small child subgroup	Colour on colouring sheet
11	2	Child-4	Male	Jr.1	40	9:10	Dramatic play centre	Child pair	Pretend to stir soup in pot
12	2	Child-4	Male	Jr.1	40	9:10	Dramatic play centre	Child pair	Pretend to eat from spoon
13	2	Child-4	Male	Jr.1	40	9:10	Dramatic play centre	Child pair	Pretend to ladle soup from pot into bowl
14	2	Child-4	Male	Jr.1	40	9:10	Dramatic play centre	Child pair	Give Child-6 bowl
15	2	Child-4	Male	Jr.1	40	9:10	Dramatic play centre	Child pair	Pretend to eat soup
16	2	Child-4	Male	Jr.1	40	9:10	Dramatic play centre	Child pair	Pick up pot

Appendix C: Ethogram

An ethogram is a list of defined behavior codes. The action descriptions collected during focal observations were coded using this ethogram, which was created prior to data collection. As not all behaviors were exhibited during data collection, not all behavior codes were used during coding.

Body Movement Units
- Automanipulation: manipulating oneself (e.g., rubbing eyes or brushing hair, facial movements [sticking out tongue, pouting], touching one's face, putting an object in mouth [includes drinking], or hiding one's face)
- Balance: lifting one or two legs to balance; includes balancing on one leg or buttocks or hanging by hands
- Bend: forward or backward hip flexion
- Crouch: knees bent but weight still on feet
- Fall: going from an upright position to the ground; may be accidental or intentional
- Fine motor motion: single movement of hands or fingers
- Fine motor movement: repetitive or sustained movement of hands or fingers that does not involve manipulating an object
- Gross motor motion: single movement of torso or limbs
- Gross motor movement: repetitive or sustained movement of body or limbs without object (e.g., waving arms up and down through the air, shaking head back and forth [without communicative intent], kicking legs)
- Hands and knees: getting onto hands and knees and remaining stationary
- Hit: extending arm or arms and using one's hand or an object being held to forcefully make contact with another individual or object
- Jump/hop: moving suddenly upward by leg and foot extension, landing on two feet (jump) or one foot (hop)
- Kick: extending one leg suddenly, causing foot to make forceful contact with an object
- Kneel: weight supported on one or both knees and lower legs
- Lie: positioning body horizontally against a surface
- Point: extending arm, either with an extended finger or while holding an object, toward an object or individual
- Reach: extending arm and fingers in an attempt to grasp an object, or extending arm while holding an object to make contact with an object not in possession
- Reposition: making slight changes in bodily position (e.g., repositioning on a couch to make room for another child but not involving moving to a new location)
- Sit: weight supported by buttocks, which are in contact with a surface
- Shuffle: moving feet along the substrate without losing contact with it
- Spin: turning one's body rapidly in circles
- Stand: standing with both feet; weight mainly or wholly on feet
- Trip: stumbling but not falling

Locomotor Units
- Backward movement: backward movement by any modality (walking backward, crawling backward, scooting backward, etc.)
- Crawl: forward movement on hands and knees
- Climb: gross physical activity with three of four limbs, resulting in a vertical motion of the whole body (up or down)
- Circle: walking in a complete circle around an object
- Forward movement: forward movement on knees or buttocks, usually over short distances
- Group run: running in a coordinated fashion with other children

- Run: moving the body forward at a rapid pace, alternating legs and with both feet off the ground instantaneously during each stride
- Roll: moving the body across a surface by turning the body
- Side movement: movement to the side, whether on feet, knees, buttocks
- Skip: moving the body forward by alternating legs, placing one foot on the substrate and hoping slightly on it before shifting the weight to the other foot to repeat the same movement
- Slide: moving the body in constant frictional contact down an inclined surface
- Walk: moving the body forward at a moderate pace, alternating legs and placing one foot firmly on the substrate before lifting the other
- Wander: walking through the room without a direct path; *wander* is indicated by multiple changes in direction

Visual Units

- Examine: looking at an object or a part of one's self (e.g., a scab on one's arm) along with tactile examination
- Glance: visual gaze of one second or less directed to another individual
- Joint attention: attention between two or more individuals is brought to the same point (e.g., looking at a book together)
- Look: visual fixation at an object or an individual's face for more than a second (thus differentiating *look* from *glance*)
- Look around: looking around room or play center without prolonged visual fixation
- Look distance: prolonged visual fixation into the distance beyond the child's immediate surroundings (e.g., looking out the window or, if looking indoors, looking at something outside of the center one is in)
- Stare: unfocused gaze
- Watch: prolonged visual fixation on another individual or group of individuals while the individual or group performs an action (e.g., coloring, walking, talking)

Social Units

- Dispute object: attempting to retain an object in conflict for possession
- Dominate: taking or keeping possession of an object when another child was in possession or attempting to get possession of it
- Fail take object: grasping object in attempt to take from another child, but then letting go.
- Hold hands: grasping another individual's hand
- Hug/hugged: encircling arms around another individual, object, or self (hug); receiving hug (hugged).
- Join: standing in close proximity to an individual or group after traveling toward them
- Listen: focal child listening to another individual with minimal to no response, since the focal child is nonresponsive, he/she must be looking at the individual speaking to him/her to be sure listening is occurring; includes listening when someone is whispering into child's ear
- Nod: nodding head up and down to communicate with another individual, indicating *yes* or agreement
- Receive: grasping an object given by another individual
- Shake no: shaking head from side to side to communicate *no* or disagreement with another individual
- Show: bringing another individual's attention to an object or part of self, typically by holding the object
- Submit: losing possession of an object from another child
- Tease: provoking in a playful way; may involve verbal teasing or facial gestures (e.g., sticking tongue out)

Animation Play Units

- Animation movement: grasping and moving an object while pretending it is an animated being; may include moving the object with wrist rotation when pretending the object is talking or moving the object across a

surface when pretending the object is walking. Moving an object through the air as if it is flying is coded as *fly object*

- Crash: hitting two objects together
- Fly object: moving an object through the air without contact to a surface; includes an arm extension, holding an object up while walking, arm movements causing the object to move up and down, or twisting an object in the air. This behavior state is common in figurine, animation, and vehicle play
- Slide object: grasping an object and moving it across a surface, maintaining contact with the surface

Fantasy Play Units
- Object fantasy play: fantasy play with dramatic play toys (e.g., plastic food, tea set, menus, medical kit). Object fantasy play is part of fantasy play rather than object use because there is an as-if component to the toy use. For example, while the child may perform the action of pouring when tilting a teapot spout over a teacup, the child is not literally pouring. The child is pretending to pour, and the pretending component differentiates this behavior from a general object use unit

Rough-and-Tumble Play Units
- Fighting stance: holding a pose during rough-and-tumble or fantasy play; typically, feet are wider apart than hip width and arms are in the air, bent at elbow, and hands in fists
- Full body contact: putting one's body weight against another individual, object, or surface; includes leaning
- Pull: applying force to an object or another individual by arm and trunk flexion, causing it to move away from its original position
- Push: applying force to an object or individual (in the case of rough-and-tumble play) by limb and trunk extension, causing it or him/her to move away from original position
- Wrestle: mock-fighting with another individual that includes grappling or sustained contact (body contact, limb contact, as in arm wrestling, or repeated hand contact)

Art Activity Units
- Color: back-and-forth motion of a coloring utensil (e.g., crayon, pencil crayon, marker) to create solid sections of color (e.g., coloring a coloring sheet, free-hand coloring)
- Cut: using scissors to sever material (e.g., paper) into multiple pieces
- Draw: using any writing utensil (e.g., pen, pencil crayon, marker) to create fine-lined markings on a surface
- Erase: using an eraser to remove a drawn image
- Fold: creasing bendable material (e.g., folding paper)
- Glue: applying glue to any art material
- Paint: using an object (e.g., brush. sponge, finger) to apply paint to any material
- Stencil: tracing a stencil with any writing utensil
- Stick: attaching materials together using adhesive (e.g., glue)

Building Activity Units
- Build: constructing a structure out of multiple pieces, which may include combinations of different materials, which include but are not limited to wooden blocks, foam blocks, Legos, toilet rolls, and connectors
- Deconstruct: taking apart all or part of a structure or object; unlike *knock down*, *deconstruct* is careful and purposeful and is often part of the building process where part of the structure is taken apart for reconstruction
- Knock down: using a body part or held object to forcefully knock over a structure

Play Dough Activity Unit

- Add: adding more play dough to the amount he/she is already working with
- Press: applying sustained pressure for more than one second with one's palm, finger, or tool being held
- Pat: repeatedly lifting and making contact with an object, substance, or surface (e.g., patting play dough to flatten or a puzzle piece into place)
- Roll object: circular or back and forth movements of the palm to manipulate the play dough into a sphere or cylinder

Puzzle Activity Units

- Fit: joining complementary pieces together
- Rotate: turning an object (e.g., a puzzle piece) to more easily determine which way it fits into the puzzle

Water Table/Sand Table Activity Units

- Dip: dunking an object underwater and immediately lifting it out of the water
- Submerge: pushing an object underwater and holding it under for an extended period of time rather than lifting it out immediately; holding the object underwater differentiates *submerge* from the behavior unit *dip*
- Scoop: using tool or hand to collect water or sand and lifting
- Pour: tipping an object (typically some sort of container) holding liquid (or sand), causing the liquid to empty out
- Stir: moving an object in a circular motion through another substance (e.g., water or sand)
- Insert: placing an object into another object like a malleable object (e.g., stick into sand or play dough) or a tight opening (e.g., stick into vent)
- Dig: using a tool or body part to create a hole
- Cover: covering an object with sand or other object to conceal the object from view
- Uncover: removing an object or substance (e.g., sand) that shielded an object from view

General Object Manipulation Units

- Adjust: repositioning an object (e.g., repositioning blocks in a tower to better balance another block on top, turning a piece of clothing inside out before putting it on)
- Close: making the interior of an object or another space inaccessible (e.g., closing a box or door)
- Dump: tipping a container, causing the contents to fall out; differs from the behavior unit *pour*, which indicates liquid (or sand) being emptied out of a container
- Fine manipulation: movement of an object involving fine muscular activity of fingers or hands
- Fix: repairing a broken part of an object (e.g., putting a broken toy back together); does not include objects that are meant for putting together and taking apart (e.g. puzzle, building blocks)
- Gather: collecting objects into a group or pile; differs from the behavior unit *sort* because *gather* does not involve creating separate groups of objects according to a particular feature
- Give: holding out an object to another individual and releasing grip when the object is taken by the other person
- Grasp: encircling fingers around object and tightening grip
- Gross manipulation: sustained or repetitive movement of an object by gross limb activity (e.g., shaking, hitting, kicking, pushing, pulling an object)
- Hand fumble: moving hands and fingers together randomly; children may hold an object during *hand fumble*
- Hold: holding an object in a stationary position (e.g., holding microphone when singing into it)
- Hold out: attempting to give an object to another individual by holding it out to him or her, but the object is not taken

- Lift: raising an object with a limb extension
- Line: placing objects in a row
- Make contact: touching body part or object to another object
- Open: making accessible an object's interior that was previously inaccessible or making a larger space accessible (e.g., by opening a door)
- Pick up: obtaining an object by grasping, followed by a continuous arm movement
- Pull back: pulling arm back while holding object in to move an object out of reach of another individual
- Put down: releasing an object by loosening grasp; includes dropping
- Put in: placing an object inside another object or cubby
- Rub: back-and-forth or circular movements on an object with palm, side of fist, or thumbs
- Sort: creating groups of objects according to a particular feature (e.g., sorting objects into groups according to color)
- Squeeze: tightening grip around object or person
- Sweep: using a brush or broom to collect objects into a pile or a dustpan
- Take out: removing an object from inside another object (e.g., taking play dough out of a mold)
- Tap: repeatedly and briefly making contact with an object, either with hand, finger, or object being held
- Throw: moving an object through the air by releasing from hand at the end of arm extension
- Wipe: removing a substance by brushing or dusting (e.g., dusting sand off hands, wiping off a kiss given by another child)

Other Behavior Units
- Acted on: passively allowing another individual to act on oneself (e.g., allowing another individual to put a hat on oneself)
- Begin action: beginning an action but not following through (e.g., starting to pick up an object but then releasing it)
- Dress off: taking off an article of clothing or object being worn
- Dress up: putting on an article of clothing or object that can be worn (even if it is not intended for wearing)
- Hide: putting one's body in a place that is out of view of others (e.g., under a piece of furniture or blanket or in cubby space); includes hiding one's face
- Leave room: leaving observation area (classroom or outdoor area)
- Read: looking at a book (not necessarily literal reading; most likely looking at the pictures)

Failed Action Units
- Failed manipulation: failure to manipulate object (e.g., fitting a puzzle piece)
- Failed social action: failure to engage with or act on another individual (e.g., put a shoe on another child's foot)
- Failed automanipulation: failure to perform action on self (e.g., braid own hair)
- Failed motor action: failure to perform a motor action (e.g., climb structure)

<div align="center">**Appendix D: Event Coding**</div>

General Rules
- Each event is initiated by event-specific rules (see below)
- An event ends after four consecutive nonevent-related actions have occurred
- An event ends if another event begins

Animation: Animating an inanimate object by giving it motion or pretending it is alive. This often involves animating toys (e.g., action figures, stuffed animals, human figurines, animal figurines) that are made to represent living things. Animation play also includes animating objects that are not representative of living creatures (e.g., pompoms, bits of paper). Animation play typically involves pretending objects can talk, walk, and interact with one another. Includes car/train play in which a toy car/train is pushed over solid surfaces (along the ground or a track) and must involve car or train sound effects vocalized by the child.

Animation Rules
- Must be initiated by vocalizations such as sound effects or words that make it clear the child is engaging in animation play. Sounds effects may include "vrmm, vrmm," "beep beep," or "choo choo." Speech during animation play often involves speaking on behalf of the animated object, and children typically alter their speaking voice (e.g., speaking in a higher pitch)
- Animation play can also be initiated by planning animation play (e.g., saying "He's going to fart" about a stuffed dog)
- Once animation play has been initiated by a vocalization, play is continued by actions that follow the theme of animation. If a child is pretending a bottle is a rocket, continuation of animation play may include moving the bottle up and down through the air. If playing with a figurine, continuation of animation play may include walking the figurine across the substrate or using the figurine to knock over blocks

Construction: Activity that involves creating something out of multiple parts. Includes art activities or building from materials like blocks or puzzle pieces; may involve the deconstruction of structures as well.

Construction Rules
- Initiated by bringing two constructive objects together (e.g., bringing marker to paper and coloring, applying glue to paper, stacking blocks on top of each other)
- Once construction is initiated, it can then include deconstructive actions (e.g., knocking down a tower, erasing, taking a puzzle apart). These actions do not initiate construction
- There are a few special instances of construction. One example is constructing with play dough. Often, particularly with young children, playing with play dough seems to be only manipulation. However, a construction event begins when children label something they have made with play dough, such as "Here is a cupcake." We can then suppose that further interaction with the play dough is constructive in nature

Fantasy Play: Play involving as-if situations in which individuals, objects, or settings are other than reality; individuals take on an identity (e.g., mother, another animal) in role play, and objects become something else (e.g., banana used as a telephone; child pretends to be in a different setting, like setting up chairs in the classroom and pretending to be on a plane).

Fantasy Play Rules

- Like animation play, fantasy play is initiated by a vocalization, including planning the play event
- After fantasy play is initiated, it continues through actions specific to that play event, which vary greatly between types of fantasy play. For example, fantasy play in the dramatic play center may be initiated by giving another individual a cup and telling him or her that it's coffee. Then, the fantasy play event continues by moving similar toys (e.g., cups, plates, pots) around the center as a child pretends to prepare a meal. If a child sets up a row of chairs pretends to be sitting on a plane, continuation of the fantasy play event may include buckling up, pretending to fly the plane, or loading up the plane with cargo
- If a fantasy play event has already taken place during a focal follow, a re-initiation of the event during the same focal follow does not require a verbalization. Rather, only the same pattern of actions is required. For example, a child barks to initiate the fantasy play event of pretending to be a dog. Then, the child continues the play event by fetching a ball and bringing it back to another child. After a break of nonfantasy play (more than four nonfantasy play actions in a row), fetching and bringing a ball back to another child can be labeled *fantasy play* even if the child does not bark again to initiate the fantasy play event

Rough-and-Tumble Play: Social play involving physical contact (e.g., grappling, wrestling, other bodily contact); intent is nonaggressive.

Rough-and-Tumble Play Rules

- Rough-and-tumble play can be initiated by sustained physical contact (e.g., wrestling, arm wrestling)
- Rough-and-tumble play can also be initiated by repeated contacts, like hits or pushes. However, isolated hits or pushes do not constitute rough-and-tumble play. Therefore, for rough-and-tumble play to occur, there must be multiple contacts; the third contact is the start of rough-and-tumble play
- In rough-and-tumble play, one child may take a dominating role. If a child is pushed and chased by another child, this counts as rough-and-tumble play; however, the child being pushed and chased must be a consenting play partner
- Noncontact actions (e.g., fighting stance, chase) can continue the rough-and-tumble play event

Travel: Moving between centers.

Appendix E: Explanation of Multilevel Model Statistical Analysis

Multilevel models were used for all analyses, as they provided a means to deal with the hierarchical and nonindependent nature of the data. Here, *hierarchical* refers to the three-level structure of the data (see Figure E1). At the top of the hierarchy is the *class level*, which had four units: Jr.1, Jr.2., Senior, and Kinder. Midlevel is the *child level*, which included 31 children (not all are identified in the figure). Multiple children were observed within each classroom, which is described in multilevel analysis as children nested in class. The bottom level is the *focal follow level*, which represents the repeated observations (not all identified in the figure) for each child (focal follow nested in child). Figure E1 provides a visual representation of our data's hierarchical structure, and Table E1 presents the number of observations at each level.
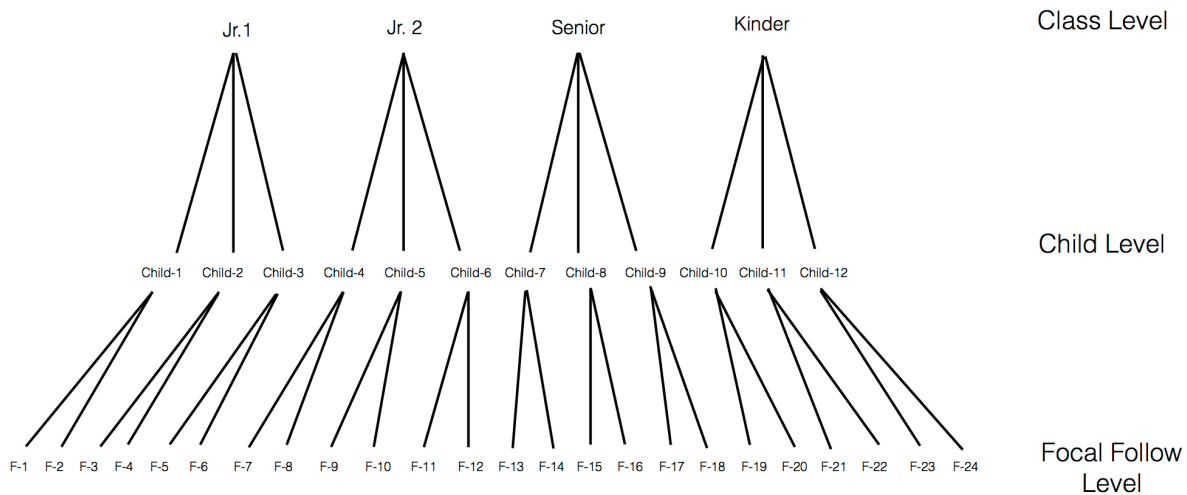

Figure E1. Hierarchical data structure.

Because of the nested structure of the data, we cannot be sure that variable measures are independent. Focal follows nested within child may be more similar than focal follows across children. For example, Child-1 may be more active than Child-2, resulting in Child-1 exhibiting more repetitive activity than Child-2. Furthermore, because children were nested in the classroom, there may also be nondependence on the child level. Children within a classroom may experience classroom-specific features that result in children within a classroom behaving more similarly to each other than to children from a different classroom. For example, the Jr.1 teacher may be more likely to interrupt children's activities than the Jr.2 teacher is, thus reducing the likelihood of long, repetitive sequences occurring in the Jr.1 classroom. Using multilevel model analyses, we were able to account for these possible differences in behavior by child and classroom. The advantage of using a multilevel model to account for these differences rather than building predictor variables into the model is that multilevel analysis allowed us to account for factors we were not aware of; building the nested structure of the data into our model (by including them as random effects, see next paragraph) served a catch-all function for detecting similarities within child and within classroom.

In multilevel model analysis, the language used to describe the model differs slightly from that of other types of statistical analyses. There are two main components in a multilevel model: main effects and random effects. Here, *main effects* are the same as in a linear regression model and refer to the independent, or predictor, variables in a model.

Table E1

Number of Observations by Level

Classroom	Child	No. of Observations
Jr.1	Child-2	10
	Child-3	10
	Child-4	13
	Child-8	10
	Child-9	9
	Child-10	10
Jr.2	Child-17	14
	Child-18	11
	Child-19	10
	Child-20	11
	Child-25	11
	Child-27	13
	Child-28	11
Senior	Child-33	13
	Child-36	10
	Child-38	11
	Child-39	7
	Child-40	13
	Child-43	10
	Child-44	10
	Child-46	10
Kinder	Child-50	10
	Child-53	10
	Child-55	11
	Child-56	9
	Child-58	7
	Child-59	8
	Child-61	9
	Child-62	11

Random effects refer to the grouping variables that make up the levels of the hierarchy. In the current analyses, children and classroom were specified as random effects in random intercept models, meaning we grouped focal follows by child and child by classroom, thus accounting for the nonindependence of focal follow and child. Multilevel model outputs provide two R^2 values: one for the main effects only and one for the whole model (main and random effects). R^2 marginal values were used to assess the main effects (i.e., how much of the variance in behavior identified as the dependent variable can be explained by the independent variables), and R^2 conditional values were used to estimate the effect of the full models (i.e., how much of the variance in the dependent variable can be explained by main and random effects; Nakagawa, Jonson, & Schielzeth, 2017). R^2 marginal and R^2 conditional values were generated by the MuMIn package (Bartoń, 2016).

Appendix F: Dealing with Overdispersion and Zero Inflation

We expected overdispersion and zero inflation in the data because focal follows without any repetitive bouts (i.e., zero-value observations) were included in the analysis. We did this because the absence of repetition was considered as meaningful as the presence of repetition; in other words, it is as important to know when repetition does not occur as it is to know when repetition does occur. Overdispersion and zero inflation were managed by creating observation-level random effects, in other words, giving each data point a unique ID that could be included in a new grouping variable (Harrison, 2014). Residual assumptions were tested again with the DHARMa package; the inclusion of observation-level random effects removed overdispersion and zero inflation.

Appendix G: Number of Spontaneous Bouts Model

Each bout was coded as outcome oriented or spontaneous. *Outcome-oriented repetition* included activities directed toward a particular goal that necessitated repeated action. For example, filling a bucket is an activity that requires repeated scooping and dumping to achieve the end result of a full bucket. In other words, there was an observable outcome beyond the repetitive actions themselves. *Spontaneous repetition* included bouts that had no observable outcome or did not require repeated action, for example, repeated spinning in circles. Reliability between independent coders was 92% (i.e., number of agreed codes/total codes × 100) for 20% of the total dataset. Fixed and random effects are reported below in Tables G1 and G2.

Coding Criteria for Outcome-Oriented and Spontaneous Repetition

Two questions were posed for each repetition bout to determine whether it was outcome oriented or spontaneous: (a) Does the repetitive activity have a higher-level outcome beyond the immediate action? and (b) If there is a higher-level outcome, does it require repeated actions?

If the answer to the first question was "no," the bout was coded as a spontaneous repetition. If the answer to the first question was "yes," it was considered a possible outcome-oriented repetition bout.

The second question was used to determine the final coding. If the answer to the second question was "yes," it was coded as outcome-oriented repetition. If the answer was "no," it was coded as spontaneous repetition.

Table G1
Fixed Effects

	Estimate	*SE*	*z* value	*p* value
Intercept	-1.64	0.16	-10.29	< .01
Follow duration	0.30	0.06	5.13	< .01
Age	-0.53	0.15	-3.62	< .01
Setting (REF: indoor)	0.58	0.26	2.19	.03
Rep. type (REF: motor)	1.68	0.16	10.23	< .01
Age*Setting	0.05	0.27	0.19	.85
Age*Rep. type	0.39	0.16	2.39	.02
Setting*Rep. type	-1.07	0.32	-3.36	< .01
Age*Setting*Rep. type	-0.18	0.33	0.54	.59

Table G2
Random Effects

Group	Variance	*SD*
Nobs	0.57	0.75
FollowID:ChildID:Class	0.00	0.00
ChildID:Class	0.02	0.16
Class	0.00	0.00