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Randomized controlled trial of an applied behavior analytic intervention for food selectivity in children with autism spectrum disorder

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Food selectivity is a common problem for children with autism spectrum disorder (ASD; Schreck, Williams, & Smith, 2004). Behavior-analytic interventions have the most empirical support for feeding disorders (Sharp, Jaquess, Morton, & Miles, 2011). However, there are no randomized controlled trials that have evaluated its effects with a well-defined cohort of children with ASD. In the current investigation, we randomly assigned 6 young children with ASD and food selectivity to either an applied behavior analytic intervention or a wait-list control. We used a crossover randomized controlled trial to evaluate the effects of a multicomponent applied behavior analytic intervention on independent acceptance and mouth clean of 16 novel foods. We subsequently exposed the wait-list control group to the intervention. We also evaluated the effects of the intervention on individual participants with single-case designs. The percentage of independent acceptance and mouth clean increased for the applied behavior analytic intervention group, but not for the wait-list control group until we implemented the intervention.

Key words: applied behavior analysis, autism spectrum disorder, escape extinction, food selectivity, randomized controlled trial

Food selectivity or "picky eating" is a common problem exhibited by children with autism spectrum disorder (ASD). Schreck, Williams, and Smith (2004) defined food selectivity as consumption of a limited number and variety of foods, and exclusion of foods based on characteristics like type, color, texture, or temperature. Hubbard, Anderson, Curtin, Must, and Bandini (2014) found that children with ASD refused more foods than typically developing children based on texture (77% vs. 36%), taste or smell (49% vs. 5%), and brand (15% vs. 1%). Even more alarming is that children with ASD often replace healthier, low calorie foods like fruits and vegetables with calorie-dense, nutritionally deficient foods like chips and candy that are often high in fat, sugar, and sodium (Peterson, Piazza, & Volkert, 2016; Schreck et al., 2004). Calorie-dense and nutritionally deficient diets increase the risk of long-term, severe health problems like chronic constipation, heart disease, obesity, and Type 2 diabetes (Freedman, Dietz, Srinivasan, & Berenson, 1999; Ludwig et al., 1999).

Studies have shown that the most harmful effects of poor nutrition occur before age 5, which is a period of critical brain development (Nyaradi, Li, Hickling, Foster, & Oddy, 2013; Rosales, Reznick, & Zeisel, 2009). Thus, diets lacking in important nutrients could lead to additional learning or behavior problems for children with ASD (Rosales et al., 2009). Fortunately, there are studies showing that we can improve the diet variety of children with ASD using applied behavior analysis (e.g., Ahearn, 2003; Kadey, Roane, Diaz, & Merrow, 2013; Laud, Girolami, Boscoe, & Gulotta, 2009; Levin, Volkert, & Piazza, 2014; Luiselli, Ricciardi, & Gilligan, 2005; Tarbox, Schiff, & Najdowski, 2010; Valdimarsdóttir, Halldórsdóttir, & SigurÐardóttir, 2010; Wood,

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Wolery, & Kaiser, 2009). For example, Kadey et al. (2013) expanded the diet variety of two participants diagnosed with ASD who were admitted to an intensive outpatient feeding program for treatment of food selectivity, using nonremoval of the spoon, noncontingent reinforcement, and a physical-guidance procedure. Valdimarsdóttir et al. (2010) increased consumption of nonpreferred foods for one participant with ASD across multiple settings using nonremoval of the fork, differential reinforcement of alternative behavior, and stimulus fading. These studies used single-case designs to evaluate the efficacy of the applied behavior analytic intervention. Although behavior analysts recognize the advantages of single-case design for establishing intervention efficacy, some professionals lack training in single-case design and are not aware of its acceptance in the evidence-based movement (Barlow & Hersen, 1973; Kazdin, 1992).

The evidence-based medicine movement has brought research design to the forefront as scientists rely in part on study design to grade the quality of research (Glasziou, Vandenbroucke, & Chalmers, 2004). Historically, scientists have assigned the highest grade to the randomized controlled trial (Concato, Shah, & Horowitz, 2000) and used the randomized controlled trial as the gold standard by which to evaluate the efficacy of interventions (Byar et al., 1976; Feinstein, 1984).

The randomized controlled trial is characterized by random assignment of a well-defined cohort of participants to an intervention or control group with identical treatment of both groups except for the tested intervention (Kendall, 2003). Presumably, statistically significant differences between the intervention and control groups suggest a cause and effect relation between the intervention and the outcome (Kendall, 2003). There are few randomized controlled trials that have assessed applied behavior analytic interventions for pediatric feeding disorders (Peterson et al., 2016; Sharp et al., 2016), and we are aware of no randomized controlled trials that have a well-defined cohort of participants with ASD and food selectivity or that have compared applied behavior analysis to a wait-list control.

Not all scientists agree, however, that the randomized controlled trial is the most stringent or appropriate method for establishing the efficacy of an intervention (Concato et al., 2000; Glasziou et al., 2004; Grossman & Mackenzie, 2005). One disadvantage of the randomized controlled trial is that it may mask idiosyncratic effects for individual participants (Grossman & Mackenzie, 2005). Single-case designs are ideal in this respect because they allow the investigator to evaluate the effects of an intervention for individual participants. Single-case research can help demonstrate the efficacy of an intervention by showing individual changes in behavior (Dallery, Cassidy, & Raiff, 2013; Slocum et al., 2014). After all, the caregiver of a child with a feeding problem and ASD is probably more interested in whether an intervention improves his or her child's feeding problem rather than whether the intervention is effective across a large group of children.

In the current investigation, we combined randomized controlled trial and single-case design methods. We randomly assigned six young children with ASD and food selectivity to either the applied behavior analytic intervention or a wait-list control group. The objective of the study was to evaluate the effects of the intervention on independent acceptance and mouth clean of healthy, novel, and nonpreferred foods.

METHOD

Power Analysis

We conducted an a priori power analysis to estimate the minimum effect size that a mixed ANOVA for percentage of independent acceptance and percentage of mouth clean could detect with the alpha level set at .01 and at .05. We set three participants per group and three

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repeated measures of the dependent variable as additional restrictions. We used the G-Power 3.0.10 program to conduct the power analysis (Faul, Erdfelder, Lang, & Buchner, 2007). Results of the power analysis indicated that this mixed ANOVA could detect a minimal Cohen's *d* effect size of 2.4 for an alpha of .01 and a minimal effect size of 0.5 for an alpha of .05. The a priori power analysis supports the small sample size of the current study.

Participants

We included six participants in the study who (a) were identified by physicians or speech and language pathologists as safe oral feeders with the oral-motor skills to manage table-textured foods, (b) consumed less than 20 but more than three foods by mouth, (c) were between the ages of 3 and 10 years, (d) consumed at least 90% of their caloric needs by mouth, (e) had a weight-for-height at or greater than the 5th percentile, (f) had a diet that was nutritionally deficient based on an analysis completed by our program's registered dietician, and (g) was diagnosed by a specialized interdisciplinary team with ASD. The team made the ASD diagnostic based on: (a) a structured interview to assess each child's history and current status of developmental, behavioral, and psychiatric disorders; (b) a mental status examination (Folstein, Folstein, & McHugh, 1975); (c) the Autism Diagnostic Observation Schedule II (Lord, Rutter, DiLavore, & Risi, 2000); and (d) the diagnostic criteria for autism spectrum disorder (American Psychiatric Association, 2000).

We asked caregivers to record the participant's oral intake for 3 consecutive days before the start of the study to determine whether a participant's diet was nutritionally deficient. The registered dietician then entered the intake records into a nutrition-analysis software (Food Processor Program, ESHA Research, 2010) to generate a report of the nutritional content of each participant's diet. The dietician then used one or more of the following criteria, according to the recommended daily allowance (National Institutes of Health, 2018), to qualify a diet as deficient: (a) nutrition came from one source like chicken nuggets; (b) failure to consume one of the food groups of fruits, grains, proteins, or vegetables; (c) consumption of less than 80% of the recommended daily allowance of vitamins and minerals for the participant's age; (d) consumption of less than 75% of recommended protein needs for the participant's age; or (e) a combination. We excluded participants who were receiving feeding-related intervention from another therapist or if a physician diagnosed a problem, like reflux, that required medical treatment or recommended a treatment that would interfere with feeding intervention, like chemotherapy. Robert, Michael, Terry, Morgan, and Luke were 3 years old, and Chris was 5 years old at the beginning of the study. Robert began the study on June 23, 2014 and ended on November 18, 2014; Michael began the study on December 8, 2014 and ended on July 1, 2015; Chris began the study on October 13, 2014 and ended on December 30, 2015; Terry began the study on October 16, 2014 and ended on January 15, 2015; Morgan began the study on October 27, 2014 and ended on July 24, 2015; Luke began the study on November 3, 2014 and ended on November 11, 2015. Before the study, Robert, Chris, and Morgan had received applied behavior analytic early-intervention services for 1 year, 1 month, and 1 month, respectively, which continued for the duration of the study. Luke had previously received 6 months of applied behavior analytic in-home early-intervention services. The early-intervention services did not address the participants' food selectivity, and none of the participants had previous exposure to feeding therapy.

Before the study, Robert only consumed carbohydrates like graham crackers, vanilla wafer cookies, pop tarts, and zero nutritional foods;

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Michael only consumed carbohydrates, fruits, and cottage cheese, for a total of 14 foods; Chris only consumed a few carbohydrates, one protein, and one fruit, for a total of 10 foods; Terry only consumed carbohydrates and proteins, for a total of nine foods; Morgan only consumed carbohydrates and proteins, for a total of 11 foods; Luke only consumed carbohydrates and proteins, for a total of nine foods. All participants except Michael also consumed sugar-laden foods like cookies and candy.

We asked the caregiver to select 16 healthy, novel, and nonpreferred target foods from food groups that the participant was not eating, but that he or she wanted the participant to eat. We randomly assigned the 16 target foods to four groupings of four foods each. Robert's caregivers selected chicken, potato, green bean, pear (Grouping 1); peanut butter and jelly sandwich, apple, carrot, brown rice (Grouping 2); chicken nugget, peach, corn, macaroni and cheese (Grouping 3); and hot dog, fruit cocktail, broccoli, french fry (Grouping 4). Michael's caregivers selected chicken nugget, green bean, brown rice, hot dog (Grouping 1); chicken, carrot, corn, mashed potato (Grouping 2); egg, hamburger, apricot, mixed vegetables (Grouping 3); and tuna, pea, broccoli, yam (Grouping 4). Chris's caregivers selected scrambled egg, peach, broccoli, white rice (Grouping 1); tuna, pineapple, pea, yam (Grouping 2); peanut butter and jelly sandwich, strawberry, corn flake with almond milk, corn (Grouping 3); and hot dog, rice with chicken and vegetable, pizza, ham sandwich (Grouping 4). Terry's caregivers selected chicken, white rice, strawberry, carrot (Grouping 1); peanut butter and jelly sandwich, potato, mandarin orange, green bean (Grouping 2); tuna, pineapple, broccoli, oatmeal (Grouping 3); and hot dog, carrot, pear, mashed potato (Grouping 4). Morgan's caregivers selected scrambled egg, cauliflower, green bean, macaroni and cheese (Grouping 1); garbanzo bean, carrot, broccoli, strawberry (Grouping 2); string cheese, pear, corn, tuna (Grouping 3); and peanut butter and jelly sandwich, mashed potato, pea, yogurt (Grouping 4). Luke's caregivers selected baked bean, pear, carrot, potato (Grouping 1); tuna, peach, pea, chicken (Grouping 2); hamburger, grape, apple, lettuce (Grouping 3); and corn, watermelon, orange, green bean (Grouping 4).

Intervention Intensity

Participants attended 1.5-hr appointments once per week. We increased the intervention intensity for Robert and Michael to three appointments per week when independent acceptance remained at zero during the first six and five intervention appointments, respectively. We chose this intensity based on family availability. Chris often missed appointments due to illness or scheduling conflicts. Therefore, his intervention intensity was one appointment every other week for a total of 28 appointments. He then took a 4-month hiatus from the study from August 10, 2015 to December 22, 2015 to participate in other activities (e.g., school) and returned for two appointments on December 22, 2015 and December 30, 2015 before terminating participation.

Setting and Materials

Feeders conducted sessions in 4-m x 4-m rooms equipped with an adjacent one-way observation room and an intercom system located in a pediatric feeding disorders program. Observers sat in the adjacent observation room. Feeders and observers were individuals with bachelor's, master's, or doctoral degrees in psychology, behavior analysis, or a related field who we trained to take data and to implement the study procedure. Children sat in age- and weight-appropriate seating like a toddler high chair or booster seat. Other materials included a scale, timers, gloves, paper towels, laptop computers, spoons, rubber-coated baby spoons,

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and plastic bowls. We used toddler-sized plastic forks for Michael, Chris, and Luke as the caregivers indicated that these participants were more proficient eating with a fork than a spoon.

Dependent Variables, Response Measurement, and Reliability

Trained observers collected data on the occurrence of independent acceptance, mouth clean, and the frequency of inappropriate mealtime behavior using laptop computers. Observers scored *independent acceptance* if the participant picked up the spoon, fork, or bite of food and deposited the entire bite, except for food the size of a grain of rice or smaller, into his or her mouth within 8 s of the presentation. During backward chaining for Chris, observers scored independent acceptance when Chris deposited the bite into his mouth and removed the empty fork from his mouth from the point at which the feeder guided his hand with the fork within 8 s. We divided the number of bites accepted by the number of bites presented and converted the ratio to a percentage. Presentations occurred when the feeder placed a single bite of a target food on a utensil in a bowl in front of the participant with the verbal prompt, "Take a bite." We cut target foods into 0.6-cm by 0.6-cm by 0.6-cm pieces and defined one 0.6-cm by 0.6-cm by 0.6-cm piece as a single bite, which weighed about 1 gram.

Observers scored *mouth clean* when there was no food larger than a grain of rice in the participant's mouth 30 s after the entire bite entered the mouth, excluding the absence of food in the mouth due to expulsion. Observers had the opportunity to score mouth clean once for each bite that entered the participant's mouth. We divided the number of mouth cleans by the number of bites that entered the participant's mouth, excluding bites that entered the mouth during re-presentation (described below), and converted that ratio to a percentage.

Observers scored *inappropriate mealtime behavior* each time the participant moved the spoon, fork, or bite of food away from the mouth before the participant or feeder deposited the bite into the mouth; threw the spoon, fork, or the bite; hit the spoon, fork, or bite against a surface; covered his or her mouth; turned his or her head or moved his or her torso 45° away from the utensil or bite while the utensil or bite was within arm's reach of the participant; or touched the feeder's arm or hand. We converted data on inappropriate mealtime behavior to responses per minute by dividing the total number of inappropriate mealtime behaviors by the total time the utensil or bite was within arm's reach of the participant.

Two observers independently and simultaneously collected data on independent acceptance, mouth clean, and inappropriate mealtime behavior during a mean of 30% (range, 13% to 47%) of sessions across participants. We calculated interobserver agreement for independent acceptance and mouth clean by dividing the number of agreements by the total number of agreements plus disagreements and converting that ratio to a percentage. We defined an agreement as both observers scoring the behavior in the same 10-s interval and a disagreement as one observer scoring and one observer not scoring the behavior in the same 10-s interval. Mean interobserver agreement across participants was 98% (range, 67% to 100%) and 99% (range, 79% to 100%) for independent acceptance and mouth clean, respectively.

We calculated exact agreement for inappropriate mealtime behavior by dividing the number of agreements by the total number of agreements plus disagreements and converting this ratio into a percentage. We defined an agreement as a 10-s interval in which both observers scored the same frequency of inappropriate mealtime behavior and a disagreement as a 10-s interval in which observers scored

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different frequencies of inappropriate mealtime behavior. Mean interobserver agreement across participants for inappropriate mealtime behavior was 91% (range, 42% to 94%).

Procedural Random Assignment with Counterbalancing

We used a random number generator to enroll participants in pairs, randomly assigning each child in the pair to either the intervention or the wait-list group. We enrolled participants in pairs to use the data from the participant in the applied behavior analytic intervention group to determine when to initiate intervention for the participant in the wait-list group. We enrolled participants into the study consecutively, such that when we completed the study for one pair, we enrolled the next pair until we had conducted the study with six children (i.e., three pairs of two participants each). Pair 1 was Robert (applied behavior analytic intervention) and Michael (wait-list control); Pair 2 was Chris (applied behavior analytic intervention) and Terry (wait-list control); and Pair 3 was Morgan (applied behavior analytic intervention) and Luke (wait-list control). The planned experimental preparation was to conduct initial baseline checks for each pair of participants during the first appointment. After the first appointment, participants in the applied behavior analytic intervention attended weekly appointments in the clinic. We instructed the caregivers of the wait-list control participants to conduct meals at home as usual and to refrain from implementing alternative strategies. We also instructed caregivers of the wait-list control participants to return to the clinic at 12-week intervals for baseline checks to evaluate levels of independent acceptance and mouth clean of the target food groupings over time. For each pair of participants, we implemented the applied behavior analytic intervention for the participant in the wait-list control group if (a) independent acceptance across the target food groupings had not increased to 80% or above during the 12-week baseline checks and (b) independent acceptance across the target food groupings maintained at high levels based on visual inspection for the participant's pair in the applied behavior analytic intervention group.

Experimental Design

We used a crossover randomized controlled trial and a multiple-baseline-across-food-groupings design for participants in the intervention condition.

Randomized controlled trial. Participants completed their assigned components of the study with no participant attrition. In addition, two of the three participants originally assigned to the wait-list control group (Michael and Luke) crossed over to the intervention condition after completion of the posttest.

Single-subject evaluation. We introduced the intervention using a multiple-baseline-across-food-groupings design for participants originally assigned to the intervention group and those originally assigned to the wait-list control group after they crossed over to the intervention condition. Each baseline consisted of one of the four groupings of caregiver-selected foods. We also conducted periodic baseline sessions for a food grouping after we initiated intervention with that food grouping. We compared independent acceptance during baseline with independent acceptance during the intervention phase by adding independent acceptance probes as a multielement component during the intervention phase.

Procedure for introducing the intervention. We conducted the initial baseline check for all participants during the first appointment to assess independent acceptance of the target food groupings. We initiated intervention during the second appointment for participants in the applied behavior analytic intervention group, beginning with the food grouping for which we

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observed the lowest and most stable levels of independent acceptance and highest levels of inappropriate mealtime behavior. When independent acceptance was above 80% for that food grouping, we implemented intervention sequentially across the other three food groupings in accordance with a multiple baseline design. We observed high, stable levels of independent acceptance with Grouping 2 foods for Luke (tuna, chicken, peach, and pea) during baseline; therefore, we did not implement intervention with that grouping of foods.

Statistical Analysis

We conducted statistical analyses following the intent-to-treat principle. The intent-to-treat principle is designed to prevent bias by including data for participants from the groups to which they were randomly assigned regardless of any deviations, like withdrawal of participants in the intervention group (White, Horton, Carpenter, & Pocock, 2011). Chris (intervention) and Terry (wait-list control) withdrew from the current study after 32 weeks of intervention and after the Week 12 check and before crossing over to the intervention, respectively. Thus, we conducted the statistical analyses at the measurement intervals for which we had data for all participants, the Week 1 baseline and the Week 12 check. This represents a highly conservative application of the intent-to-treat principle relative to methods that involve creating missing data like imputing the mean or using data smoothing.

We conducted our statistical analyses of independent acceptance and mouth clean by randomly selecting data from three sessions from each food grouping, which we will refer to as Sessions 1, 2, and 3, for each participant from the Week 1 baseline check and from the Week 12 check. We calculated the mean across food groupings for Sessions 1, 2, and 3 from the Week 1 baseline check and for Sessions 1, 2, and 3 from the Week 12 check. We used the same statistical analysis for percentage of independent acceptance and percentage of mouth clean. Specifically, we used a mixed-design analysis of variance (ANOVA) with group membership as a two-level, between-groups factor (intervention vs. wait-list control group), and measurement time as a three-level, within-groups factor (dependent measures from Week 12 Sessions 1, 2, and 3) to analyze the intervention's effects on percentage of independent acceptance and percentage of mouth clean. We could not use the percentage of independent acceptance or percentage of mouth clean during Week 1 baseline Sessions 1, 2, and 3 as covariables in the statistical model because percentage of independent acceptance was zero for all participants except Terry, who accepted two bites in baseline. Participants who did not accept bites did not have the opportunity to have mouth clean, and Terry had 100% mouth clean for the two bites that he independently accepted. Therefore, the Week 1 data could not account for any of the variance observed during the Week 12 sessions. We did not include other participant characteristics as covariables (e.g., age, autism severity) due to the small sample size.

We examined the data for outliers using boxplots and examined the statistical assumptions of independence of measures, normality, heterogeneity of variance, and sphericity before conducting the mixed ANOVA (Leech, Barrett, & Morgan, 2011). Based on the random assignment procedures described above, it is clear that the between-subjects data met the assumption of independence. To test for normality, we examined the skewness scores for each pretest and posttest variable; all were within the typically accepted range of -1 to 1 (*M* = .09; *SD* = .04). We used the Levene's test to examine homogeneity of variance and found significantly unequal variances across the groups for both percentage of acceptance and percentage of mouth clean (all Levene's statistics >7.0, all *p*-values < .05). Unequal variances

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between the intervention and wait-list control groups occurred because percentage of independent acceptance was zero for the participants in the wait-list control group during the Week 12 sessions, resulting in zero variance, whereas these values were well above zero for the intervention group. However, unequal sample variances tend to have limited effects on Type-1 errors when sample sizes are equal across groups, which was the case in the current investigation (Box, 1953; Leech et al., 2011). Nevertheless, we set a conservative criterion for statistical significance (i.e., $p < .01$) to counteract any potential inflation in Type-1 error rates due to unequal variances. Finally, we evaluated sphericity using Mauchly's test, which produced epsilon estimates greater than 1. Epsilon estimates greater than 1 indicate that the data violate the sphericity assumption. Therefore, we adjusted the degrees of freedom using the Huynh-Feldt epsilon statistic ($\varepsilon = 0.93$) for percentage of independent acceptance and using the Greenhouse–Geisser epsilon statistic ($\varepsilon = 0.60$) for percentage of mouth clean to correct for significant sphericity. Statisticians typically use the Huynh-Feldt epsilon statistic when the Huynh-Feldt epsilon exceeds 0.75 and the Greenhouse–Geisser epsilon statistic when the Greenhouse–Geisser epsilon is less than 0.75 (Leech et al., 2011). We also analyzed the size of the effect of the intervention using the Cohen's d statistic. Cohen (1988) considered an effect size of 0.8 or greater as "large."

General Procedure

During each session, the feeder presented the four foods from one of the food groupings in a random order for a total of four bite presentations per session. The feeder presented the 0.6-cm by 0.6-cm by 0.6-cm bites approximately every 30 s. The feeder placed the bite of food on the utensil in a bowl in front of the participant simultaneously with the prompt, "Take a bite." The feeder provided descriptive praise (e.g., "Great job taking your bite!") for independent acceptance and activated a timer for 30 s. The feeder initiated a mouth check at the expiration of 30 s. The feeder prompted, "Show me, ahhh" while modeling an open mouth. If the participant did not open his or her mouth after the prompt, the feeder used a baby spoon to prompt the participant to open by inserting the spoon at the side of the lips and turning the spoon 90°. The feeder provided descriptive praise for mouth clean (e.g., "Great job swallowing your bite!"). If the participant was packing, defined as food larger than a grain of rice inside the mouth 30 s after the bite entered the mouth, the feeder said, "Swallow your bite" and presented the next bite. If the participant was packing a bite(s) 30 s after the feeder presented the fourth bite, the feeder prompted the participant to "Show me" and "Swallow your bite" every 30 s until the participant swallowed or until 10 min had elapsed from the start of the session. The feeder removed packed food from the participant's mouth with a rubber-coated baby spoon and paper towel at the expiration of the 10-min time cap. Note that observers did not score mouth clean or pack for these subsequent mouth checks. The feeder provided no differential consequences for coughing, gagging, inappropriate mealtime behavior, or vomiting.

Baseline. The feeder followed the general procedure. If the participant did not place the bite in his or her mouth within 30 s of the presentation, the feeder removed the bowl, utensil, and bite, and presented the next bite. The feeder provided no differential consequences for expels.

Applied behavior analytic intervention. The feeder followed the general and baseline procedure, with the following modifications. The feeder implemented hand-over-hand guidance with nonremoval of the spoon (Ahearn, Kerwin, Eicher, Shantz, & Swearingin, 1996; Cooper et al., 1995; Peterson et al., 2016;

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Piazza, Patel, Gulotta, Sevin, & Layer, 2003; Reed et al., 2004) if the participant did not exhibit independent acceptance within 8 s of the bite presentation. The feeder implemented hand-over-hand guidance and nonremoval of the spoon by placing his or her hand over the participant's hand to guide the participant to grasp the utensil, lift it to his or her lips, and deposit the bite into the mouth. The feeder immediately re-presented expelled bites by forking or scooping the expelled bite and depositing it into the participant's mouth without hand-over-hand guidance. If the participant was expelling when the 30-s interval elapsed, the feeder continued to re-present the bite until the bite remained in the participant's mouth for at least 3 s, and then the feeder immediately presented the next bite. If the participant continued to expel without holding the bite in his or her mouth for 3 s, the feeder continued to re-present until the time-cap elapsed. The session continued until the participant swallowed the four bites or 10 min elapsed. The feeder continuously interacted with the participant throughout the session by talking and singing (Reed et al., 2004).

Backward chaining (Chris). When independent acceptance did not increase for Chris after seven appointments, we asked his caregivers to bring him to the clinic more frequently, but they were not able to do so. Therefore, we added backward chaining (Peterson et al., 2016) to the intervention. We selected backward chaining because we used it to increase self-feeding for children with ASD and food selectivity in a previous study (Peterson et al., 2016). We added backward chaining to hand-over-hand guidance, nonremoval of the spoon, re-presentation, and continuous interaction with the following modifications. The feeder presented the bite on the fork and guided Chris to complete part of the acceptance response. After the feeder guided Chris to place the fork in the targeted position, the feeder discontinued guidance. The feeder provided descriptive praise if Chris completed the acceptance response at the prescribed step. If Chris did not complete the acceptance response, the feeder used hand-over-hand guidance to complete the acceptance response. If Chris completed the acceptance response on 80% or more of bite presentations and had fewer than five inappropriate mealtime behaviors for at least three consecutive sessions, the feeder implemented the next step of the acceptance response. The steps of the acceptance response were as follows. The feeder guided Chris to place the spoon (a) inside his mouth, (b) at the lips, (c) 2.54 cm from the lips, (d) 5.08 cm from the lips, (e) 7.62 cm from the lips, (f) 10.16 cm from the lips, (g) 12.7 cm from the lips, (h) 15.24 cm from the lips, (i) just above the bowl, and (j) inside his hand. The feeder conducted probes of the terminal step after Chris mastered each step. The terminal probe was identical to the hand-over-hand guidance, nonremoval of the spoon, re-presentation, and continuous interaction condition, which we continued if independent acceptance was at or above 80%. We discontinued probes and went to the next step if independent acceptance was below 80% during the probe. We began backward chaining with the Grouping 3 foods and hand-over-hand guidance, nonremoval of the spoon, re-presentation, and continuous interaction for food Groupings 1, 2, and 4. Independent acceptance increased for food Groupings 1, 2, and 4 after we implemented backward chaining with food Grouping 3. Thus, we did not implement backward chaining for food Groupings 1, 2, and 4. Chris's caregivers ended his participation in the study early because they were not able to bring Chris to feeding therapy consistently due to Chris's involvement in eight other therapeutic activities and full-time school.

Wait-list control. Levels of independent acceptance did not change for the participants in the wait-list control group after the baseline checks. Therefore, we implemented the applied behavior analytic intervention as described

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above with Michael and Luke. We did not implement the applied behavior analytic intervention with Terry because his caregiver terminated his participation in the study after his 12-week baseline check. Caregivers reported that Terry's diet variety had improved, although we did not observe improvements during our 12-week check.

Poststudy Caregiver Training

After the study, we trained caregivers to implement the applied behavior analytic intervention with 90% or greater integrity in the clinic using written instructions, modeling, and feedback (Mueller et al., 2003). We then conducted training in the home and gave the family a plan for maintenance and further advancement of feeding skills. Data from caregiver training are available from the first author.

RESULTS

Group Analysis

Results of the mixed ANOVA indicated a large and significant main effect on the percentage of independent acceptance for the between-groups factor (intervention vs. wait-list control; F (1, 4) = 143, $p < .0001$; Cohen's d = 12.0). The within-groups factor produced negative results (Week 12, Sessions 1, 2, 3; F (2, 8) = 0.4; p = .7), as did the interaction term of the model between group membership and Week 12 session number (F (2, 8) = 0.42; p = .7). The Cohen's d of 12 represents an unusually large effect size, which probably resulted in part from the absence of variability during baseline. The means for Week 12, Sessions 1, 2, and 3 were 90%, 89%, and 92%, respectively, and the standard deviations for Week 12, Sessions 1, 2, and 3 were 13, 13, and 14, respectively, for percentage of independent acceptance for the intervention group. The means and standard deviations for Week 12, Sessions 1, 2, and 3 were 0 for percentage of independent acceptance for the wait-list control group.

Results of the mixed ANOVA indicated a large and significant main effect on the percentage of mouth clean for the between-groups factor (intervention vs. wait-list control; F (1, 4) = 341, $p < .0001$; Cohen's d = 18). The within-groups factor produced negative results (Week 12, Sessions 1, 2, 3; F (2, 8) = 0.03; p = .9), as did the interaction term of the model between group membership and Week 12 session number (F (2, 8) = 0.03; p = .89). The main effect for the between-groups factor produced a Cohen's d of 18. The Cohen's d of 18 represents an unusually large effect size, which probably resulted in part from the absence of variability during baseline. The means for Week 12, Sessions 1, 2, and 3 were 92%, 94%, and 93%, respectively, and the standard deviations for Week 12, Sessions 1, 2, and 3 were 14, 10, and 6, respectively, for percentage of mouth clean for the intervention group. The means and standard deviations for Week 12, Sessions 1, 2, and 3 were 0 for percentage of mouth clean for the wait-list control group.

Single-Case Analysis

Figure 1 displays percentage of independent acceptance (top) and grams consumed (bottom) for Robert for food Groupings 2 (top), 3 (second), 1 (third), and 4 (bottom). Means for percentage of independent acceptance, grams consumed, percentage of mouth clean (data not shown), and inappropriate mealtime behavior per minute (data not shown) were 0.5% (range, 0% to 25%), 0.08 (range, 0 to 1), 0.5% (range, 0% to 25%), and 25 (range, 1 to 52), respectively, across food groupings during baseline before intervention. Means for percentage of independent acceptance, grams consumed, percentage of mouth clean, and inappropriate mealtime behavior per minute were 68% (range, 0% to 100%), 3 (range, 0 to 6), 74%

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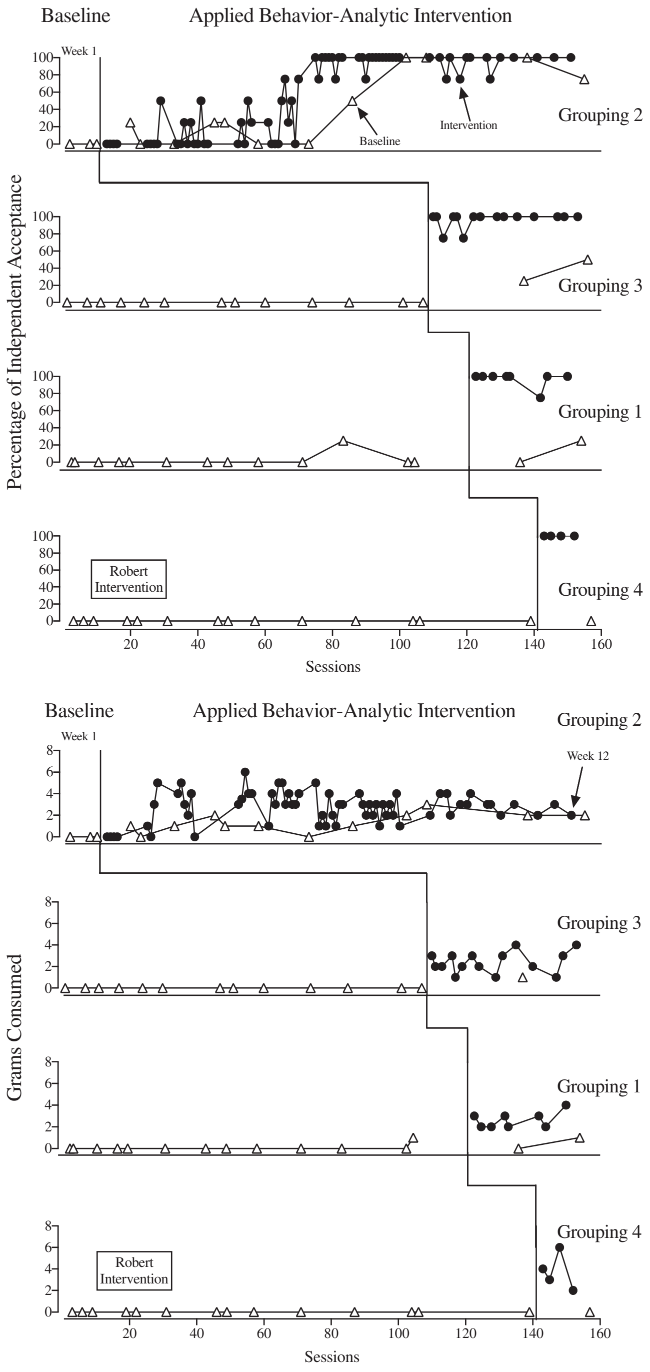

Figure 1. Percentage of independent acceptance (top) and grams consumed (bottom) across food groupings for Robert (intervention group).

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(range, 0% to 100%), and 8 (range, 0 to 54), respectively, across food groupings when we implemented the applied behavior-analytic intervention. Means for percentage of independent acceptance, grams consumed, percentage of mouth clean, and inappropriate mealtime behavior per minute were 35% (range, 0% to 100%), 1 (range, 0 to 3), 44% (range, 0% to 100%), and 13 (range, 0 to 31), respectively, during the baseline sessions of the multielement comparison.

Figure 2 displays percentage of independent acceptance (top) and grams consumed (bottom) for Michael for food Groupings 1 (top), 2 (second), 3 (third), and 4 (bottom). Means for percentage of independent acceptance, grams consumed, percentage of mouth clean (data not shown), and inappropriate mealtime behavior per minute (data not shown) were 7% (range, 0% to 100%), 0.2 (range, 0 to 2), 4% (range, 0% to 50%), and 23 (range, 0 to 64), respectively, during baseline before intervention. Means for percentage of independent acceptance, grams consumed, percentage of mouth clean, and inappropriate mealtime behavior per minute were 58% (range, 0% to 100%), 2 (range, 0 to 6), 61% (range, 0% to 100%), and 12.3 (range, 0 to 187), respectively, across food groupings when we implemented the applied behavior analytic intervention. Means for percentage of independent acceptance, grams consumed, percentage of mouth clean, and inappropriate mealtime behavior per minute were 33% (range, 0% to 100%), 1 (range, 0 to 4), 48% (range, 0% to 100%), and 11 (range, 0 to 56), respectively, during the baseline sessions of the multielement comparison.

Figure 3 displays percentage of independent acceptance (top) and grams consumed (bottom) for Chris for food Groupings 3 (top), 4 (second), 1 (third), and 2 (bottom). Means for percentage of independent acceptance, grams consumed, percentage of mouth clean (data not shown), and inappropriate mealtime behavior per minute (data not shown) were 7% (range, 0% to 75%), 0.2 (range, 0 to 3), 4% (range, 0% to 75%), and 17 (range, 0 to 66) across food groupings during baseline before intervention. Means for food Grouping 3 for percentage of independent acceptance, grams consumed, percentage of mouth clean, and inappropriate mealtime behavior per minute were 5% (range, 0% to 50%), 2 (range, 0 to 4), 37% (range, 0% to 100%), and 5 (range, 0 to 23) when we implemented the applied behavior analytic intervention relative to means of 0, 0, 0, and 9 (range, 2 to 21), respectively, during the baseline sessions of the multielement comparison. Although percentage of independent acceptance was low, Chris passively allowed the feeder to guide the bites into his mouth 8 s after the bite presentation (data available from the first author). Therefore, we added backward chaining for food Grouping 3. Means for food Grouping 3 for percentage of independent acceptance, grams consumed, percentage of mouth clean, and inappropriate mealtime behavior per minute when we added backward chaining were 92% (range, 25% to 100%), 2 (range, 0 to 6), 73% (range, 0% to 100%), and 3 (range, 0 to 29), respectively, relative to means of 29% (range, 0% to 75%), 0.6 (range, 0 to 2), 18% (range, 0% to 75%), and 13 (range, 0 to 33), respectively, during the baseline sessions of the multielement comparison. Means for food Grouping 3 for percentage of independent acceptance, grams consumed, percentage of mouth clean, and inappropriate mealtime behavior per minute were 64% (range, 0% to 100%), 3 (range, 0 to 6), 62% (range, 0% to 100%), and 5 (range, 0 to 22), respectively, during the terminal step of backward chaining, relative to means of 45% (range, 0% to 75%), 0.8 (range, 0 to 2), 75% (range, 0% to 75%), and 5 (range, 2 to 15), respectively, during the baseline sessions of the multielement comparison. Means for percentage of independent acceptance, grams consumed, percentage of mouth clean, and

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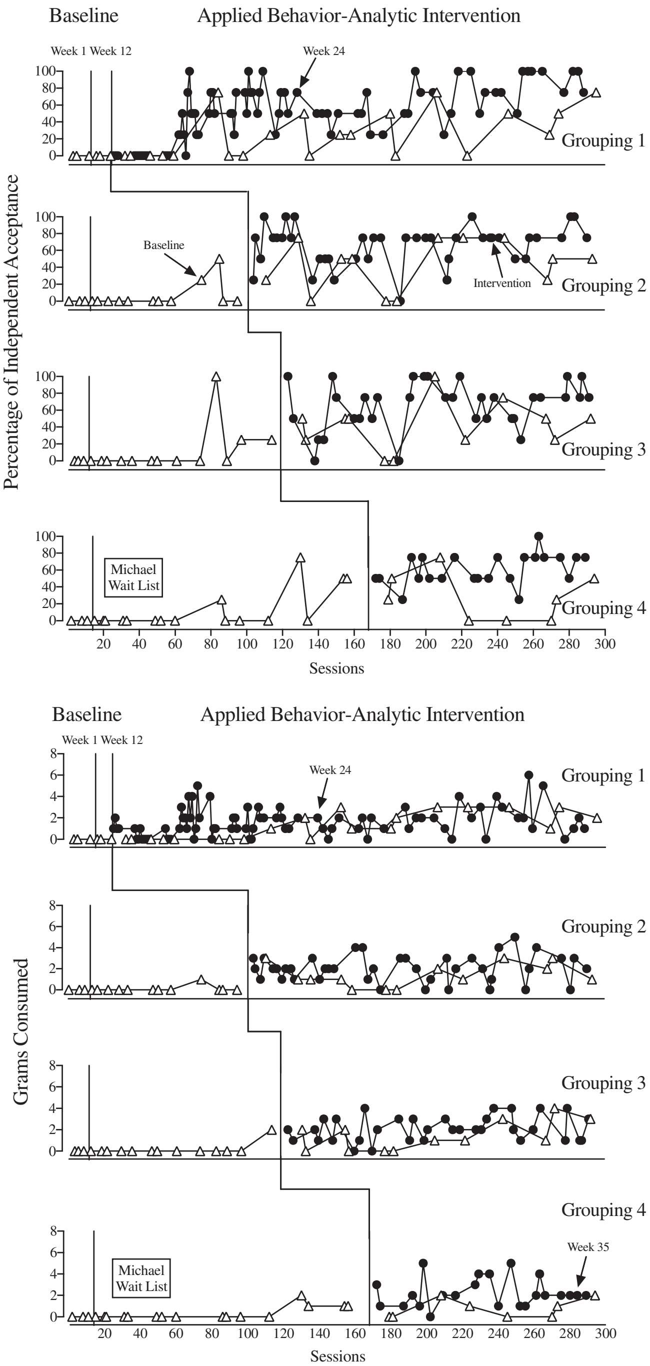

Figure 2. Percentage of independent acceptance (top) and grams consumed (bottom) across food groupings for Robert (intervention group).

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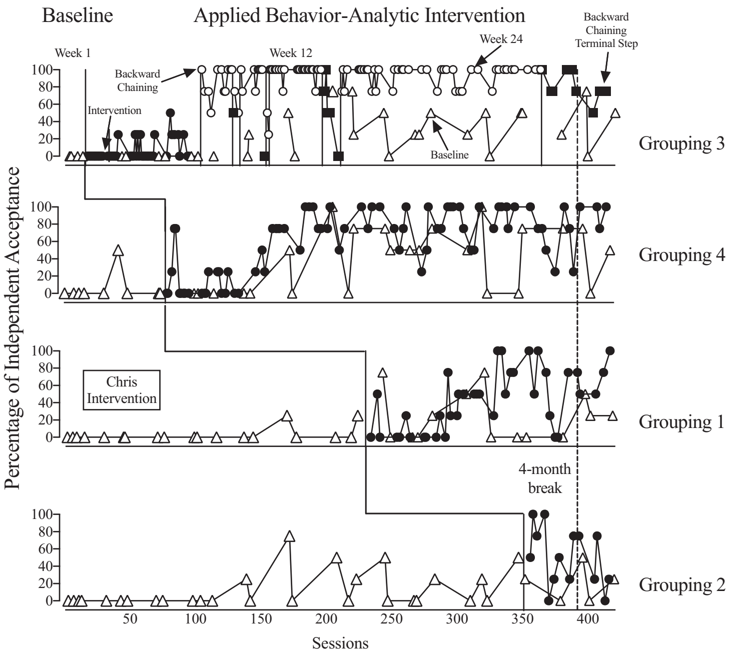

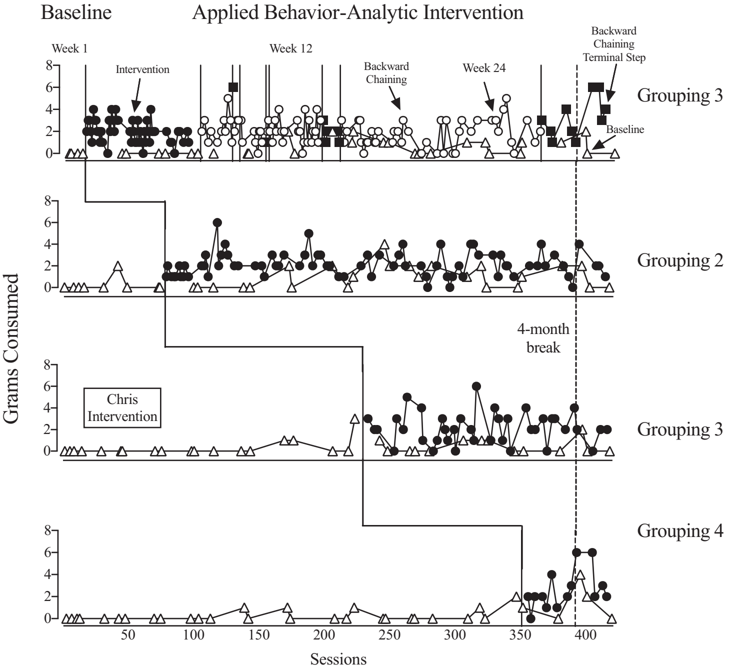

Figure 3. Percentage of independent acceptance (top) and grams consumed (bottom) across food groupings for Chris (intervention group).

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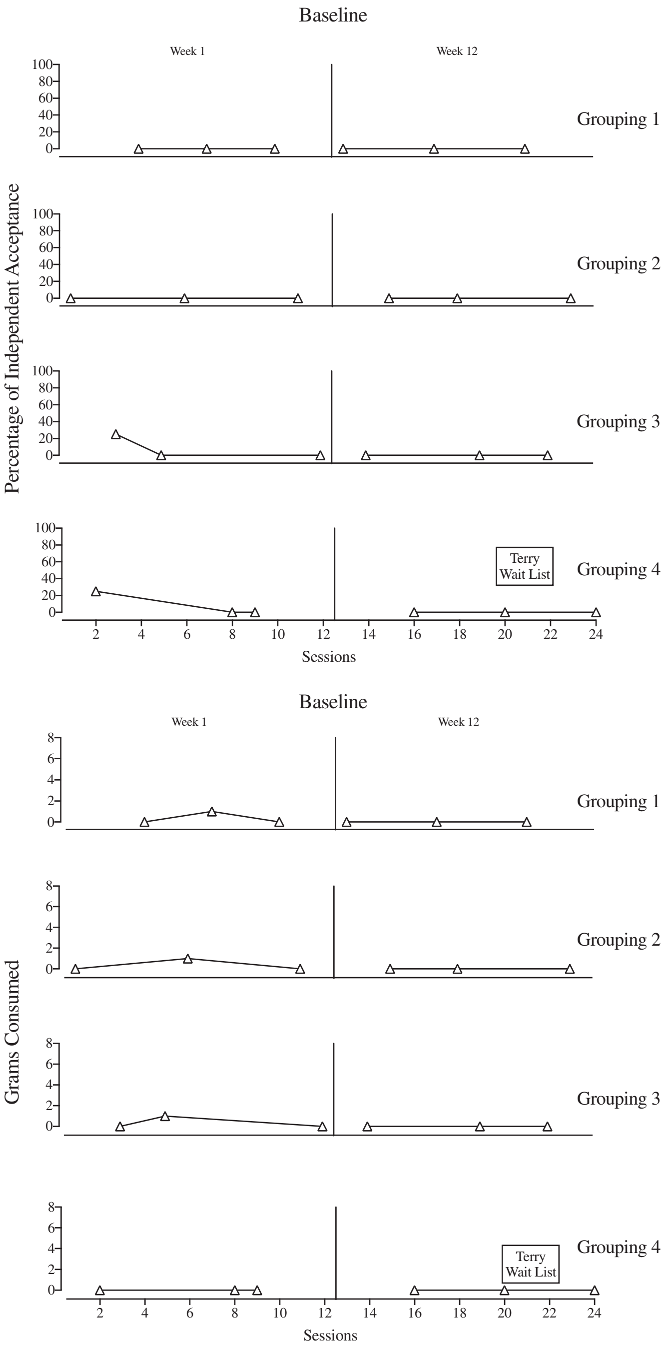

Figure 4. Percentage of independent acceptance (top) and grams consumed (bottom) across food groupings for Terry (wait list group).

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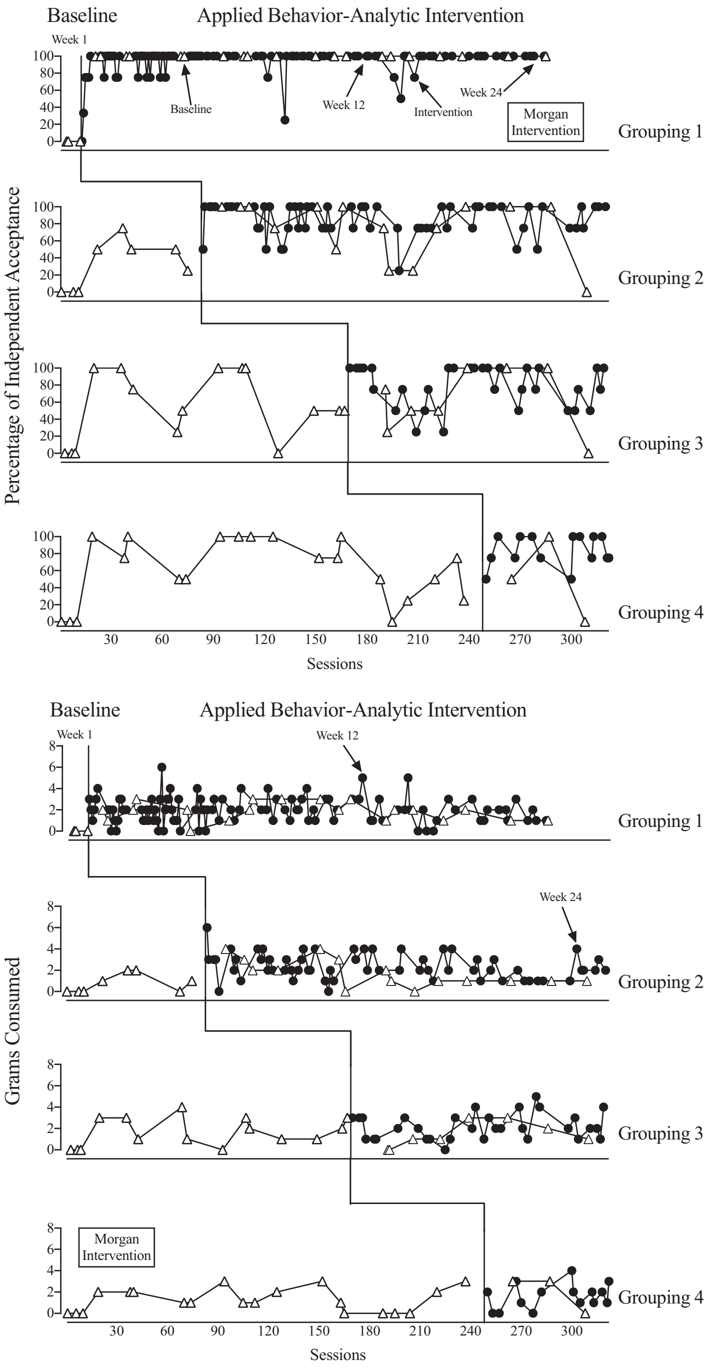

Figure 5. Percentage of independent acceptance (top) and grams consumed (bottom) across food groupings for Morgan (intervention group).

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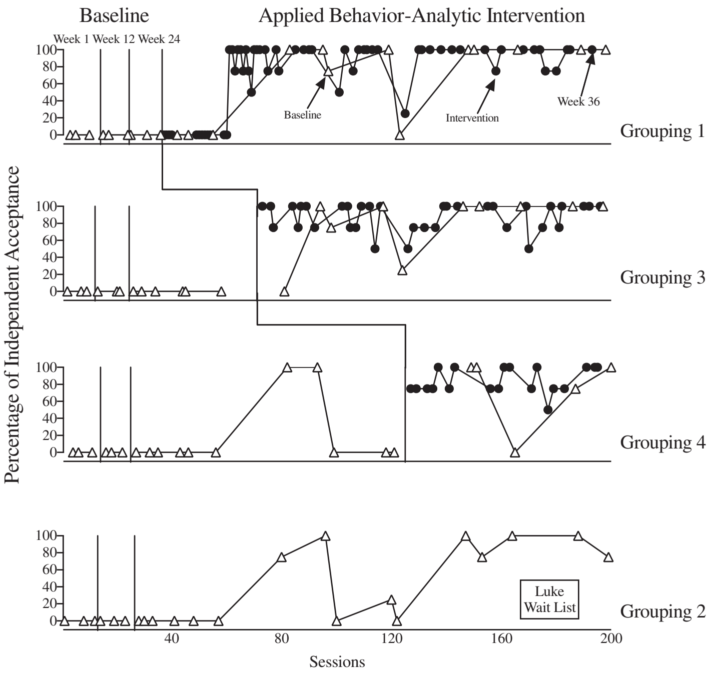

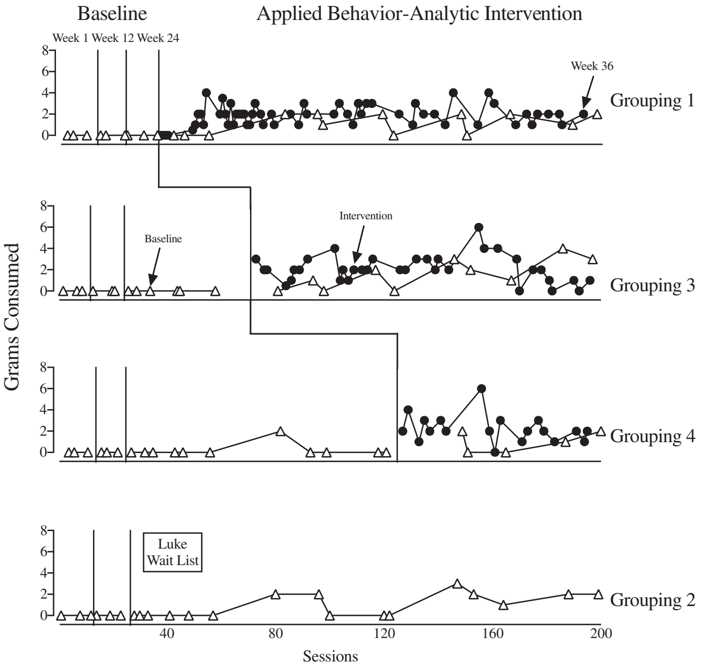

Figure 6. Percentage of independent acceptance (top) and grams consumed (bottom) across food groupings for Luke (wait list group).

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inappropriate mealtime behavior per minute were 54% (range, 0% to 100%), 2 (range, 0 to 6), 54% (range, 0% to 100%), and 6 (range, 0 to 25), respectively, during the applied behavior analytic intervention with food Groupings 4, 1, and 2. Means for percentage of independent acceptance, grams consumed, percentage of mouth clean, and inappropriate mealtime behavior per minute were 32% (range, 0% to 100%), 0.9 (range, 0 to 4), 21% (range, 0% to 100%), and 8 (range, 0 to 55), respectively, during the baseline sessions of the multielement comparison.

Figure 4 displays percentage of independent acceptance (top) and grams consumed (bottom) for Terry for food Groupings 1 (top), 2 (second), 3 (third), and 4 (bottom). Means for percentage of independent acceptance, grams consumed, percentage of mouth clean (data not shown), and inappropriate mealtime behavior per minute (data not shown) were 4% (range, 0% to 25%), 0.3 (range, 0 to 1), 6% (range, 0% to 25%), and 19 (range, 5 to 30), respectively, across food groupings during the initial baseline check. Means for percentage of independent acceptance, grams consumed, percentage of mouth clean, and inappropriate mealtime behavior per minute were 0, 0, 0, and 6 (range, 3 to 17), respectively, across food groupings during the subsequent baseline check 12 weeks later.

Figure 5 displays percentage of independent acceptance (top) and grams consumed (bottom) for Morgan for food Groupings 3 (top), 4 (second), 1 (third), and 2 (bottom). Means for percentage of independent acceptance, grams consumed, percentage of mouth clean (data not shown), and inappropriate mealtime behavior per minute (data not shown) were 49% (range, 0% to 100%), 1 (range, 0 to 4), 22% (range, 0% to 100%), and 8 (range, 0 to 31) across food groupings during baseline before intervention. Means for percentage of independent acceptance, grams consumed, percentage of mouth clean, and inappropriate mealtime behavior per minute were 88% (range, 0% to 100%), 2 (range, 0 to 6), 67% (range, 0% to 100%), and 3 (range, 0 to 38), respectively, across food groupings when we implemented the applied behavior analytic intervention. Means for percentage of independent acceptance, grams consumed, percentage of mouth clean, and inappropriate mealtime behavior per minute were 82% (range, 0% to 100%), 2 (range, 0 to 4), 67% (range, 0% to 100%), and 4 (range, 0 to 37), respectively, during the baseline sessions of the multielement comparison.

Figure 6 displays percentage of independent acceptance (top) and grams consumed (bottom) for Luke for food Groupings 1 (top), 3 (second), 4 (third), and 2 (bottom). Means for percentage of independent acceptance, grams consumed, percentage of mouth clean (data not shown), and inappropriate mealtime behavior per minute (data not shown), were 14% (range, 0% to 100%), 0.3 (range, 0 to 3), 11% (range, 0% to 100%), and 24 (range, 0 to 85), respectively, across food groupings during baseline before intervention. Means for percentage of independent acceptance, grams consumed, percentage of mouth clean, and inappropriate mealtime behavior per minute were 79% (range, 0% to 100%), 2 (range, 0 to 6), 92% (range, 0% to 100%), and 3 (range, 0 to 22), respectively, when we implemented the applied behavior analytic intervention for food Groupings 1, 3, and 4. Means for percentage of independent acceptance, grams consumed, percentage of mouth clean, and inappropriate mealtime behavior per minute were 73% (range, 0% to 100%), 1 (range, 0 to 4), 72% (range, 0% to 100%), and 6 (range, 0 to 36), respectively, during the baseline sessions of the multielement comparison.

DISCUSSION

These results show that the applied behavior analytic intervention was effective for increasing

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consumption of a variety of healthy foods among young children with ASD and food selectivity. We observed increases in independent acceptance across 16 healthy, novel, and nonpreferred target foods for the participants initially assigned to the applied behavior analytic intervention group in 12 (Robert), 24 (Morgan), and 32 (Chris) appointments. By contrast, independent acceptance remained at zero for the three participants in the wait-list control group at the 12- (Michael, Terry, Luke) and 24- (Luke) week baseline checks. We observed increases in independent acceptance across 16 healthy, novel, or nonpreferred target foods for two of the participants initially assigned to the wait-list control group in 23 (Michael) and 12 (Luke) appointments when we implemented the applied behavior analytic intervention. Terry, the other participant assigned to the wait-list control group, discontinued participation in the study before we could implement the applied behavior analytic intervention.

We achieved these outcomes with weekly, 1.5-hr appointments for Morgan and Luke. Robert and Michael's level of independent acceptance did not increase until we increased treatment intensity to three appointments (4.5 hr of therapy) per week. Chris had the lowest treatment intensity; he attended appointments approximately every other week. Even with modifications to his intervention, mean independent acceptance across food groupings was 64% after 30 appointments. Chris's caregivers terminated his participation at this point; therefore, we do not know whether levels of independent acceptance would have increased over time. Studies on early intervention have shown that treatment is more effective when delivered early in life, consistently, and with high intensity (Filipek et al., 1999; Howard, Sparkman, Cohen, Green, & Stanislaw, 2005). These studies, however, did not include food selectivity as a target behavior. The results from the current investigation provide preliminary data to suggest that treatment intensity may impact the rapidity and level of behavior change for young participants with food selectivity and ASD. Future researchers should evaluate what intensity of the applied behavior analytic intervention is necessary and optimal to increase diet variety.

Selective eating is a common problem in typically developing infants and toddlers, which often resolves over time without intervention (Babbitt et al., 1994). Although some children may "grow out of" their feeding problem, several studies have shown that some childhood feeding problems persist and may even worsen over time in the absence of intervention (Dahl, 1987; Dahl & Kristiansson, 1987; Dahl & Sundelin, 1992; Schreck et al., 2004). The data from the current study show that the food selectivity of participants with ASD assigned to the wait-list control group did not improve over a 3- (Michael, Terry) or 6- (Luke) month period. We do not know, however, whether their diet variety would have improved had we waited longer. Future investigators might extend the waiting period to determine whether feeding difficulties resolve with more time in the absence of intervention. Suarez, Nelson, and Curtis (2014) sent electronic surveys to parents of children with ASD and food selectivity and found no difference in food selectivity over a 20-month period.

To our knowledge, this is the first randomized controlled trial with a well-defined cohort of participants with ASD and food selectivity that has compared an applied behavior analytic intervention to a wait-list control. The results are important in providing empirical support for the applied behavior analytic intervention for food selectivity in children with ASD. The current study is consistent with the guidelines in the National Standards Project, Phase 2 (National Autism Center, 2017), such that strength of evidence would be high for the applied behavior analytic intervention. That is, we implemented the study with a clearly

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defined cohort of young participants between the ages of 3 and 5, with food selectivity and ASD. A team of experts who were not involved in the study used well-established criteria to diagnose each participant. We included randomization of participants to intervention and control groups to minimize selection bias, and we demonstrated a statistically significant effect between the intervention and control groups. In addition, we demonstrated functional control for our intervention via a multiple-baseline-across-food-groupings design with five participants. We collected reliable data on the dependent variable using direct-observation measurement. We assessed generalization by conducting repeated baseline sessions across food groupings in which we did not conduct the applied behavior analytic intervention. Limitations of the study design included the small number of participants and the absence of blinding for the data collectors. Due to the small sample size, an imbalance of significant factors among the two groups is possible.

The results of the current study are consistent with previous studies on the effects of nonremoval of the spoon and continuous interaction for four of the five participants. Reed et al. (2004) showed that acceptance increased and inappropriate mealtime behavior decreased when feeders implemented nonremoval of the spoon. Continuous interaction was associated with marginal reductions in inappropriate mealtime behavior, tantrums, or both for some participants when combined with escape extinction. Reed et al., however, did not use hand-over-hand guidance. We did not conduct a component analysis in the current investigation; therefore, we cannot determine the contribution of the individual components to the intervention effects.

Nonremoval of the spoon with hand-over-hand guidance and continuous interaction did not result in increases in acceptance for Chris until we added backward chaining for one of the food groupings. Chris allowed the feeder to put the bites in his mouth in the absence of inappropriate mealtime behavior during nonremoval of the spoon with hand-over-hand guidance; however, he did not accept bites independently with consistency. One advantage of using single-case design was that we had the flexibility to modify the intervention if it was not effective for individual participants. One disadvantage, however, is we do not know whether other applied behavior analytic intervention modifications would have been effective for Chris. Future analyses could lead to a technology of prescriptive assessments that would delineate the conditions under which clinicians should use one or a specific combination of applied behavior analytic interventions.

One interesting finding, but a potential limitation of the current study, is that we observed generalization within and across food groupings for many of the participants when we implemented the applied behavior analytic intervention. For example, independent acceptance increased to high levels for Luke for Groupings 4 and 2 after we initiated the intervention for Groupings 1 and 3. Although we eventually needed to implement the intervention with Grouping 4, levels of independent acceptance for Grouping 2 remained high without intervention. Generalization may have occurred because we implemented the intervention across multiple, different foods (i.e., four groupings of four foods for a total of 16 foods per participant). One potential explanation for this finding is that we trained sufficient exemplars such that we observed generalization to groups of foods that we had not exposed to intervention (Stokes & Baer, 1977). We observed a similar outcome in a randomized controlled trial comparing the modified sequential oral sensory approach to an applied behavior analytic approach in the treatment of food selectivity in a group of young children with ASD (Peterson et al., 2016). Future investigators might evaluate how to facilitate generalization further to promote age-typical eating in

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the absence of intervention (Peterson et al., 2016). Finally, we did not assess caregiver satisfaction or acceptability of our applied behavior analytic intervention in the current study. Future researchers should include this critical component to ensure that relevant stakeholders (e.g., parents, teachers) not only accept, but understand the intervention and are willing to continue implementing the intervention after study completion.

Autism spectrum disorders are characterized by impairments in social relatedness and language, and inflexible or repetitive behavior. In addition to the core symptoms of ASD, many children with ASD display co-occurring food selectivity (Ahearn, Castine, Nault, & Green, 2001; Hubbard et al., 2014; Schreck et al., 2004). We know that nutritionally deficient diets are associated with long-term health, behavior, and learning problems in other populations (Grantham-McGregor & Ani, 2001). The current investigation suggests that such effects may be preventable among children with ASD with a multicomponent applied behavior analytic intervention. Importantly, participants consumed zero (Robert) to 14 (Michael) nutritional foods, none of the participants consumed vegetables, participants consumed zero (Robert, Terry, Morgan, Luke) or one (Chris) fruits, and five out of six consumed junk foods. By the end of the study, we had increased five out of six participants' diets by 16 healthy, novel, and nonpreferred foods. Long-term evaluations are necessary to determine whether improvements in the nutritional content of the diet impact the core symptoms of ASD and the long-term health, learning, and behavior of this group of children.

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