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# Evaluating a Computer Flash-Card Sight-Word Recognition Intervention With Self-Determined Response Intervals in Elementary Students With Intellectual Disability

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A concurrent multiple-baseline across-tasks design was used to evaluate the effectiveness of a computer flash-card sight-word recognition intervention with elementary-school students with intellectual disability. This intervention allowed the participants to self-determine each response interval and resulted in both participants acquiring previously unknown words across all word sets. Discussion focuses on the need to evaluate and compare computer flash-card sight-word recognition interventions with fixed and self-determined response intervals across students and dependent variables, including rates of inappropriate behavior and self-determination in students with intellectual disability.

*Keywords:* computer-based flash-cards, word reading, elementary school, intellectual disability



Flash-card instruction has been used to enhance sight-word acquisition, automaticity, and maintenance among students with intellectual disability (Browder & Lalli, 1991; Browder, Wakeman, Spooner, Ahlgrim-Delzell, & Algozzine, 2006; Nist & Joseph, 2008). Because students who can read commonly used words automatically (e.g., accurately and quickly) have more available cognitive resources (e.g., attention and working memory), flash-card instruction may allow for greater passage comprehension (Browder et al., 2006; Daly, Neugebauer, Chafouleas, & Skinner, 2015; Tan & Nicholson, 1997). A series of stimulus–response–stimulus (S–R–S) learning trials are typically applied during teacher-led flash-card instruction (Albers & Greer, 1991; Yaw et al., 2012). Students are presented with the word (stimulus) and given time to read the word (response interval). The teacher then provides another stimulus that can serve as immediate feedback (e.g., merely reading the word aloud), which ends the S–R–S trial. In some instances, students repeat the word immediately after they hear it read aloud (S–R–S–R trial). This postfeedback responding may enhance learning because it increases correct responding rates and the probability that their final response to the printed word is correct (Browder & Xin, 1998; Skinner & Smith, 1992; Yaw et al., 2014).

Researchers have developed several strategies designed to address the primary limitation

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of teacher-led flash-card instruction: the 1:1 student-to-teacher ratio. Working with students with disabilities, some researchers have examined small-group instruction with classmates observing each other participating in flash-card learning trials. Across two studies (Hanely-Maxwell, Wilcox, & Heal, 1982; Orelove, 1982), researchers found that all students learned words they were taught directly and that some students did not learn any words that they observed peers being taught (incidental learning). While some did learn incidental words, across both studies, all students learned more words that were taught via direct flash-card instruction. Another limitation associated with small-group incidental learning is that it can also be difficult to develop a pool of words that all students have not acquired. Even if this is accomplished, because all students will not acquire words simultaneously, students may be directly or indirectly exposed to learning trials targeting words they have already learned. Numerous researchers have found that applying instructional time to learned words, as opposed to unknown words, reduces learning rates (e.g., Forbes et al., 2013; Joseph & Nist, 2006; Mulé, Volpe, Fefer, Leslie, & Luiselli, 2015; Nist & Joseph, 2008).

Computer flash-card programs have been used to enhance sight-word acquisition (accurate word reading), automaticity (e.g., accurate responding within 2 s), maintenance (e.g., over summer break), and/or generalization (e.g., to hand-printed flash-cards and passages) in students with intellectual disability, autism, and specific learning disability in reading (Baumgart & VanWalleghem, 1987; Hilton, Hopkins, Skinner, & McCane-Bowling, 2011; Kodak, Fisher, Clements, & Bouxsein, 2011; Yaw et al., 2011, 2012). Computer flash-card reading (CFR) instruction may address many of the limitations associated with teacher-led individual and small-group flash-card instruction. CFR can require little teacher time and may allow educators to maximize learning with individual instruction targeting idiosyncratic words and using flow-list procedures (i.e., when a student learns a word, it is removed from flash-card interventions and replaced with unknown words) to prevent students from spending instructional time on learned words (Skinner, 2008; Yaw et al., 2014).

## Setting Computer-Based Response Intervals

One challenge associated with CFR instruction is establishing the appropriate response interval, or the amount of time students have to respond to each computer flash-card (Yaw et al., 2014). With teacher-led S–R–S flash-card instruction, after the initial word is presented, the response interval, or time between the first and second stimulus, is malleable and can be controlled by the teacher. If the student responds quickly, the teacher can provide immediate feedback and increase learning trial rates by rapidly moving to the next flash-card. More immediate feedback and faster paced learning trials can enhance learning per trial and learning speed (Hawkins, Skinner, & Oliver, 2005; Kulik & Kulik, 1988; Riley, 1986; Robinson & Skinner, 2002; Skinner, Fletcher, & Henington, 1996; Yaw et al., 2014).

Although briefer response intervals can allow for more immediate feedback and faster paced trials, brief intervals do not always provide sufficient time for students to respond (Riley, 1986). Because increasing active, academic responding can enhance learning, intervals that are too brief may reduce responding and decrease learning (Belfiore, Skinner, & Ferkis, 1995; Ferkis, Belfiore, & Skinner, 1997; Greenwood, Delquadri, & Hall, 1984; Skinner et al., 1996). Across individuals, there are several factors that may impact the time needed to respond, including processing speed (Lobier, Dubois, & Valdois, 2013), reading skill development (Shapiro, 2011), and previous reading instruction (e.g., phonemic instruction vs. whole-word instruction; see Yaw et al., 2012).

Within-student factors may explain why researchers comparing CFR interventions with different response intervals have found idiosyncratic effects. For example, working with two students with intellectual disabilities, Black et al. (2016) compared word acquisition across three CFR computer programs that employed different response intervals (1, 3, and 5 s). Results for one student showed a linear relationship between response intervals and word acquisition. Specifically, the student learned nine 5-s words, seven 3-s words, and five 1-s words. However, the other student showed no clear differences in learning as a function of response interval. Yaw et al. (2014) compared word acquisition across two CFR interventions that employed either a 1-s or 5-s response interval and found no consistent differences in words acquired per session.

Within-student learning may be enhanced when response intervals are varied across words. For example, a student may only need a brief response interval (e.g., 1 s) to read a short, commonly used word that he or she has previously acquired but failed to maintain (Yaw et al., 2014). The same student may need more time to respond (e.g., 3 s) to a longer word that was never acquired, is phonetically regular, and is in his or her expressive vocabulary—and an even longer response interval (e.g., 5 s) may be required if the longer word is phonetically irregular and not in his or her expressive vocabulary.

One solution to this problem of setting fixed computer-based response intervals is to let each student self-determine each response interval. Turnbull et al. (2016) altered typical CFR procedures so that after the word first appeared on the screen (first stimulus), an adult postsecondary student with intellectual disability merely pressed the space bar when she was ready (response interval) to hear the correct reading of the word (second stimulus). This alteration allowed the student more time to respond when needed (e.g., when she attempted to decode the word on the screen). When she responded rapidly, this alteration allowed for more immediate feedback and more rapid pacing, both of which have been shown to enhance learning (Kulik & Kulik, 1988; Yaw et al., 2014). Turnbull et al. (2016) found that the adult student quickly acquired words through this computer flash-card program with self-determined response intervals.

Turnbull et al. (2016) noted several limitations of their study. There was only one participant—an adult learner enrolled in a postsecondary program for students with intellectual disabilities—who was highly motivated and had previously participated in CFR instruction with fixed, brief intervals. The current study was designed to replicate and extend this research to children with disabilities who report having no prior experience working with computer flash-card sight-word reading programs. Specifically, a concurrent multiple-baseline across-tasks (i.e., word sets) design was used to evaluate the effects of a CFR program with self-determined response intervals on sight-word acquisition in two elementary students with intellectual disability.

## Method

### Participants, Setting, and Materials

Two students with intellectual disability attending an elementary school in the southeastern United States participated in this study. The primary researcher completed some practicum assignments in the teacher's classroom, during which she indicated that these two students were struggling with reading. The teacher also stated that the students were receiving at least 1.5 hr/day of phonemic-based instruction, and she asked the experimenter if she could help them acquire commonly used words. She informed the researcher that the students only had about 10 min/day available to work on learning these words. Mark was a 12-year-old fifth-grade student, and Susan was a 9-year-old third-grade student. Both of these students are Caucasian and spend a majority of their academic day in a cognitive development classroom (CDC). When asked, neither student reported having experience using computer-based flash-card reading procedures.

Prior to beginning the study, informed consent was obtained from the teacher, the principal, the school district institutional review board, a university institutional review board, the students' parents, and the participants. Both students assented to participate. Based on advice received from educators at the school, we did not seek informed consent to review or report specific test scores; however, the school psychologist indicated that both of these students qualified to be in the CDC at their school. To qualify for the CDC, students must meet the following criteria: an adaptive home and school standard score below 70, a cognitive standard score below 70, and an achievement score below the 5th percentile on response-to-intervention measures. One of the school system professionals reviewed each student's file and confirmed that both students met the aforementioned criteria.

Procedures were conducted at a table in the back of the students' classroom. To construct assessment flash-cards, an experimenter used a wide, felt-tip black marker to hand-print words on unlined, white 3 × 5 index cards. Instructions provided by Hopkins, Hilton, and Skinner (2011) guided the creation of the CFR programs using Microsoft PowerPoint and a laptop computer.

## Design, Dependent Variable, and Procedures

A concurrent multiple-baseline across-tasks (i.e., three mutually exclusive word sets of 10 unknown words) design was used to evaluate the effects of the CFR intervention on sight-word acquisition. While accurate responding is the focus of acquisition, responding correctly only one time is not considered acquisition (Haring & Eaton, 1978). In response to a flash-card, a variety of reasons could account for a student stating the correct word without actually reading the word correctly (e.g., guess, repeating a remembered word numerous times). Thus, for the current study, a word was considered acquired when it was read correctly within 3 s across two consecutive assessment sessions. This operational definition, which is consistent (i.e., they had 2- to 3-s time limits and required consecutive correct responses) with that of previous researchers who evaluated the effects of interventions on sight-word acquisition rates, prevents researchers from drawing spurious conclusions and prevents practitioners from assuming that a word was prematurely acquired and subsequently ceasing instruction on that word (Black et al., 2016; Cazzell et al., 2016; Forbes et al., 2013; Ryan et al., 2016; Taylor et al., 2016; Turnbull et al., 2016; Yaw et al., 2014). After a student acquired 8 of 10 words (80%) from a word set, the intervention was applied to another word set.

**General procedures.** This study included three phases: pretest, baseline, and intervention. Sessions were conducted with one student at a time and were scheduled during classroom rotations between 10:30 and 11:00 a.m. 3 days/week. Some sessions were canceled because of absences, school closings, and scheduling conflicts.

**Assessment procedures: Pretesting and baseline.** Pretesting assessments were used to identify a pool of unknown words. Each student started with a different set of 60 flash-card words. Based on teacher reports and informal assessments (i.e., oral reading fluency measures administered by the teacher), the words for Mark were obtained from a fourth-grade Dolch word list (Dolch List—Fourth Grade, n.d.) and the words for Susan were selected from a list of sixth-grade Dolch words (Sixth Grade Sight Word List, n.d.). During assessments, words hand-printed on index cards were presented in random order for no more than 3 s. The student was instructed to try his or her best to read each word correctly within 3 s. This process was repeated during the following session. If a word was read correctly within 3 s on either pretesting day, the word was considered known. Pretesting yielded 39 unknown words for Mark and 31 unknown words for Sarah. The primary experimenter used stratified (based on the number of letters in each word) random assignments to develop three mutually exclusive 10-word sets (see Appendix A). Baseline-phase data were collected by administering all 30 target words, 10 from each set in random order. Each baseline assessment was conducted on a separate school day, and procedures were identical to those used during pretesting.

**Computer-based flash-card reading procedures.** For each student, a CFR intervention was created for each of the three sets of 10 unknown words. Each of these 10 unknown words was presented in random order three times during each intervention session; therefore, each student completed 30 CFR S–R–S–R learning trials each session. Prior to the first intervention, the primary experimenter taught each student to use the CFR program. The following instructions from Turnbull et al. (2016) were used:

> We are going to have you read some words today with a computer program. When you are ready, press the space bar to see your first word. When the word appears, attempt to read the word to the best of your ability. After you read the word, press the space bar to hear the word read aloud to you. Upon hearing this word read aloud, repeat the word before pressing the space bar to move on to the next slide. Do you have any questions?

After these instructions were read, each student was presented with a training CFR session containing three PowerPoint slides. The first slide contained the word *START*, and the student was instructed to press the space bar to begin. Their respective names were on the next slide, which the students always read correctly. The last slide contained the word *coyote*. The word *coyote* was not included in the 30 unknown target words, and both students had failed to read this word correctly during pretesting. Thus, each student had a practice trial with both a known and an unknown word, which allowed them to press the space bar to hear the word being read aloud and repeat the word after they heard the recording. Additionally, they learned to press the space bar again to display the next word.

Immediately after completing this single brief training, the intervention for each student began with his or her respective Set A words. Before beginning the intervention, each student was told that the 10 words in the intervention may be difficult for them to read and that they should try their best because they would have multiple opportunities to read the words. During the intervention, the program always began with the *START* slide displayed on the laptop. The student then pressed the space bar to progress through the word set. If a student paused for more than 10 s, an experimenter prompted the student to continue working through the program (e.g., "press the space bar to hear the word"). The students completed each intervention program during each session.

After completing each intervention program, each student was assessed across all 30 words. Assessment procedures were the same as those used during baseline. A word was considered acquired when it was read correctly within 3 s across two consecutive assessments. After acquiring eight (80%) words in a set, the students were told that they were starting with a new set of unfamiliar and potentially challenging words.

### Treatment Integrity and Interobserver Agreement

The primary experimenter used a checklist to guide her procedural integrity and to record notes on any additional prompts (see Appendix B). A second experimenter independently recorded procedural integrity across 50% of the intervention sessions and words read accurately within 3 s across at least 50% of the assessments for each phase (pretesting, baseline, intervention, and maintenance). Results showed 100% procedural integrity across all sessions, and neither experimenter ever noted the delivery of any additional prompts. To calculate the percentage of interobserver agreement per session, the number of agreements on words read correctly was divided by the number of agreements plus disagreements on words read correctly and then multiplied by 100. Each student spoke clearly, and interobserver agreement was 100% for each session during which interobserver agreement data were collected.

## Results

Repeated-measures graphs illustrating the number of words that Susan and Mark acquired across phases are provided in Figures 1 and 2. Across all three word sets, Susan read one Set B and one Set C word correctly, only one time each during baseline, but did not acquire (i.e., read correctly within 3 s across two consecutive assessments) any words during baseline. After the CFR intervention was applied, Susan quickly acquired words across each word set, meeting the criteria for each set (8 of 10 words acquired) after three sessions. The rapid increase in words acquired following the application of the CFR intervention to those words and the failure to find concomitant increases in words assigned to word sets that were still in baseline provide evidence that the CFR intervention, as opposed to some other threat to internal validity, caused the increase in words acquired.

Susan acquired one additional Set A word after the intervention was withdrawn from Set A and applied to Set B. Acquisition required correct responding within 3 s across two consecutive assessments, indicating that Susan did respond correctly to this word following the final application of the intervention to Set A words. Therefore, this one-word increase may be indicative of a treatment effect as opposed to learning caused by some other threat to internal validity. Susan continued to read all acquired Set A and B words correctly and within 3 s after the intervention was withdrawn from those word sets.

During baseline, Mark read zero Set A words correctly, seven Set B words correctly, and 11 Set C words correctly; however, across the three word sets, Mark did not acquire any words during baseline (see Figure 2). Mark required five sessions to meet the criteria (8 of 10 words acquired) for Set A but only three sessions for Sets B and C (80%). The rapid increase in words acquired following the application of the

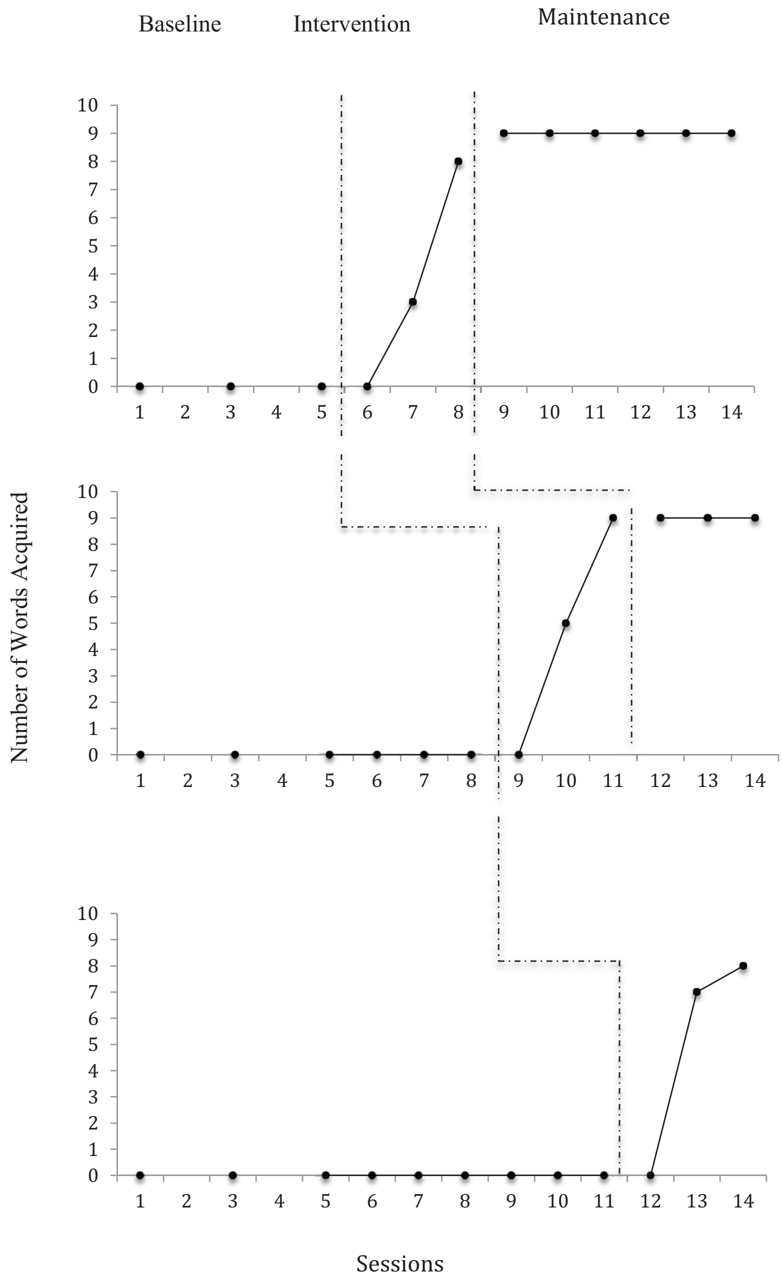


*Figure 1.* The number of words Susan acquired and maintained across phases and sessions.

intervention to those words and the failure to find concomitant increases in words assigned to word sets that were still in baseline provide evidence that the CFR intervention caused the increase in words acquired.

With Mark, initial intervention-phase data and maintenance-phase data suggest that not all learning could be contributed to the CFR intervention. During the first intervention session, Mark acquired three words (two Set B words

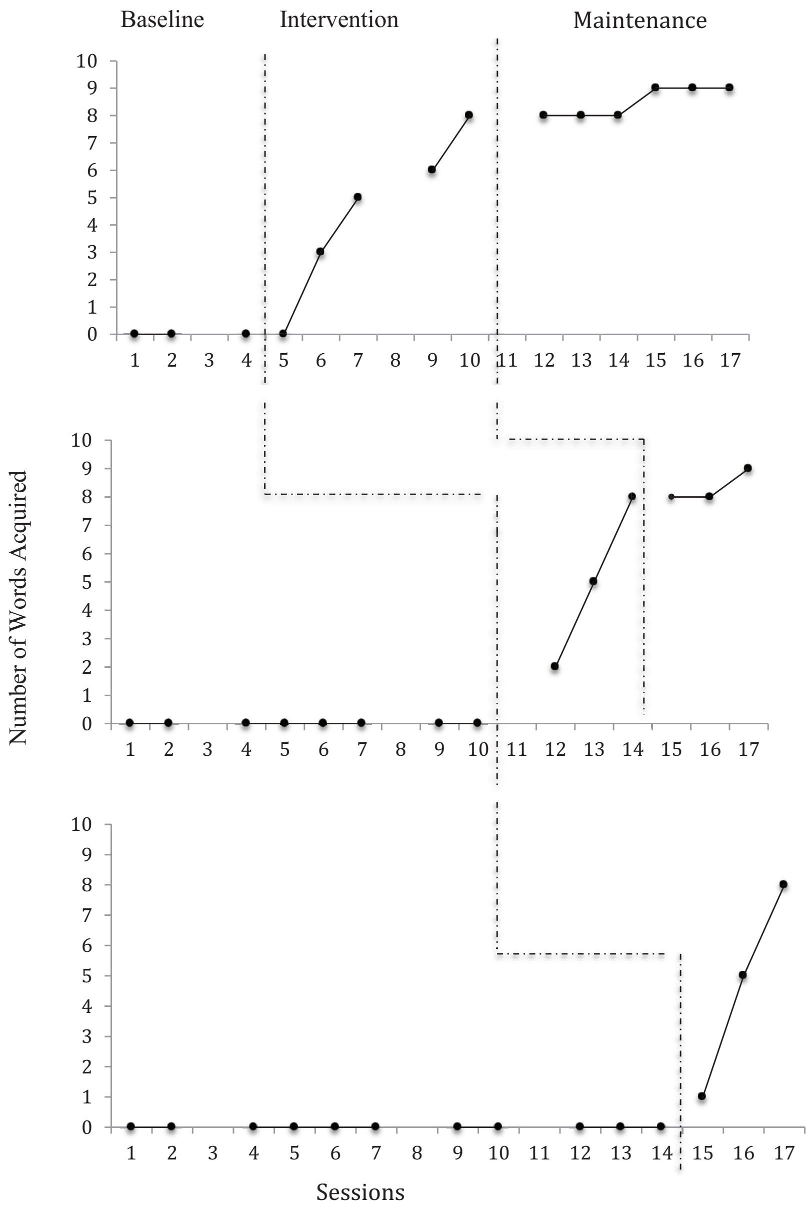


*Figure 2.* The number of words Mark acquired and maintained across phases and sessions.



and one Set C word). Because words were only considered acquired when they were read correctly within 3 s across two consecutive assessment sessions, these data indicated that some learning may have occurred during baseline. Also, Mark acquired one additional Set A word and one additional Set B word after the intervention was withdrawn from those sets and applied to another word set. These small increases in word-reading performance may have been caused by testing effects (e.g., learning caused by the repeated baseline and maintenance assessments), carryover effects (e.g., learning some earlier set words helped him acquire words), and/or history effects (e.g., activities outside experimental procedures such as his regularly scheduled reading instruction). These small increases are not enough to account for the rapid and large increases in word acquisition following the application of the interventions. Like Susan, Mark maintained (i.e., continued to read correctly and within 3 s) all Set A and B words after the intervention was withdrawn from those sets.

## Discussion

The purpose of the current study was to determine if a CFR program with self-determined response intervals would enhance sight-word acquisition in two elementary students with intellectual disability. Across all three word sets, neither Susan nor Mark acquired any words during baseline, but they did rapidly acquire words after the intervention was applied. Thus, the current study provided six demonstrations of a treatment effect, and the across-phase, across-series comparisons (i.e., the failure to find concomitant increases in words still in baseline) suggest that the CFR intervention, as opposed to some other threat to internal validity, can account for most of the increases in sight-word acquisition. Maintenance-phase data illustrate that students were able to continue to read words within 3 s after the intervention was withdrawn and applied to another word set. These results are consistent with those of previous research conducted with an adult student with intellectual disability (Turnbull et al., 2016).

Because the current results suggest that CFR procedures may be effective when elementary students with intellectual disability self-determine each response interval, future researchers should conduct additional studies designed to extend this research. Susan's and Mark's baseline-phase data and Susan's maintenance data suggest that the current study was not contaminated by threats to internal validity. Although the teacher indicated that no additional supports or changes in instruction were provided to Mark, during maintenance, Mark acquired one Set A word and one Set B word. These increases suggest that some of Mark's learning may have been caused by repeated assessments (i.e., testing effect), learning outside experimental conditions (e.g., history effect), and/or carryover effects where learning words from other word sets may have helped him acquire previously targeted words. While these effects were small (i.e., only two words), future researchers may want to investigate these potential confounds, as their findings could have applied implications. For example, researchers may find that learning some words enhanced Mark's ability to acquire other words, which may have implications for how word sets are formed and how words are sequenced for instruction.

Because researchers did not record the time students spent engaged in the CFR instruction, this study does not allow one to calculate learning speed (e.g., the number of words learned per cumulative instructional minute). As CFR interventions can be effective when the students are provided brief (e.g., 1 to 3 s) response intervals (see Black et al., 2016; Forbes et al., 2013; Yaw et al., 2014), future researchers should compare CFR interventions with self-determined response intervals and brief, fixed response intervals across different populations. Such studies should include a measure of cumulative instructional time so that researchers can identify which intervention causes the most rapid learning (Skinner, 2010; Yaw et al., 2014).

Another limitation was that students were assessed immediately after each CFR intervention, which means that our acquisition data may have been artificially inflated by assessing immediately after students heard words being read correctly. To address this concern, words were only considered acquired when they were read correctly across two consecutive sessions. Additionally, during maintenance phases, students read acquired words that had not been modeled for days and weeks. Thus, our maintenance data (100%) mitigate this concern.

In the current study, students were able to self-determine each response interval and intertrial intervals (i.e., the time between the completion of one S–R–S–R trial and the beginning of the next trial). Neither student ever escaped working on the task by pausing for more than 10 s. Students may not have paused because of reactive arrangements—the experimenter was sitting next to each student monitoring his or her behavior as he or she completed the CFR intervention. Also, the ability to choose response and intertrial intervals may have contributed to this behavior. Previous researchers have found that providing choices can reduce incompatible inappropriate behavior (e.g., Dyer, Dunlap, &

Winterling, 1990). Future researchers should consider conducting comparative effectiveness studies to determine if allowing students to choose response intervals reduces undesired behaviors and enhances student acceptability of CFR interventions. Although researchers initiated and monitored all CFR sessions, the CFR program should allow students to complete the program independently. Researchers could develop more sophisticated computer programs that allow them to collect relevant data (e.g., average response intervals, number of trials completed) needed to conduct additional studies in which students are taught to use the program but allowed to use it when and how they want, without prompting or monitoring. For example, researchers could determine whether students are more likely to choose to engage in CFR interventions when they have the opportunity to self-determine response intervals.

In this study, only isolated word reading was measured. Although previous researchers have found evidence that flash-card sight-word instruction can cause increases in passage reading accuracy and passage comprehension (Tan & Nicholson, 1997), future researchers should evaluate whether CFR generalizes to reading words in text and comprehension of printed text (see Cuvo & Klatt, 1992; Turnbull et al., 2016). Our maintenance data were also limited. Future researchers should determine if words acquired during the CFR intervention are maintained over longer periods of time (e.g., over the summer; see Yaw et al., 2012). Additional external validity limitations could be addressed by running similar studies across participants (e.g., students with attention disorders, students with slow processing speed) and target words (e.g., words with phonetic irregularity, more difficult words).

To prevent drawing spurious conclusions, acquisition was defined as reading a word correctly within 3 s across two consecutive assessments. Across a total of 18 baseline assessments, Susan read two words correctly: one Set B word and one Set C word. Across 22 baseline assessments, Mark read 18 words correctly (seven Set B words and 11 Set C words) but never read the same word correctly across two consecutive baseline-phase assessments. These baseline data, especially Mark's, support the beliefs of those who suggest that acquisition should never be based on a single accurate response (Haring & Eaton, 1978) because to do so may cause educators to cease instruction prematurely and introduce unwanted variance that hinders researchers' interpretation of acquisition data. Future researchers should conduct additional studies examining how operational definitions of acquisition affect measures of acquisition and automaticity development or speed, maintenance of acquired words, and variability across these different measures of learning (Yaw, 2012).

As they are developing, students with intellectual disability may have fewer opportunities to make choices than general education students, which may hinder their development of self-determination skills and sense of autonomy (Wehmeyer & Garner, 2003). During the CFR intervention, students self-determined response intervals 59 times in each session. Researchers should evaluate the effects of the current intervention and similar academic interventions that occasion high rates of choice on students' self-determination skills and behavior. Such studies may show that CFR interventions with self-determined intervals do more than enhance academic skills; they may provide a mechanism for promoting self-determination and enhancing autonomy in students with intellectual disability (Wehmeyer, Palmer, Lee, Williams-Diehm, & Shogren, 2011).

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(*Appendices follow*)

## Appendix A

### Word Sets

Please note that acquired words are in italics.

**Sarah**

Set A: *sign*, *heir*, *thigh*, *align*, *fright*, benign, *hydrant*, *polygon*, *hydrogen*, *incision*
Set B: *myth*, *dough*, cycle, *admire*, *system*, *rhythm*, *cyclone*, *antonym*, *moveable*, *quotient*
Set C: cyst, *pedal*, *lymph*, *ought*, *resign*, *coarse*, foreign, *campaign*, *patience*, *admirable*

**Mark**

Set A: *bit*, *bend*, *felt*, *lift*, *shut*, *till*, creek, *knock*, *stood*, *broken*
Set B: *cap*, *busy*, *lead*, *seat*, *soap*, *brick*, *early*, *march*, sweep, *center*
Set C: hid, *chin*, *leaf*, *seem*, *suit*, cause, *fresh*, *shook*, *trade*, *course*

## Appendix B

### Experimental Integrity Checklist

1. ______ The experimenter set up a work area containing a laptop and three chairs.
2. ______ The experimenter instructed the student to sit in his or her chair of choice.
3. ______ The student was instructed that upon pressing the computer space bar, words would appear on the screen. Upon pressing the space bar a second time for each slide, the words would be read aloud. The student was told to press the space bar again to move on to the next slide.
4. ______ The student then proceeded by pressing the space bar.
5. _______ The student attempted to read the word, pressed the space bar, and repeated the word again after hearing it read.
6. ______ After the intervention was completed each day, the experimenter got out a pile of flash-cards.
7. ______ The student was instructed to read the words on the flash-cards to the best of his or her ability. If he or she did not read the word within 3 s, it would be read aloud to him or her.
8. ______ The student went through the flash-cards as the experimenters recorded correct and incorrect responses.
9. ______ Upon completing the flash-cards, the student returned to his or her classroom tasks.
10. ______ After the student completed the CFR procedures, the experimenters compared their data sheets, checking for interscorer agreement and treatment integrity.

*Tally each 10-s prompt delivered: ______________.

Note any additional prompts that may have been needed: ____________________________

________________________________________________________________________________

________________________________________________________________________________

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