The rehabilitation of verbal operants following acquired brain injury

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Abstract
Although verbal deficits are major concerns for individuals following an acquired brain injury (ABI), behavior-analytic research on language training in neurorehabilitation settings is extremely limited. The purpose of the current study was to systematically replicate the work of Sundberg et al. (1990) in which the authors evaluated the acquisition and functional interdependence of verbal operants for adults following ABI. We used slightly modified procedures (e.g., inclusion of high preference activities, progressive prompt delay) and compared acquisition rates of tacts, mands, and intraverbals with three adult ABI survivors. We also assessed if directly training one verbal operant led to the emergence of untrained, topographically similar verbal operants. Contrary to Sundberg et al., we found mand training was successful for all participants and led to the greatest amount of transfer under tact conditions, and we offer potential explanations for our differing results.
In his analysis, Skinner (1957) proposed the loss of functional relationships for ABI survivors might be due to injuries affecting specific classes of stimulus-response relations and not others. Researchers have since utilized identity and nonidentity matching tasks to identify affected classes of stimulus–response relations (Leicester et al., 1971; Sidman, 1971; Sidman et al., 1971). Identity tasks involve the same sample and comparison forms (e.g., spoken letter to spoken letter) while nonidentity tasks involve different sample and comparison forms (e.g., spoken letter to written letter). Sidman (1971) hypothesized nonidentity tasks to be more vulnerable to disruption for individuals with aphasia. In addition, Baker et al. (2008) presented a behavior-analytic conceptualization and taxonomy for aphasia based on Skinner’s (1957) analysis of verbal behavior. Baker et al.’s taxonomy is a departure from the traditional psycholinguistic model of language (based on form and grammatical structure; LaPointe, 2005) and allows for empirical research on the function-based treatment of aphasia and other verbal deficits following ABI.

In addition, Skinner (1957) explained verbal deficits observed in ABI survivors through functional independence of verbal operants—in which a unique antecedent and consequence maintain each verbal operant—suggesting a learned response may not necessarily result in the emergence of other verbal operants without direct training under specific control. Researchers have demonstrated functional independence of verbal operants in several studies including children with (e.g., Hall & Sundberg, 1987; Kelley et al., 2007) and without developmental disabilities (e.g., Lamarre & Holland, 1985).

On the other hand, researchers have also been successful in demonstrating functional interdependence with both typically developing children (e.g., May et al., 2016; Rosales et al., 2011) and individuals with developmental disabilities (e.g., Finn et al., 2012; May et al., 2013; Wallace et al., 2006). Functional interdependence involves the emergence of one verbal operant (e.g., tact) after another (e.g., mand) is directly trained. Efficient language training procedures are of great importance in neurorehabilitation settings due to varied access and rising cost of rehabilitation in the United States (Ashley, 2016). Wallace et al. (2006) found functional interdependence of operants was more likely to occur if the operants directly trained included high preference (HP) items for three adults with intellectual disabilities. The authors also suggested that the lack of transfer in previous studies might be due to an absence of the establishing operation (EO) because the studies were not evaluating HP items or contriving strong conditioned EOs.

Most studies evaluating behavior–analytic procedures to teach weak or missing verbal operants have been conducted with individuals with developmental disabilities or young children. However, Sundberg et al. (1990) evaluated the interdependence of verbal operants with two, adult male ABI survivors to assess (a) which verbal

socially significant skill deficits within a population in which behavior–analytic research has been limited (Heinicke & Carr, 2014). Further investigation may also demonstrate differences between two populations (i.e., naïve vs. previously competent speakers) and add to the literature of functional independence and interdependence of verbal operants. Adding to these lines of literature may lead behavior analysts to develop more efficient verbal behavior programming to facilitate interdependence in neurorehabilitation settings.

The purpose of the current study was to replicate and extend the Sundberg et al. (1990) investigation by addressing a few limitations and incorporating more recently evaluated language-training procedures utilized for individuals with developmental disabilities. First, we modified tact training to include a 3-item array to promote conditional discrimination as recommended by Green (2001). Second, mand training included HP activities rather than arbitrary household items used in Sundberg et al., which may have resulted in weak EO control. Previous studies found emergence of mands after tact training for HP items (e.g., Gilliam et al., 2013; Wallace et al., 2006), which may be why direct tact training for failed mand targets was necessary for one of two participants in Sundberg
et al. Third, we included a progressive prompt delay rather than the constant 5-s delay used by Sundberg et al. in all verbal operant training conditions to avoid errors early in training. Finally, we defined the amount of trials in training sessions and mastery criteria and held these variables constant across conditions and participants.

2 | METHOD

2.1 | Participants

The university’s Institutional Review Board approved all recruitment and experimental procedures described below. Mac was a 26-year-old man, seven years post injury, diagnosed with a traumatic insult injury resulting from a skateboarding accident. Mac was in a coma for three weeks after his injury, and he was prescribed Keppra during the course of the study but had been seizure free for one year. He reported receiving speech and occupational therapy (OT) in the past. Dee was a 29-year-old woman, 2 years after injury, diagnosed with a severe traumatic impact injury and aphasia resulting from a motorcycle accident. Dee scored a three on the Glasgow coma scale (i.e., the minimum score on the scale indicating deep coma or a brain-dead state) at the time of her injury and was in a coma for 24 weeks. Her medications at the time of the study included Keppra, Baclofen, and Nuedexta, and she reported receiving past physical therapy (PT) services. Charlie was a 32-year-old man, 13 years after injury, diagnosed with a nontraumatic brain injury and aphasia resulting from a brain hemorrhage secondary to a brain tumor and was in a coma for 4 weeks. His medications at the time of the study included Vimpant, Onfi, Zoloft, and Propanalol, and he reported receiving OT, PT, and speech therapy in the past.

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A trained observer or video camcorder was present during all sessions for interobserver agreement (IOA) and procedural integrity purposes.

We conducted approximately 2–3 experimental visits each week, and each visit lasted no longer than 2 h including 5–10 min leisure breaks provided after every training session. The duration of training sessions varied based on type. Tact, mand, and intraverbal training sessions averaged 2 min and 9 s, 9 min and 2 s, and 2 min and 6 s in duration, respectively. The total time commitment for each participant ranged from 13 to 17 weeks (including follow-up sessions), and we compensated participants for their time with a $50 gift card after the last follow-up session.

3 | MATERIALS

We divided nine items related to participants’ preferred activities identified via pre-experimental assessments (described below) into three sets for each participant, and we presented these items during some sessions (e.g., mand training) and not others (e.g., intraverbal training). For example, if a participant’s preferred activity was listening to music from their smart phone and a charger was the targeted item for tact training, an uncharged (or “dead”) phone was also present during transfer probes under mand conditions. See Table 1 for a list of activities and targeted items for each participant (full list of additional items per activity available from the corresponding author). The treatment room or partitioned area also contained one table and chairs for the participant, experimenter, and one additional data collector. Additional materials necessary for data collection included a video camcorder, data sheets, clipboards, and a pen.
3.1 | Experimental design and dependent measures

We utilized a concurrent multiple-baseline design across behaviors (i.e., verbal operants; Cooper et al., 2007) to control for historical and maturational confounds across the replication of treatment effects. The dependent measures were consistent with Sundberg et al. (1990) and included the percentage of correct responses during probe and training conditions and the number of training sessions required to meet the mastery criterion for each set. When one verbal operant was placed under training conditions for a particular set, we conducted transfer probes for the other two verbal operants for that set every third training session.

A correct response was scored if the participant’s response was independent and corresponded with the item being tested, which included responses that were preceded by statements such as “Ahh, let’s see, that’s a…”, or “Oh yeah that’s a…”, similar to Sundberg et al. (1990). An incorrect response was recorded if any other responses were emitted first or if responses were emitted in the wrong order (e.g., “album photo” for the response “photo album”). A prompted response was recorded if correct responses occurred following the experimenter’s echoic prompt.

### Table 1

**Assignment of high preference activities and associated targets to sets per participant**

<table>
<thead>
<tr>
<th>Set (Verbal Operant)</th>
<th>Mac</th>
<th>Associated target item</th>
<th>Dee</th>
<th>Associated target item</th>
<th>Charlie</th>
<th>Associated target item</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 (Tact)</td>
<td>Listening to Charger</td>
<td>Looking at old</td>
<td>Photo album</td>
<td>“Scattergories”</td>
<td>Timer</td>
<td>Preferred activity</td>
</tr>
</tbody>
</table>

3.2 | Pre-experimental procedures

Unlike the Sundberg et al. (1990) investigation, participants in the current study were exposed to a series of pre-experimental procedures to determine whether participants had the necessary prerequisite skills to participate (e.g., scanning an array of three stimuli during tact training), as well as to confirm deficits in tact, mand, and intraverbal repertoires. Additionally, to promote transfer across verbal operants, we included HP items based on the results of a preference assessment. We conducted pre-experimental procedures in the order in which they are described below.

3.3 | Discrimination assessment

After obtaining consent, we conducted the Assessment of Basic Learning Abilities – Revised (ABLA-R; DeWiele et al., 2011) to assess participants’ discrimination abilities. We used this assessment to guide our selection of the most appropriate modality (e.g., tangible, pictorial, verbal) in which to present stimuli in subsequent paired-stimulus preference assessments, because past research suggests that the discrimination skills in ABLA-R correspond to those needed to make meaningful choices in alternative modality preference assessments. For
example, Heinicke et al. (2013) found that verbal preference assessments were successful for brain injury survivors who passed Level 6 of the ABLA-R. The ABLA-R consists of six levels that are organized in a hierarchical manner. These levels include a simple imitation task (Level 1), two-choice positional discrimination (Level 2), two-choice visual discrimination (Level 3), two-choice visual match-to-sample discrimination (Level 4), two-choice auditory-visual discrimination (Level 5), and two-choice auditory-visual combined discrimination.

3.5 | Preference assessment for activities

Participants and caregivers were asked to complete a reinforcer survey developed by the authors (available from the corresponding author) to develop a list of participants' preferred activities. We then assessed the top 12 nominated activities (e.g., watching TV, board games, crossword puzzles) in a paired-stimulus preference assessment (Fisher et al., 1992) to identify a hierarchy of these activities. We conducted preference assessments using a verbal modality for all participants to decrease the length of the assessment as they all scored at Level 6 on the ABLA (Heinicke et al., 2013). Although we assessed a total of 12 activities, we only included the first nine highly or moderately preferred activities in training to promote interdependence of mands in tact and intraverbal training conditions (Wallace et al., 2006). That is, we assigned the top three activities to the mand set to increase the likelihood that the EO was high for these items. We also excluded the three least preferred activities and randomly assigned the remaining six activities to tact or intraverbal sets.

3.6 | Target item identification and assignment

The experimenters and research assistants developed lists of items related to the preferred activities identified for each participant. Similar to Sundberg et al. (1990), we assessed participants' verbal repertoires for these listed items until we identified one item per activity for which the participant could not emit the tact, mand, or intraverbal response. For example, for the HP activity of crossword puzzles, a pencil was presented in the tact condition, while a crossword puzzle, clues, and instruction, "Write in the answers in a way that you can erase it" were provided in the mand condition, and the verbal description of a pencil was presented in the intraverbal condition. Therefore, each mand, tact, and intraverbal set included three target items yielding a total of nine target items used during training (see Table 1).

During this phase, correct, incorrect, and no responses (i.e., failure to respond within 5 s) resulted in a neutral statement and presentation of the next trial. If the participant responded correctly on any trial, we removed that item from the experimenters' list and tested the next item. For the tact condition, the experimenter presented the instruction, "For this activity, I am going to point to an item, and I want you to tell me what it is." The experimenter then presented an array of three items, which were counterbalanced in the left, center, and right positions across trials, and pointed to the target item while asking, "What is it?" per trial. For the mand condition, the experimenter presented the instruction, "For this activity, I'd like you to complete activities. If you are missing any items you need to complete the activity, tell me what you need and I'll give it to you." The experimenter then presented the preferred activity (e.g., crossword puzzle and clues) related to the item being tested, while keeping the target item (e.g., pencil) out of the participant's sight per trial. For the intraverbal condition, the experimenter presented the...
phase as baseline (i.e., they only included two baseline data points for each set), we conducted a separate baseline condition to meet the requirements of a concurrent multiple-baseline design. That is, we presented the three target items in a set three times each in a random order within a baseline session for a total of nine trials. Baseline trials were conducted in the same manner as the “Target Item Identification and Assignment” phase. Baseline sessions continued until data were stable.

4.2 | Training probes

Similar to Sundberg et al. (1990), a first-trial probe was conducted for each target in a set (i.e., a total of three trials) before each training session, in which correct responding to the first-trial probe resulted in social praise (and the delivery of the target item in mand trials). If a participant correctly responded to all three targets in a set during first-trial probes, the experimenter terminated the session and training did not occur. Any incorrect responses on first-trial probes resulted in a neutral statement and initiation of a training session.

We conducted transfer probes at the beginning of every third training session and immediately after mastery of a set to assess for transfer to the untargeted operants. Transfer probes consisted one trial for each of the three target items for a set, and we conducted these probes under the two untrained verbal operant conditions, yielding a total of six trials. For example, if tact training included a pencil, eraser, and clues, these three items were probed once under mand and intraverbal conditions every third training session. All responses resulted in neutral feedback and presentation of the next trial.

4.3 | Verbal operant training

Treatment began with tact training, followed by mand training, then intraverbal training to replicate Sundberg et al. (1990). Mand and intraverbal conditions, respectively, did not begin until mastery of the previous set. Trials in all three training conditions were presented in the same manner as described in “Baseline,” with the addition of echoic prompts, a progressive prompt delay, and programmed consequences. Our progressive prompt delay, opposed to the constant 5 s prompt delay used by Sundberg et al., progressed from 0 to 3 to 5 s. To increase the prompt delay, participants were required to correctly respond across six consecutive trials (or respond correctly to the prompt in the 0-s delay for six trials), similar to Shillingsburg et al. (2016). The experimenter regressed to the previous prompt delay if participants responded incorrectly or did not respond.

4.4 | Abolishing operations probe

We conducted an abolishing operation (AO) probe for each target (i.e., three trials) immediately after mastery of mand training sets to assess for appropriate EO control (Shillingsburg et al., 2014), which was not assessed by Sundberg et al. (1990). The AO session was conducted in a similar method to that of training (i.e., same instruction and presentation of materials); however, the missing item was provided to the participant along with the training stimuli at the beginning of each trial.
4.5 | Follow-up

We conducted a follow-up assessment 2–3 weeks after participants met mastery criteria for a set to assess the maintenance of the verbal operant directly trained as well as transfer to the untrained operants, which also was not assessed in the previous study (Sundberg et al., 1990). Each target in a set was tested once under tact, mand, and intraverbal conditions, for a total of nine trials in a follow-up session. These trials were presented in the same manner as first-trial probes, but incorrect responses did not initiate a training session.

4.6 | Interobserver agreement

A secondary observer collected data in vivo or via video recordings for a minimum of 33% of sessions to assess IOA. The point-by-point method (Kazdin, 2011) was used to calculate IOA, and the definition of an agreement depended on the type of experimental session being conducted. For paired-stimulus preference assessment sessions, an agreement was defined as both the experimenter and secondary observer recording the same selection for a trial. For the ABLA-R, the VBAB, and tact, mand, and intraverbal probe, baseline, and training sessions, an agreement was defined as the experimenter and secondary observer both recording a correct, incorrect, or nonresponse for a trial. Agreement for pre-experimental procedures, baseline, and training sessions averaged 100%, 99.7% (range: 89%-100%), and 100%, respectively.

4.7 | Procedural integrity

5 | RESULTS

Results of verbal operant training for Mac, Dee, and Charlie are depicted in Figures 1–3, respectively. Tact, mand, and intraverbal conditions are represented in the top, middle, and bottom panels across experimental conditions. Participants' performance during first-trial probes and training for each set is depicted in the top portion of each panel, while performance during transfer probes for each set is depicted in the bottom portion of each panel. Performance is consistent across all participants and conditions during the initial phase due to the zero-correct criterion used to progress to baseline (described above in “Target Item Identification and Assignment”). Participants' performance during baseline remained low across conditions with the exception of Set 2 for Charlie. Charlie reported contacting two of the experimental stimuli (i.e., remote and bowl) outside of training sessions; therefore, we replaced the items for which he was correctly manding with new items using the zero-correct criterion before initiating training in his second panel.

Mac (Figure 1) met mastery criteria for tact training after seven training sessions by responding 100% correct across two consecutive training sessions. He responded with an average of 11% and 22% correct under mand and intraverbal conditions, respectively, for the transfer probes in Set 1. Mac's performance
decreased under tact conditions during follow-up (i.e., 67% correct), while he responded 0% and 67% correct under mand and intraverbal conditions, respectively. Mac met mastery criteria for mand training after 14 training sessions by responding 100% correct across two consecutive first-trial probes. He responded an average of 47% and 0% correct under tact and intraverbal conditions, respectively, for the transfer probes in Set 2. Mac responded 33% correct during the AO probe, in which he continued to emit the response for two of the three targets. Mac withdrew from the study before intraverbal training could be completed due to the declining health of his caregiver; however, he completed seven training sessions, with his last three sessions including two first-trial probes at 100% correct responding. He responded an average of 34% and 17% correct under tact and mand probes, respectively, for the transfer probes that were completed for Set 3 before his withdrawal.

Dee (Figure 2) met mastery criteria for tact training after 31 training sessions by responding 89%–100% correct across two consecutive training sessions. She responded with an average of 15% and 30% correct under mand and intraverbal conditions, respectively, for the transfer probes in Set 1. These responses did not maintain during follow-up, in which Dee responded 33% correct across all conditions for Set 1. Dee met mastery criteria for mand training after 25 training sessions by responding 100% correct across two consecutive first-trial probes. She responded with an average of 44% and 22% correct under tact and intraverbal conditions, respectively, for the transfer probes in Set 2. Dee’s performance also declined during follow-up for these responses, in which Dee responded 0% correct across all conditions. Dee required 36 sessions of intraverbal training to meet mastery
TABLE 2  Summary of results

<table>
<thead>
<tr>
<th>Number of sessions to mastery</th>
<th>Average % correct across transfer probes</th>
</tr>
</thead>
</table>

Note: Average performance of the patients across transfer probes for each condition.

First Trial Probe
- Tact
- Mand
- Intraverbal

Set 1 Transfer Probes
- Set 1 Tact Training
- Set 1 Mand Training
- Set 1 Intraverbal Training

Set 2 Transfer Probes
- Set 2 Tact Training
- Set 2 Mand Training
- Set 2 Intraverbal Training

Dee.

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Table 2 summarizes the results for Mac, Dee, and Charlie. Overall, the differences in the average training sessions to meet mastery criteria per condition were negligible. That is, on average, participants required a similar number of training opportunities to relearn “lost” tacts, mands, and intraverbals. However, the total training time to meet mastery differed across conditions. Participants took the least amount of time to relearn tact \( (M = 44 \text{ min}) \) and intraverbal \( (M = 46 \text{ min}) \) targets, while participants required more than twice the amount of training time \( (M = 153 \text{ min}) \) to relearn mand targets. In addition, we observed the most emergence of untrained verbal operants under tact conditions after either training type (i.e., mand or intraverbal), followed by moderate levels of emergence of mands, and the lowest levels of emergence of intraverbals.

6 | DISCUSSION

The purpose of this study was to add to the limited literature on the rehabilitation of verbal operants following ABI. We evaluated if we could replicate Sundberg et al.’s (1990) findings after including more recent language-training methods used for individuals with developmental disabilities (e.g., use of HP items, errorless learning, a 3-item array during tact training). More specifically, we aimed to determine (a) which “missing” verbal operant (i.e., tacts, mands, or intraverbals) would be relearned first through direct training, and (b) whether ABI survivors would demonstrate functional independence or interdependence of verbal operants following training.

Participants in Sundberg et al. (1990) relearned tacts and intraverbals with the least number of training sessions, and only one of the two participants acquired “lost” mands. One participant (Charlie) in the current study

<table>
<thead>
<tr>
<th>Participant</th>
<th>(total training time in min)</th>
<th>Tact training</th>
<th>Mand training</th>
<th>IV training</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Tact Mand IV Tact Mand IV Tact IV</td>
<td>Tact IV Mand</td>
<td>Tact IV Mand</td>
<td></td>
</tr>
<tr>
<td>Mac</td>
<td>7 (15) 14 (149) 7(^a) (12)</td>
<td>11% 22% 47% 0% 34% 17%</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Dee</td>
<td>31 (96) 25 (193) 36 (107) 15% 30% 44% 22% 33% 39%</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Charlie</td>
<td>8 (22) 11 (118) 10 (18) 44% 0% 92% 33% 92% 67%</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>M</td>
<td>15 (44) 17 (153) 18(^a) (46) 21% 21% 56% 18% 46% 41%</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Abbreviation: IV, intraverbal training.
\( ^a \) Intraverbal training was not completed for Mac.
responding to item descriptions—frequently in their natural environments. Future research evaluating procedures
to further strengthen functional interdependence, especially to intraverbal conditions following ABI is warranted.

There are a few explanations as to why participants in the current study performed differently during mand
training compared with the participants in Sundberg et al. (1990). First, we exposed participants to items used in HP
activities throughout all conditions, opposed to the arbitrary household items used in the prior investigation. The
improved responding following this procedural modification supports the claim made by Wallace et al. (2006), in
which functional interdependence may be more likely to occur when training stimuli include HP items. This may be
because during tact training of a preferred item, the EO is present during the emission and reinforcement of the
tact response, which assists in the establishment of a functional relationship between the EO and response
topography.

Differences in prompting and error correction procedures may also explain the contrasting results between the
current study and Sundberg et al. (1990). Sundberg et al. used a constant 5-s delay throughout all conditions, which
allowed participants to make errors early in training. We used a progressive prompt delay with clear progression
and regression criteria, which likely decreased the number of errors to mastery (Walker, 2008). Sundberg et al. also
required participants to respond correctly to all three targets in a row or five transfer trials (e.g., tact-echoic-tact)
for each target before a training session ended, which resulted in participants being exposed to up to 65 trials
within one training session. Instead, we only represented the echoic prompt up to two times before presenting the
next trial, decreasing the trial duration and allowing participants to come into contact with reinforcement sooner.

It should be noted that we observed emotional responding during intraverbal training for Dee, which took her
the greatest number of sessions to meet mastery criteria. Intraverbal training was the only condition that did not
include visual stimuli, and these visual stimuli may have served as additional discriminative stimuli as a result of
contiguous usage (Skinner, 1957) that helped evoke correct responses in Dee's other training conditions. For

Shillingsburg et al., 2014). Although these studies were conducted with children with developmental disabilities, it
may be that embedding AO conditions throughout training with individuals with ABI is necessary to promote
appropriate EO control as well. Second, our verbal operant training procedures differed slightly across panels in our
concurrent multiple baseline design, which is not how this single-case research design is typically used (i.e., the
independent variable is held constant; Kazdin, 2011). Researchers interested in replicating our study should
consider employing an adapted alternating treatments design (Sindelar et al., 1985) to evaluate equivalent sets of
stimuli taught under tact, mand, and intraverbal training conditions.

Third, we defined mastery of a training set as two consecutive sessions at 89%–100% during training or first
trial probes, with one session occurring on another day. Although we attempted to make mastery criteria more
stringent by requiring the second session to occur on another day, our criteria may not have been rigorous enough
to produce maintenance of effects. That is, only one participant (Charlie) was able to maintain responses at 100%
during follow-up. For example, Fuller and Fienup (2018) compared the effects of three differing mastery criterion
levels (i.e., 50%, 80%, and 90%) on the maintenance of spelling and reading sight words with three children with
autism spectrum disorder and found that mastery at a higher performance level was predictive of greater main-
tenance performance. Given the ultimate goal of reteaching of ABI survivors language is to maintain "lost" verbal
operants across differing contexts over time, a 100% correct criterion across several days may be necessary,
particularly given that memory deficits are common in this population.

In addition to addressing the limitations mentioned above, investigators interested in extending the current
study might consider additional procedural modifications. First, researchers might evaluate other mand training
conditions that do not involve the use of an interrupted chain procedure. This procedure likely involves aversive properties that closely resemble survivors’ daily lives, as evidenced by participants’ emotional responding during this phase in both Sundberg et al. (1990) and the current study. The authors reported participants often vocalized statements such as, “Dammit, I know this, dammit” (p. 97). We observed similar responses for all participants in the current study, with participants engaging in statements such as, “Dammit, I’m so stupid” or “I know this one, dammit”, and nonvocal behaviors such as kicking nearby items and crying. Additionally, the requirements of the interrupted chain procedure (i.e., setting up the chain, delivering the missing item, allowing the participant to complete the chain) are likely why the total training time in mand conditions was over twice that of tact and intraverbal training. Identifying less aversive and more efficient mand training is especially important given the cost of rehabilitation (Humphreys, et al., 2013). For example, experimenters could provide access to an item and subsequently block access to the item (e.g., Buckley & Newchok, 2005) or implement tact to mand transfer procedures (e.g., van der Meer et al., 2012; Sweeny-Kerwin et al., 2007). It may be designed to task a mand condition using these procedures as the responses intended to be trained as mands may come under control of discriminative stimuli rather than motivating operations, resulting in faulty stimulus control as reported in a review by Gamba.

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this one live?” while presenting a picture of a fish) followed by intraverbal probes (e.g., “Who lives in the sea?”). The authors’ hypothesized that participants’ use of overt or covert tacts during training may have aided in the generalization of this tactic to intraverbal probe trials, leading to better emergence. We did not include overlapping discriminative stimuli in the current study, thus researchers interested in verbal behavior and brain injury should familiarize themselves with the existing literature base on emergence of verbal operants for other populations to potentially increase the efficiency of language retraining.

Fourth, researchers might also consider further evaluating the VBAB (Gross et al., 2013) for individuals with ABI. Currently, there are no assessment tools evaluating individual verbal operants for this population; therefore, we borrowed the VBAB from the behavioral gerontology literature. Future research could focus on both updating the assessment targets to replace less relevant stimuli (e.g., removing items such as “protractor” and “trellis” that might not be familiar items to young adults) and validating this assessment with ABI survivors using similar methods to Gross et al.

Finally, researchers might consider evaluating the efficacy of teaching problem-solving strategies to ABI survivors who are re-learning language. Mac and Charlie were 7 and 13 years after injury, respectively, at the time of the study, and these participants may have acquired problem-solving strategies during rehabilitation that boosted their reacquisition rates. In comparison, Dee was only 2 years after injury and required the highest number of training sessions. Her caregiver also reported that Dee received very limited rehabilitation services following her injury. Anecdotally, Mac and Charlie would mouth-out or vocalize the beginning letter or syllable of the target item (e.g., “ch-ch-charger”), as well as self-correct using the same strategy (e.g., “ch-ch-no that’s not right, it’s photo album!”). On the other hand, Dee created a specific acronym for the targets in intraverbal training—that is, WMC for “wipes,” “markers,” “charger”—which she substituted for more common labels (e.g., woman, man, child). We consider this a maladaptive strategy, because it would not be helpful in her natural environment where these stimuli will not appear together in repeated trials as presented in training. Problem-solving strategies, such as visual imagery (e.g., Kisamore et al., 2011), and procedural modifications, such as multiple exemplar training (e.g., Allan et al., 2015), could be evaluated to determine whether they assist in the reacquisition and maintenance of verbal operants for ABI survivors.

Although the line of research on reteaching verbal operants to ABI survivors is very small, we would like to
provide a couple of preliminary clinical recommendations for behavior analysts targeting language deficits in neurorehabilitation settings. First, practitioners might consider using HP stimuli along with a progressive prompt delay to increase the likelihood that clients contact reinforcement early in rehabilitation. Second, practitioners might consider using the VBAB to identify a verbal repertoire that may not be as affected to program for the support of weaker ones. For example, if a survivor is able to mand for items, but cannot emit tacts or intraverbals for these items, practitioners may find it beneficial to create scenarios in which items need to be requested.

CONFLICT OF INTERESTS
The authors declare that there are no conflict of interests.

ETHICS STATEMENT
All procedures performed in studies involving human participants were in accordance with the ethical standards of the institutional and/or national research committee and with the 1964 Helsinki declaration and its later amendments or comparable ethical standards.

DATA AVAILABILITY
The data that support the findings of this study are available from the corresponding author upon reasonable request.

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