Ergonomic Evaluation of the KinderZeat Child Seat in a Preschool Setting

Cornell University
DEA 470 Spring 2002
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May 2002

INTRODUCTION

Several research studies have investigated the design requirements for children's seating. Since children remain seated for long periods of time in school settings, many countries have passed standards which assign school-age children suitable seating (e.g., Japanese Standards Association cited in Hibaru and Watanbe, 1994). Some studies have shown that standards set by the International Standardization for school furniture (ISO, 1979) appear to focus on the wrong dimensions of the child's body when determining the appropriate chair size. Cho (1994) concluded that to improve seated posture and decrease discomfort in Korean children, lower leg length (from the knee down) should be used to determine optimal chair size. Another study done by Hibaru and Watanbe (1994) showed that the Japanese standards for determining chair height for children, based on a calculation between child stature and upper leg (hip to knee) length, resulted in poor posture and increased complaints of lower back pain. Their findings agreed with Cho's, indicating that lower leg length is important in determining appropriate chair height for good posture.

Pre-school children are expected to sit about 30% of their time during school and teenagers, ages 13-18 years old, are expected to sit about 78% of their time. Sitting occupies a large percentage of waking hours at an age when the human body is still in growth (Dillon, 1976). Mandal (1985) noted the importance of furniture specifically designed for a child's body proportions and recommended different sitting postures for different activities. He argued that for some activities an upright posture may be best, but added that it is unrealistic to expect of a child to sit in this way for extended periods of time, especially if the seat is set at an improper height for the child. It is necessary for a seated child to be able to move and change their posture in order to reduce the onset of muscle fatigue, although a chair should not cause so much postural shifting that the child's concentration is impaired (Laville, 1985).

Research conducted on children's posture in ergonomically designed chairs shows only minor improvement in favor of ergonomic seating as compared to ISO standard chairs (Troussior, 1999). Although increased perception of comfort and longer seating time was recorded for ergonomic chairs when compared to the ISO furniture, such improvements were minimal if the ergonomic chair is not properly fitted to the child (Knight, 1999). It seems that

ergonomic seating enhances posture and perceived comfort in long-term studies, though the research is limited to children who are aged five years and older.

The need for specialized children's seating has been recognized for centuries, yet no studies have systematically investigated the effects of ergonomically designed seating on the posture and behavior of younger children (between the ages of three and four years). Pre-school children can sit in a variety of chair designs, but the advantages and disadvantages of different styles remains unexplored. Over the past 150 years there have been two recurrent styles of children's seating: the low chair, which is below the height of an ordinary chair, and the high chair, which raises a child above the seat height of a typical adult (Ollgaard, 2002). These two styles are present in modern children's seating, both in their original form and in new designs. In addition, two other recent designs have been developed to accommodate the seated younger child: the booster seat, and the KinderZeat. These four different design solutions for young children's' seating are as follows:

The low chair - is a scaled version of an adult chair intended to be used with other child-scaled furniture. This type of furniture is commonly found in kindergartens and other preschool settings (Figure 1). The low chair allows the child to easily manipulate and interact with their surroundings. In addition, a chair that is low to the ground decreases the chance of a severe injury if the child were to fall. Although the scale of the chair and furniture may help socialization between a child and his/her peers, it may inhibit child/adult interaction. When to allocate different chair sizes to different sizes children is an issue with these chairs.

Figure 1 Example of low chairs sized for children (Source: Virco IQ - http://www.virco.com/Pages/setL1.htm).

The high chair - raises a child above the normal adult seat height and is used by children from the age at which they can sit up on their own until they outgrow the chair, which is typically around the age of two (Figure 2). High chairs date back to 400 BC and are depicted in

ancient Greek artwork. Today's high chair typically contains a seat with a harnessing device, armrests that support a tray, and sometimes a footrest. High chairs can be built with plastic, wood, or metal frames and also contain fabric and other materials (O'Donnell, 2001).

The main goal of a high chair is to allow a child to engage in activities around an adult-sized table, such as eating or playing games. This may promote positive social interaction between children and adults. Recently, several high chairs have been recalled by manufacturers due to safety issues. These issues include lack of stability and harness-related security as well as the potential hazards of loose parts. Ingress and egress often are beyond the child's control and an adult has to assist.

Figure 2 Example of child's high chair (Source: Moonpie Designs - http://www.moonpiedesigns.com/prices.html)

The booster seat – is a child's seat that is made of either wood or a durable plastic. Normally the booster seat rests upon the seat pan of an adult-sized chair and it may or may not be attached to that chair (Figure 3). The goal of the booster seat is equivalent to that of the high chair: to involve the child in an activity at an adult-sized table. Drawbacks of the booster seat involve its stability regardless of attachment to the base chair. Poor balance or improper fit may result in the child, booster seat, or entire structure tipping over. Ingress and egress often are beyond the child's control and can be difficult because of seat stability, requiring that the child is lifted off the chair.

Figure 3 Example of a child's booster seat. (Source: Cambro Merchandising - http://www.universalequipment.com/cambro_merchandising.htm

The KinderZeat – is an innovative variation of traditional children's seating (see Figure 4). It combines the idea of a high chair with the idea of a low chair. It has a wooden frame with

an adjustable height seat and independently adjustable height footrest. The adjustability of the KinderZeat allows it to accommodate a child from an age when they are able to sit up until they outgrow the chair (typically from around two through fifteen years old). The KinderZeat is produced by Stokke Ltd., a Norwegian furniture company.

According to the chair designer, Peter Opsvik, the KinderZeat's goal is to lift the child up to standard table height while maintaining support, balance, and movement. Guidelines for proper seating are in accordance with the KinderZeat design:

"Working with relaxed upper arms and elbows at about ninety degrees provides comfort and helps maintain straight wrists, which can be beneficial…The work surface should be at a level that places the working height at elbow height" (Sanders & McCormick, 1993).

Figure 4 Example of the KinderZeat. (Source: Stokke Ltd. - http://www.stokkeusa.com/)

The KinderZeat designer's claim is that the footrest is the key to maintaining this support, balance, and movement.

> *"If children are seated in adult furniture, they lose contact with the floor. The solution was to create a chair, which moved the floor up to the children, instead of the opposite approach. The footrest provides the child with the basic stability upon which movement is based" (Stokke Newsletter).*

Research conducted by Mandal (1981), Troussier (1999), and Knight (1999) supports the claim that the use of a footrest should improve the comfort and posture of seated children who use it. Ingress and egress can more readily be under the child's control in the KinderZeat.

RESEARCH OBJECTIVES

The present study was conducted to test the claim that the KinderZeat's footrest provides the "basic stability upon which movement is based" and is essential in "alleviating strain and reducing 'fidgeting". To do this we devised a series of tasks to be performed by young preschool children while sitting in the KinderZeat with the footrest, or without the footrest, a condition equivalent to the child sitting in either and adult chair with or without a booster. Tasks were devised to test the various reach capabilities and also the task persistence of young children sitting in these test conditions. Specifically, the study tested whether:

1. Use of the KinderZeat with footrest improves the maximum reach distance of young children across a horizontal tabletop.
2. Use of the KinderZeat with footrest improves the convenient reach distance of young children across a horizontal tabletop.
3. Use of the KinderZeat with footrest improves children's task persistence at a boring task performed on a horizontal tabletop.
4. Use of the KinderZeat with footrest improves the postural stability and reduces distracting fidgeting in young children working at a horizontal tabletop. More fidgeting may indicate greater discomfort and possibly greater postural strain.

METHODS

Subjects

All subjects were between three and four years old, and were attending the Cornell University Early Childhood Program, located on the campus in Martha Van Rensselaer Hall, Cornell University. Children were selected based upon age, normal motor ability, and their interest in performing the required tasks. A total of 21 test trials was conducted with 19 children: two children were allowed to repeat the study at their request and 6 children chose not to complete both sets of experimental tasks. Consequently, complete data on both sets of trials were available for 13 subjects. All subjects voluntarily participated in all aspects of this study.

Experimenters

All class members served as experimenters. All had successfully completed the University's Human Subjects training prior to conducting the study.

Apparatus

Two KinderZeats were used: one with an adjustable footrest (see Figure 5) and one without the adjustable footrest, along with collapsible tables (33.5 inches square and 27.5 inches high). The height and depth of the chairs were set according to the age based settings specified in the manufacturer's instructions sent with the chair. Two identical paintings of the solar system were made for use in the maximum reach task (see Figure 6). Two identical long boxes with their tops decorated as ladders and with coin slots cut every half-inch (spanning a ladder 17 inches long) were made for the convenient reach task (see Figure 7). Two identical boxes of colored pegs and several colored cups were used for the sorting task. All experimental sessions were videotaped with identical VHS videocameras (Hitachi) each mounted on a tripod. All tasks were performed on the tabletops. All distances were measured with a tape measure. A checklist was used to record subject's fidgeting and postural stability during the sorting task.

Figure 5 KinderZeat with footrest

Figure 6 Solar System (Maximum Reach Task)

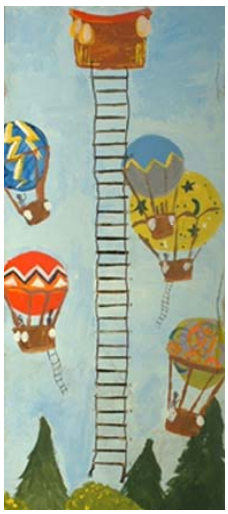

Figure 7 Box with slots (Convenient Reach Task)

Experimental Tasks

Subjects performed the following tasks:

1. Maximum seated reach task. Maximum reach is the farthest distance that can be reached by extending the arm from the shoulder.

2. Convenient seated reach task. Convenient reach is the farthest one can reach while maintaining the ability to manipulate an object while seated.
3. Task persistence, postural stability and fidgeting. A simple sorting task was used to occupy subject's attention while their postural stability and fidgeting were recorded on prepared checklists. Colored pegs mixed in a large tub were manually sorted by color into each of 4 cups. The task was timed to measure task persistence.

Procedure

Testing was conducted in the classrooms of the Cornell Early Childhood Program located in Martha Van Rensselaer Hall, Cornell University. Prior to any data collection, the experimenters received instruction on how to work with young children from the Director of the Center and visited the daycare center before beginning research to become familiar with the space and materials that would be used. Experiments took place inside the classrooms during daycare hours. Experimenters worked in groups of 2-3 per test session. Children were recruited by being asked if they wanted to play some games with the researchers. The games took place amid the activities of other children, leading to more recruits and spectators, but not halting the activities in the preschool.

At the beginning of each session, the distance between the KinderZeat and the tabletop was measured by asking the child to stand up on the footrest while an experimenter moved the table towards the child until it slightly touched their thighs. The location of the chair and table was marked by placing a piece of masking tape on the floor in front of the chair and table legs for later reference. The two KinderZeats (with foot rest and without footrest) were alternated as starting chairs for each child. A video camera was placed on a tripod close to the chair and table such that the entire seated child was captured from a right-hand side profile. Taping began as the child entered the chair.

The entire experiment consisted of three separate "games." The rocket ship game tested for maximum reach. The coin slot game tested for convenient reach. The sorting task that was used tested for task persistence, postural stability and fidgeting. These "games" were always administered in the same order in each test condition. Once seated, the child was asked if they would like to play the first game. If they said "yes", then the maximum reach task was performed. If they responded "no", the experimenter continued speaking with the child until s/he felt comfortable enough to continue or decided to withdraw from the experiment.

For the maximum reach task the painting of the solar system was placed flat on the table with the edge matching up with the edge of the table closest to the child. A tape measure was centrally placed on top of the painting, such that 0 inches was flush with the edge of the table closest to the child. The child was asked to place one hand over the other (middle fingers lined up) and then asked to pretend that his/her hands were a "rocket ship." S/he was then asked to reach out as far as s/he could along the tape measure three times. The distance from the starting line (the edge of the table) to the tip of his/her middle fingers was recorded. Note: it was most desirable that the child remained seated in order to get an accurate reach distance, however, many children propped themselves up in order to reach farther.

The child's convenient reach zone was measured by placing the front edge of the coin slot box (with a maximum possible convenient reach of 17 inches) at the point of the child's maximum reach distance. The child was asked to insert coins in every slot, beginning from the one closest to them and ending with the farthest one they could comfortably reach. The number of the last hole was recorded. The task was performed three times.

Task persistence, postural stability and fidgeting were measured by timing and observing performance on a color sorting task. The task was intentionally designed to be tedious, but not daunting, to see how long children would perform a task and how much they fidgeted. A bin of colored pegs (four different colors) was set out before the child along with corresponding colored cups. The child was asked to place each peg into its corresponding colored cup (red pegs in red cups, green pegs in green cups, etc.). A three- minute time limit was imposed. Any indicators of postural discomfort, fatigue, adjustment, restlessness, or fidgeting were recorded on a prepared checklist. Additionally, the length of time the child worked on the task uninterrupted was recorded, as was the number of times the child asked when the task was going to be over.

The child's dismount off of the KinderZeat and entrance onto the next KinderZeat was videotaped. The entire procedure was repeated again using the alternate chair. The distance from the table to the second chair was held constant by the use of the masking tape marks previously laid out on the floor to implement the placement of the chair.

After all three tasks were completed in both seats (KinderZeat with footrest and KinderZeat without footrest), the experimenter(s) thanked the child for a marvelous job, acknowledging that s/he has helped tremendously. The experimental arrangement was reset for the next subject. See Appendix A for a more detailed outline of the test procedure.

Data Analysis

All distance data, measured in inches, and counts of fidgeting and of postural stability indicators were entered into a computer and analyzed in the Statistical Package for the Social Sciences (SPSS v.11). Differences between the two test conditions: with footrest (F) and without footrest (NF), were tested. For the maximum reach task two measures were tested: the average values of the 3 maximum reach distances per child per condition, and the maximum value of the maximum reach distance per child per condition. For the distance measures this testing was done using paired sample t-tests. For the counts of fidgeting and stabilization movements this was done using a Wilcoxon Matched Pairs signed ranks test.

RESULTS

Maximum Reach Distance

There was a significant difference ($t = 2.681$, $df = 12$, $p = .020$) in the average of the maximum reach distances for the three trials between the two conditions (see Figure 8**)**. For seat F this distance was 25.3 ± 0.8 inches and for seat NF it was 21.5 ± 1.4 inches. Using only the greatest reach values for each child, the difference between conditions remained significant ($t = 2.314$, $df = 12$, $p = .03$), and the average of these maximum reach distances for seat F was 26.9 ± 1.0 inches and the mean distance for seat NF was 21.5 ± 1.8 inches.

Convenient Reach Distance

There was no significant difference for either the average or maximum convenient reach distances between the two seating conditions. For the average of the three convenient reach distance trials per child, the mean distance for both seat F and for seat NF was 16.4 ± 2.4 inches. For the maximum of any convenient reach distance per child the mean distance for seat F was 176 ± 1.7 inches and the mean distance for seat NF was 16.1 ± 0.9 inches.

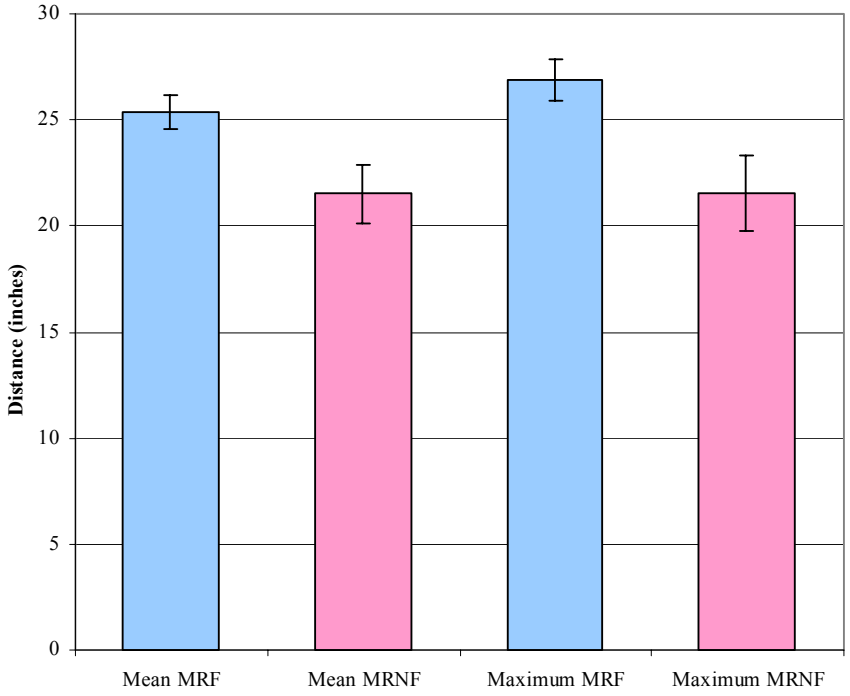

Figure 8 Distance vs. Seat Condition for Maximum, Maximum Reach and Mean Maximum Reach (MRF – Maximum Reach with Footrest; MRNF - Maximum Reach without Footrest)

Task Persistence, Fidgeting and Stability

There was no significant difference for task persistence measures between the two groups. The mean duration on task performance for seat F was 108.0 $\pm$ 21.9 seconds and for seat NF this was 116.7 $\pm$ 22.5 seconds.

Initially, a count of each subject's total distracted behaviors was used to determine whether or not this was influenced by the presence of a footrest (see Table 1). The videotapes were also reviewed to obtain a count of the physical movements made by the subjects in each test condition. Upon analysis it was noted that many of the movements constituted body stabilization movements rather than fidgeting. As a result, fidgeting and stabilization movements were analyzed separately. The Wilcoxon test showed a statistically significant difference between the the seat F and NF conditions for the number of fidgeting movements ($Z = -2.719$, $p = 0.007$) and the number of stabilizing body movements ($Z = -2.680$, $p = 0.007$: see Figure 9).

	Footrest	No footrest
Turns head away from task	8	10
Eyes wander around room	9	4
Inquires about stopping, moving, or doing something else	4	2
Verbal complaint (negative statement about task or personal physical state)	0	2
Change in physical position to ways that will not benefit performance	7	17
Stopping task prematurely	2	2

Table 1 Total number of distracted behaviors observed in each test condition.

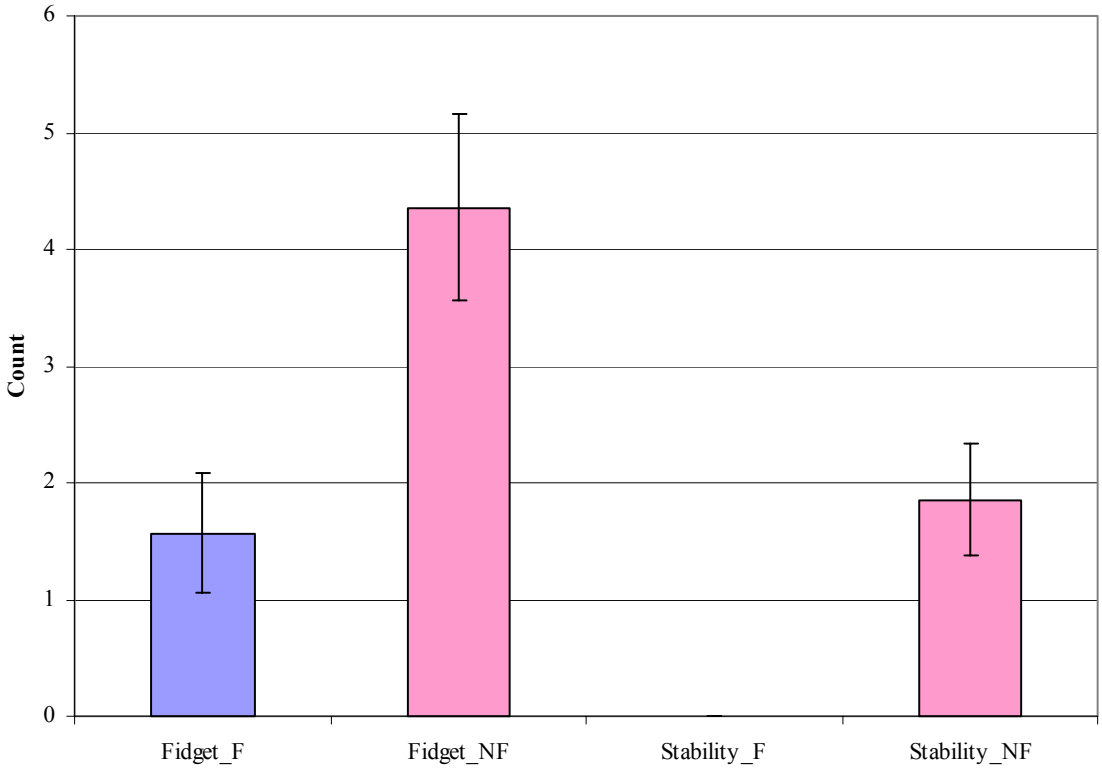

Figure 9 Number of fidgeting and body stabilization movements for each seat condition

DISCUSSION

This study found a significant effect of using the KinderZeat footrest on the young child's maximum reach distance. The presence of the footrest allowed children to both squat and stand, helping them reach further on the table. For the average maximum reach distances for 3-4 years old children the use of the footrest added 3.8 inches to the reach distance and for their greatest maximum reach the use of the footrest added 5.4 inches to this distance. Children could reach further with the footrest present, probably because it helped provide additional support and stability. When no footrest was present children had no obvious place for their feet to rest and were unable to reach as far on the test table. The reduction in maximum reach probably occurs because of the difficulty of stabilizing the body with unsupported feet.

The presence of the footrest did not significantly influence the average and maximum convenient reach distances as measured by the coin slot game. Since the children were sitting down to perform this convenient reach task, they did not need to use to the footrest to help them reach further. Also, some problems in the data collection phase might have affected these results. It was difficult to explain to the young children that the goal of the game was to put the penny coin in the farthest slot, and many children were content with just putting the penny in any slot. Sometimes, it was difficult to measure the exact distance of the slot from the edge of the table, as the box had to be moved between trials. Additional convenient reach studies should be conducted to ensure there is no relationship between the different chair conditions and convenient reach tasks.

The task persistence data showed no statistically significant difference between the footrest and no footrest conditions. Children did not spend any more time pursuing the sorting task in either condition. Many confounding variables may have been present in this portion of the study that could have influenced this result. Children were asked to perform the task twice, and they might have become bored or fatigued the second time around. Although the order of testing of the chairs was counterbalanced, many children ended the task early the second time around, which indicates a possible practice effect with the sorting task. Further studies of task persistence should be conducted to evaluate possible differences between the footrest and no footrest conditions.

The results from the fidgeting data show a statistically significant difference between the two chair conditions, indicating that fidgeting was much more common in the no footrest condition. The footrest was used to provide additional support by the children, which resulted in less overall fidgets and movements. When children sat in the chair with no footrest, they seemed to move more because they had less support for their body, resulting in fidgeting as they tried to get comfortable while performing the task. The body stabilization results between the two conditions also showed a statistically significant difference. Children moved more in the no footrest condition because they were trying to stabilize their lower bodies by wrapping their feet around the chair legs or trying to use the small cross bar beneath the seat, whereas in the condition with the footrest they had a place to rest their feet.

The results of this study clearly show the importance of good foot support for the seated child. The differences found resulted from comparing the same chair design with or without the footrest. However, one problem with the no footrest condition tested is that children tried to find something else to stabilize their bodies and with this chair design they succeeded, and this would not be true had they been sitting in a booster seat. In the no footrest condition many children were able to use the reinforcement bar at the bottom of the chair to stand on to help them perform the tasks, which helped to improve their maximum reach performance. Children also used the reinforcement bar beneath the seat to stabilize themselves. In the footrest condition some children stood on this to complete the reach tasks. Finally, the classroom environments in which the testing occurred proved to be very distracting to the young children, possibly affecting they responded to the various tasks.

In conclusion, this study shows that the KinderZeat with its footrest does help improve the young child's maximum reach distance, their body stability when seated and also reduces the amount of fidgeting. In this testing it did not influence the convenient reach distances or task persistence. Additional research is needed to investigate the how body postures are influenced by the KinderZeat for children performing a range of activities. It would also be interesting to test children at different ages, to see what results the footrest and no footrest would have on various age levels. The research conducted thus far has shown that the KinderZeat with a footrest does help improve children's functioning while sitting, and it opens doors for future exploration in these concepts of ergonomic seating for children.

APPENDIX A: DETAILED PROCEDURES

1. Set up one KinderZeat and one table, out of direct eyesight of the rest of the waiting subjects where possible. Have the second KinderZeat nearby. The two seats should be adjusted to the same height and depth, however one of the KinderZeats should have a footrest and the other should not.
2. Affix the Maximum Reach posters to the tables with tape, aligning the zero line with the edge of the table facing the chair. Make ready the data sheets, Fidgeting Checklists, pen, blocks, cups, slot box and coins.
3. Place a camera at each station such that the participants are recorded in profile, from approximately elbow height when seated, and at a zoom percentage that captures the entire child's body and movements yet retains detail.
4. The experimenter welcomes the child into the area, introducing him or herself. Invite the child to join you at the table to play some games. The recorder writes comments on the child's approach and entry of the chair.
5. Ask the child to stand on the footrest, and slide the table up to the child's body. Then ask the child to sit.
6. Mark the floor with tape where the legs of the table are located and the back of the KinderZeat's legs are located. *(NOTE: for every other child, begin with no footrest instead of footrest.)*
7. Begin the maximum reach task: ask the child to pretend his or her hands are a rocket ship, and to reach out with both hands as far as he or she can, straight out. At the furthest reach of the child's hands, make a mark and write the child's initials next to it. Record the distance from the starting line (the edge of the table) to the mark AND THE UNITS OF YOUR MEASUREMENT. Note: it is desirable that the child remains seated; if he or she stoops or stands, disregard the measurement and ask him or her to repeat the reach. Repeat this task for a total of 3 measurements, having the same person read the measurements each time.
8. Next, the Convenient Reach activity: place the box in front of the child such that the last slot is at his or her furthest Max Reach mark and the row of holes proceeds toward the child. Ask the child to put the coins into the holes in the box, starting with the closest one and working

his or her way outward. Record the number of the last hole the child could effectively reach. Repeat for a total of 3 trials.

9. Then the Task Persistence observation: replace the box and coins with a bin of mixed colored items and four cups (red, yellow, green and blue). Ask the child to sort the items into the cups by color. This bin of colored items should be sufficiently large such that the child will not be able to sort all of the items in a three-minute period. Observe the child while he or she is sorting, and record any indicators of discomfort, fatigue, restlessness, or fidgeting as per the Fidgeting Checklist. Also record the amount of time the child continues working on the task uninterrupted. If he or she works the entire three minutes, stop the child and record three minutes. *At the two minute mark, tell the child that he or she will have to stop soon, to play a different game.*
10. Ask the child to dismount the KinderZeat and replace it with the other KinderZeat. Make sure the chair and tables are put back in the same place as before, according to your tape marks on the floor.
11. Reset the props for the maximum reach activity and repeat as above, so that each child performs all 3 tasks in a seat with a footrest and a seat without a footrest. Record data for the second round on the appropriate data sheet, making sure that the measurements are recorded on the same numbered line and with the same initials as the first sheet.
12. The experimenter should then thank the child for playing, and direct him or her back to the classroom. Record the child's dismount of the KinderZeat.
13. When all of the data have been collected, stop the video cameras and save the grid papers. Put away all the supplies in their proper places (or in the designated spot for the next group of experimenters).
14. Report any troubles with the experiment or important findings to the other members of the class so that they may have enough time to make changes as necessary.
15. Analyze the data. Compare each child to him or herself.
16. Plot these data and complete statistical computations as necessary. Does the presence of a footrest improve the overall ability of the children to reach, manipulate objects, and pay attention to tasks?
17. Re-examine the video tape(s) to further observe the children's movements, postures, and use of the chairs. Do the KinderZeats encourage good posture? Why or why not?

ACKNOWLEDGEMENTS

We thank all of the children who participated in this study. We gratefully acknowledge the help and encouragement of Elizabeth Stilwell, Director of the Early Childhood Center at Cornell University. We thank Stokke Limited for their support for this research study.

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