Listening with Tools: The Intersection of Affordances and Language

A dissertation submitted in partial fulfillment of the requirements for the degree of
Doctor of Philosophy in Psychology

by

Kenneth W. Jacobs

Dr. Linda J. Hayes/Dissertation Advisor

May, 2018
We recommend that the dissertation prepared under our supervision by

KENNETH W. JACOBS

Entitled

Listening with Tools: The Intersection of Affordances and Language

be accepted in partial fulfillment of the requirements for the degree of

DOCTOR OF PHILOSOPHY

Linda J. Hayes, Ph.D., Advisor

Steven C. Hayes, Ph.D., Committee Member

Jacqueline C. Snow, Ph.D., Committee Member

Barbara Kohlenberg, Ph.D., Committee Member

Kenneth W. Hunter, Sc.D., Graduate School Representative

David W. Zeh, Ph. D., Dean, Graduate School

May, 2018
Abstract

Seventeen undergraduates participated in five single-case experiments that investigated whether the provision of handheld tools, to manipulate objects specified by instructions, would facilitate or inhibit instruction following. Participants were presented with stimulus arrays accompanied by either ambiguous or unambiguous instructions. Ambiguous instructions could be interpreted as specifying either of two actions and unambiguous instructions could be interpreted as specifying only one action. The study was designed to test whether tools would constrain participants’ possibilities for action and clarify ambiguous instructions as a result. Experiment 1 showed that tools do not clarify instructions that are ambiguous, as participants emitted more incorrect responses with a tool than with their hands. Experiment 2 strengthened that claim by showing that the structure of stimulus arrays alone did not control the incorrect responding observed when participants wielded a tool in the first experiment. Experiment 3 showed that the emission of incorrect responses with a tool could be remedied with the addition of verbal contextual cues that rendered ambiguous instructions unambiguous. Given unambiguous instructions, correct responses were emitted on all trials with a tool. Experiment 4 was a replication of Experiment 1 with positive results and Experiment 5 tested whether tools that do not constrain possibilities for action would still result in a decrement in correct responses. Experiment 5 showed that when constraints on responding by tools are absent, listeners do not emit the incorrect responses observed in Experiments 1 and four. Altogether these experiments provide evidence that tools that constrain possibilities for action inhibit instruction following unless a speaker’s utterances are fully unambiguous.
To my mother, father, sisters, and brothers.
Acknowledgments

Thank you to each member of the Parrott-Hayes Lab, a witting and familial group to which I am grateful to be a part. Thank you especially to Linda J. Hayes for her guidance and continual support. Linda taught me how to think—not just for myself—but for the community of behavior scientists and all others who might benefit from it. Special thanks are in order for my friend, Zach Morford, for listening to my musings and making me a better person and behavior scientist. Zach taught me how to ask a research question, and his thoughts on this project were invaluable as usual. Andrew Evans, the research assistant with me since the beginning of this project, deserves recognition and thanks for his role in contributing to the design and execution of the experiments herein. Designing stimulus arrays and preparing them for presentation was not a simple task, so thank you Andrew for the dedication needed to make this possible. Thank you also to Martha Zimmermann, for loving me and challenging me to pursue research in the way of helping others. Last, and certainly not least, thank you to the people of The Shire, my colleagues at McCormick’s Deli, and those friends who brought me up and keep me down to earth.
# Table of Contents

Abstract  
Dedication  
Acknowledgement  
Table of Contents  
List of Tables  
List of Figures  
Introduction  
Experiment 1  
Experiment 2  
Experiment 3  
Experiment 4  
Experiment 5  
General Discussion  
Conclusion  
References  
Appendix
List of Tables

Table 1: Practice Round Instructions & Stimulus Arrays from Exp. 1-5 55
Table 2: Ambiguous Instructions & Stimulus Arrays from Exp. 1-4 56
Table 2: Continuation of Table 2 57
### List of Figures

<table>
<thead>
<tr>
<th>Figure</th>
<th>Description</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>Figure 1</td>
<td>Chambers et al. (2004) stimulus array</td>
<td>39</td>
</tr>
<tr>
<td>Figure 2a &amp; 2b</td>
<td>Ambiguous-with-a-tool and no tool arrays</td>
<td>40</td>
</tr>
<tr>
<td>Figure 3</td>
<td>Schematic of correct/incorrect responses</td>
<td>41</td>
</tr>
<tr>
<td>Figure 4</td>
<td>Experiment 1 cumulative and percent correct</td>
<td>42</td>
</tr>
<tr>
<td>Figure 5</td>
<td>Experiment 1 correct/incorrect response forms</td>
<td>43</td>
</tr>
<tr>
<td>Figure 6</td>
<td>Ambiguous-with-a-tool array</td>
<td>44</td>
</tr>
<tr>
<td>Figure 7</td>
<td>Experiment 2 cumulative and percent correct</td>
<td>45</td>
</tr>
<tr>
<td>Figure 8</td>
<td>Experiment 2 correct/incorrect response forms</td>
<td>46</td>
</tr>
<tr>
<td>Figure 9</td>
<td>Experiment 3 cumulative and percent correct</td>
<td>47</td>
</tr>
<tr>
<td>Figure 10</td>
<td>Experiment 3 correct/incorrect response forms</td>
<td>48</td>
</tr>
<tr>
<td>Figure 11</td>
<td>Experiment 4 cumulative and percent correct</td>
<td>49</td>
</tr>
<tr>
<td>Figure 12</td>
<td>Experiment 4 correct/incorrect response forms</td>
<td>50</td>
</tr>
<tr>
<td>Figure 13</td>
<td>Experiment 5 cumulative and percent correct</td>
<td>51</td>
</tr>
<tr>
<td>Figure 14</td>
<td>Experiment 5 correct/incorrect response forms</td>
<td>52</td>
</tr>
<tr>
<td>Figure 15</td>
<td>Constraints and no constraints</td>
<td>53</td>
</tr>
</tbody>
</table>
Listening with Tools: The Intersection of Affordances and Language

Language and tools pervade the lifespans of humans. Children exhibit communicative acts as early as 12 months (Tomasello, 2008) and acts of tool-use as early as two-years (Lockman, 2000). Behavior scientists of the operant tradition have studied the interaction between language acts and nonverbal acts such as button presses (Hayes, Brownstein, Haas, & Greenway, 1986; Hayes, Brownstein, Zettle, Rosenfarb, & Korn, 1986; Monestès, Greville, & Hooper, 2017; Shimoff & Catania, 1998), but have yet to study the interaction between language acts and tool-use. Given the prevalence of tools, and their use in solving problems, it is the aim of the current research to study their use in the context of instructions.

A principle particularly useful to the current investigation is affordance (Gibson, 1979/1986; see Killeen & Jacobs, 2017a, for a review of affordances in behavior science). Affordances are possibilities for action relative to the perceptual system of the organism in question (see Chemero, 2003, for affordances as relations between organism and environment). Those possibilities are constituted by combinations of substances and surfaces perceived through media such as air or water (Richardson, Shockley, Riley, Fajen, & Turvey, 2008). A rock, for example, is a solid substance with a coarse surface that is graspable by an organism with a hand of commensurable size. That rock may afford throwing for a human but climbing for an ant (Turvey, 2013). Tools are a special case of affordance, as they alter the possibilities for action for those organisms who wield them.
Tools make the unreachable reachable, unmovable movable, and unmalleable malleable. They afford actions that otherwise could not be emitted. The implementation of tools by humans, however, occurs in conjunction with rules and instructions that are susceptible to multiple interpretations based on the history of the listener, audience variables, and the demands of the environment (Hayes, Barnes-Holmes, & Roche, 2001; Skinner, 1957/1992; see Tanenhaus, Spivey-Knowlton, Eberhard, & Sedivy, 1995, for the effects of the environment on spoken language comprehension). Furthermore, “Not all contingencies can be replaced with rules…” because the subtleties of those contingencies escape verbal description (Skinner, 1974, p. 192). Rules and instructions lacking those subtleties could be ambiguous in that they do not effectively control prescribed behavior. This raises the question as to whether the provision of tools, and their possibilities for action, could specify that which ambiguous rules or instructions do not.

Preliminary evidence indicates that the affordances of tools do factor into the control of behavior by instructions (Chambers, Tanenhaus, & Magnuson, 2004). By providing participants with a handheld tool for use, a stimulus array for manipulation, and an ambiguous instruction for execution, Chambers et al. (2004) showed that participants oriented to and fixated on incorrect stimuli for more time than those who did not have a tool. Figure 1 is a sample array that was accompanied by the vocal instruction, “Put the whistle on the folder in the box.” The tool provided was a handheld hook and the incorrect stimulus to which participants oriented was the empty folder (top right). The correct stimulus, as opposed to incorrect, was the empty box (bottom right) to which the whistle on the folder was supposed to be put.
The fixation of the eyes on the empty folder is curious because the handheld hook afforded only the movement of the whistle with the lanyard, which was already on a folder (top left, Figure 1). If participants had moved the whistle with the lanyard onto the empty folder, then they would not have engaged the part of the instruction that specified the box (bottom right, Figure 1). Whether participants actually moved objects such as the whistle to an incorrect stimulus is unclear, as Chambers and colleagues’ (2004) dependent measure was restricted to eye movements. Participants looked to incorrect stimuli when wielding a tool, but that does not necessarily entail the actual movement of objects to those incorrect stimuli.

The eye movement results from Chambers et al. (2004) are consistent with the behavioral research showing that the control of behavior by instructions is a function of contextual cues (Hayes, Thomspon, & Hayes, 1989; O’Hora, Barnes-Holmes, & Roche, 2004; O’Hora, Barnes-Holmes, & Stewart, 2014). Contextual cues are stimuli that control the behavior of responding to one stimulus in terms of another (Hayes et al., 2001). The statement, “Nickels are bigger than dimes, but dimes are more than nickels” includes the contextual cues “bigger than” and “more than,” which specify the formal (i.e., size) and arbitrary (i.e., “worth”) relations between the nickel and the dime. Contextual cues range from verbal abstractions such as “same,” “opposite,” “before,” and “after,” to intonation, gesturing, and words not often emitted alone: in, on, and, but, that, is, etc. “Put the whistle on the folder in the box,” therefore, is an ambiguous instruction because it lacks

---

1 The technical term for responding to one stimulus in terms of another is “relational responding,” and contextual cues are what bring a particular history of relational responding to bear upon present circumstances (see Hayes et al., 2001).
some of the contextual cues that would otherwise disambiguate the relations between certain stimuli. For example, the phrase “that is” in “Put the whistle that is on the folder in the box” clarifies that one should select the whistle on the folder (top left, Figure 1) as opposed to the whistle that is not on the folder (bottom left, Figure 1). The addition of “that is” is subtle, but its presence vs. absence could be the difference between effective and ineffective action on the part of a listener.

The present study borrows the experimental preparation used by Chambers et al. (2004) to determine the effects of tools on following instructions that are ambiguous. The current research sought to determine whether the provision of tools confers an advantage or disadvantage upon the execution of instructions by a listener. The general research question was this: Will the affordances of tools function as contextual cues that disambiguate instructions that are ambiguous, or will the affordances of tools interfere with instruction following by affording actions that are inconsistent with instructions? Experiment 1 tested whether tools functioned as contextual cues. Experiment 2 tested whether variables other than tools were responsible for the effects observed in the first experiment, and Experiment 3 tested the effects of verbal contextual cues in conjunction with the affordances of tools. Experiments 4 and 5 were conducted in order to test the reliability of effect observed in Experiment 1 and to further determine the cause of the behavior of listeners when wielding a tool.

**Experiment 1**

Experiment 1 was designed to determine whether the affordances of tools disambiguate instructions that are ambiguous, where ambiguous refers to instructions
lacking conventional contextual cues. Ambiguous instructions were modeled after those used in Chambers et al. (2004). Below is an example of an ambiguous instruction from Experiment 1:

(1) Put the flashlight on the book in the bag.

Instruction (1) was accompanied by the stimulus array shown in Figure 2a. Unlike the Figure 1 array used by Chambers et al. (2004), Figure 2a is a “fully ambiguous” stimulus array (see Coco & Keller, 2015, p. 8). This is to say that listeners could do either of at least two things: 1) put the flashlight that is on the book in the empty bag or 2) put the flashlight on the book that is in the bag.

While tools afford actions that otherwise might not be possible, they also constrain the range of stimuli with which an organism can interact. A handheld hook in the presence of the stimuli in Figure 2a should constrain participants’ possibilities for action, and therefore, disambiguate which stimulus to select and where to place it. As such, it was predicted that participants would use the hook to pick up the flashlight with the lanyard, which was on a book, to be put into the empty bag.

Method

Participants and setting. Three University of Nevada, Reno (UNR) undergraduates were recruited through the Psychology Department’s SONA System. One participant (790) reported that English was a second language, but self-described as being fluent. The study took place on campus, in a standard office that included a table, desk, chairs, whiteboard, and windows.
**Materials.** The experiment was video recorded with a Sony HDR-CX405 Handycam, on a Sunpak 58 inch camcorder tripod positioned to the right-hand side of each participant. Participants stood, forward facing, on the left-hand side of the center of a 7x3 ft. table on which they interacted with stimulus arrays. A 36x48 in. corrugated tri-fold display board partitioned that table at its center. The display board was to the right-hand side of participants and occluded a research assistant preparing stimulus arrays for each trial. Stimuli were presented on a white, 24x24 in. sheet of cardboard. On each trial, at least four stimuli were arranged and presented on that white cardboard in a 2x2 array.

Stimuli, including the tools used, were everyday household items such as clothes, toys, kitchenware, and office supplies. Some of the tools used, such as the wrench, needle-nose pliers, screwdriver, and fork, had culturally instituted purposes. Those tools, however, were not necessarily used in the manner intended by plumbers, electricians, or diners. For instance, the screwdriver was used for lifting baskets while the fork was used for moving money. This unconventional pairing of tools with stimuli was for the purposes of minimizing any potentially confounding history of reinforcement with respect to tools.

In conjunction with each stimulus array there was a corresponding instruction. There were 30 instructions in total, which included 15 ambiguous instructions and 15 ambiguous-with-a-tool instructions. Alex, a text to speech program on the MacBook Air (13-inch, Mid 2013; OS X El Capitan version 10.11.6), was used to vocalize those instructions. This was for the purposes of minimizing contextual cues such as gesturing and intonation. Alex’s speaking rate was set to “normal.” Readers can find a
comprehensive list of the instructions, stimuli, and tools used by accessing the link provided in the appendix (cf. Tables 1 & 2). Below we describe the general structure of each set of instructions.

**Ambiguous instructions (no tool).** Ambiguous instructions took either of the following forms: Put the [x] in the [y] on the [z]; Put the [x] on the [y] in the [z]; Place the [x] in the [y] on the [z]; Place the [x] on the [y] in the [z]. Ambiguous instructions did not include the contextual cue “that is.” Figure 2b is an exemplar array representative of all other arrays on ambiguous instruction trials. The Figure 2b array was accompanied by the ambiguous instruction: “Put the rock in the hat on the picture.”

Among the 15 ambiguous instructions, seven began with *put* and eight began with *place*. The first prepositional phrase in four out of the seven began with *in* (Put the [x] *in* the [y] on the [z]), while the remaining three out of the seven began with *on* (Put the [x] *on* the [y] in the [z]). The first prepositional phrase in four out of the eight began with *in* (Place the [x] *in* the [y] on the [z]), while the remaining began with *on* (Place the [x] *on* the [y] in the [z]). *Put, place, in,* and *on* were varied in order to control for participants deriving rules about how to complete instructions (e.g., “Always *put* the object that’s *on* something, *into* something else.”).

**Ambiguous-with-a-tool instructions.** These instructions took the same form as the ambiguous instructions. The only difference was that during the vocalization of these instructions participants were holding a tool to be used for the execution of the instructed action. Among the 15 ambiguous-with-a-tool instructions, eight began with *put* and seven began with *place*. The first prepositional phrase in four out of the eight began with *in* (Put
the [x] in the [y] on the [z]), while the remaining four out of the eight began with on (Put the [x] on the [y] in the [z]). The first prepositional phrase in three out of the seven began with in (Place the [x] in the [y] on the [z]), while the remaining began with on (Place the [x] on the [y] in the [z]). Figure 2a is an exemplar array representative of all other ambiguous-with-a-tool arrays. This is to say that for every array with a tool, the tool only afforded action with respect to a stimulus that was either in or on another stimulus.

Procedure. On arrival, participants were instructed to stand in front of the 24x24 in. white cardboard sheet on the table. They were told that they would move objects on that cardboard sheet and that the experiment would take 60 min or less. Participants were informed that their participation was voluntary and that they could exit the experiment, without penalty, at any time. They then signed a video consent form, which gave the experimenter permission to video record responses for research use only. No participants exited the experiment early and all participants consented to video recording the experiment. The experiment was approximately 30 min in duration from the time they arrived to the end of debriefing.

Seated across from the participant, the experimenter read the following instructions aloud:

During the study, instructions will be read aloud by this computer. The computer cannot repeat any instructions and I, the experimenter, cannot answer any questions related to what the computer says during the experiment. In a few seconds I will have the computer describe what you will be doing in the
experiment, so you know what to do and so you can hear what the computer sounds like. Are you ready for the computer to describe the experiment?

Following confirmation that the participant was ready to hear the computer-read instructions, the experimenter pressed play:

In this study I will give you instructions. Your job is to follow those instructions by moving objects with your hands. Sometimes, the experimenter will give you an instrument to move the objects. If you are given an instrument, then you must use the instrument instead of your hands. After you complete each instruction, the experimenter will give you a new instruction, with a new set of objects. Lastly, I cannot repeat any instructions. Any questions?

Note that the word “tool” was not used in any instructions. This was to minimize any chance that participants might make inferences, based on a history of tool-use, about the intended purpose of the instruments they were required to use. Following the computer-read instructions, the experimenter initiated a practice round followed by the experiment proper.

**Practice round.** Four trials made up the practice round: two tool trials and two no tool trials. To minimize practice effects, the instructions in the practice round did not include prepositional phrases. On the tool trials the experimenter handed the participant the tool, the research assistant slid the stimulus array out from behind the display board (with assistance from the experimenter), and the experimenter immediately played the corresponding instruction. The experimenter then recorded the participant’s response and cleared the table of the stimuli and white cardboard sheet for the next trial.
On the trials without a tool, the research assistant slid the array out from behind
the display board (with assistance from the experimenter) and the experimenter
immediately played the corresponding instruction. The experimenter then recorded the
participant’s response and cleared the table of the stimuli and white cardboard sheet to
begin the experiment proper. Practice round instructions and stimulus arrays can be found
in Table 1 in the appendix or by clicking the link in the appendix.

**Experiment proper.** On ambiguous-with-a-tool trials, participants were provided
the tool first, then the array, immediately followed by the computer-read instruction. On
all other trials without a tool, the array was presented first, then immediately followed by
the computer-read instruction. The procedure was the same as the practice round; the
only exception being that there was no experimenter contrived consequences provided on
any experimental trials. All the experimenter did was hand participants tools on
ambiguous-with-a-tool trials, help slide the arrays out from behind the display board, play
the instructions, record responses, and clear the table of stimuli at the end of every trial.

**Dependent measure.** The primary behavior of interest was percent of correct
responses on both ambiguous trials and ambiguous-with-a-tool trials. Percentages for
ambiguous and ambiguous-with-a-tool trials were calculated by dividing the number of
correct responses by the total number of trials for each condition. The product of that
division was then multiplied by one hundred. Seven correct responses on ambiguous
instruction (no tool) trials, for example, would equate to 7/15, or 47 percent.

**Correct responses.** For expository reasons, Figure 2b is used to describe correct
responses representative across all other arrays used on ambiguous and ambiguous-with-
a-tool trials. For an exposition of correct and incorrect responses not limited to the array shown in Figure 2b, see Figure 3 for a generic depiction.

Given the stimulus array in Figure 2b, and its accompanying instruction to “Put the rock in the hat on the picture,” there were three possible responses that counted as correct. Those responses included: (a) putting the rock that is in the hat onto the empty picture, (b) putting the lone rock in the hat that is on the picture, and (c) putting the hat, with the rock still in it, onto the empty picture. Response (a) is equivalent to the instruction “Put the rock *that is* in the hat on the picture”, while response (b) is equivalent to the instruction “Put the rock in the hat *that is* on the picture”. Response (c), although topographically different from (b), results in the same outcome as (b). This is to say that both responses—(b) and (c)—differ in terms of initial stimuli selected (i.e., the lone rock vs. the hat with the rock in it), but both result in a “rock in the hat *that is* on the picture.”

**Incorrect responses.** Based on Figure 2b, incorrect responses included: (i) putting the lone rock on the empty picture, (ii) putting the rock that is in the hat, into the other hat that resided on the picture, and (iii) putting the hat, with the rock still in it, onto the other hat that was on the picture. (i) does not engage the part of the instruction that specifies “hat” while (ii) and (iii) engage the part of the instruction that specifies “hat,” but do so twice. Response (ii) is a redundancy in that the rock selected was already in a hat; so to put it in another hat is inconsistent with the stated instruction. Response (iii) is also a redundancy in that both hats, rather than one of the hats, are engaged. Other incorrect responses included moving both rocks, putting hats on rocks or pictures on rocks, and putting the lone rock in the hat already containing a rock.
Design. A variation of the within-subjects alternating treatments design (ATD; Barlow & Hayes, 1979) was used to assess any difference between ambiguous and ambiguous-with-a-tool conditions. The variation of the ATD used was a restricted alternating treatments design (Onghena & Edgington, 1994), or randomized alternation design (Onghena & Edgington, 2005). Randomized ATD entails the random assignment of treatment conditions to measurement times. The 15 ambiguous instructions (no tool), in conjunction with their respective stimulus arrays, comprised condition A. The 15 ambiguous-with-a-tool instructions, in conjunction with their respective stimulus arrays, comprised condition B. In total, there were 30 trials, or in other words, 30 measurement times to which A and B conditions could be randomly assigned. The a priori random assignment of conditions to measurement times makes the ATD subject to randomization tests, which are free of distributional assumptions and particularly applicable to single-case experimental designs (Edgington & Onghena, 2007; Heyvaert & Onghena, 2014). The only restriction on the random assignment was that conditions A and B could not be presented to participants more than three times consecutively.

Regarding the 2x2 stimulus array, there are 24 possible stimulus location permutations. For each set of 15 instructions, 15 of the 24 possible stimulus location permutations were randomly selected. This was done to minimize the chances that participants might select stimuli purely based on their location, a position bias that could manifest in the form of rules (e.g., “The bottom right stimulus is always correct” or “The instructions always require me to move things onto an object in the top right quadrant”). Participants were exposed to the same randomly selected stimulus location permutations.
with a few exceptions. One stimulus array was arranged differently for p360 and three stimulus arrays were arranged differently for p790. The differences were due to experimenter error while arranging the arrays for presentation. Those mistakes were marked in the link provided in the appendix and did not undermine the validity of experimental trials or the randomization tests described below (Edgington & Onghena, 2007).

**Data analysis.** The null hypothesis was that there is no difference between treatment conditions A (ambiguous instructions, no tool) and B (ambiguous-with-a-tool instructions). More specifically, the percent of trials with correct responses will be the same regardless of conditions A (no tool) or B (tool). The alternative hypothesis was the converse, a difference in percent of correct responses given conditions A or B.

Since the data in this experiment were dichotomous (i.e., correct vs. incorrect on each trial), the test statistic was the absolute difference between percent of correct responses within conditions A and B: |A - B|. Provided the observed test statistic, a two-tailed, non-directional randomization test was computed for each participant. Randomization tests entail a comparison of the observed test statistic against other test statistics derived from a reference set comprised of all possible random assignments of conditions to measurement times. All possible random assignments of conditions are superimposed over the observed data to return a p-value—the proportion of test statistics that are equal to or larger than the observed test statistic (see Onghena & Edgington, 2005).
Given the cumbersome number of ways to randomly assign conditions A and B to the 30 measurement times, a Monte Carlo procedure was used to randomly select 1000 random assignments to make up the reference set. Therefore, if there were 60 out of 1000 random assignments that resulted in a test statistic of greater or equal value to the observed test statistic, then we would fail to reject the null at the p 0.05 level of significance. Sixty out of 1000 gives a p-value of 0.06. The smallest p-value obtainable was 1/1000, or p = 0.001. All randomization tests were conducted using the Single-Case Randomization Tests (SCRT) R package developed by Bulté and Onghena (2008).

**Inter-observer agreement (IOA).** Responses recorded during the experiment were corroborated with reference to the video recordings. An independent observer watched all participant recordings and compared their results to those recorded by the experimenter. Percentage of IOA was determined by dividing the number of agreements by the total number of agreements plus disagreements multiplied by 100. The IOA for Experiment 1 was 99 percent. The single disagreement was rectified with corroboration to the video recording.

**Results**

Figure 4 includes cumulative records and percentages correct within conditions for each participant. The cumulative records reflect the randomized alternating treatments for each participant and their trial-by trial responses for each condition. Participants received a one for correct trials and zero for incorrect trials. “No tool” represents trials on which participants were presented with ambiguous instructions and manipulated objects with their hands. “Tool” represents ambiguous-with-a-tool trials.
All participants in Figure 4 responded correct on every no tool trial. As for tool trials, there was a decrement in correct responses. Participant 360 emitted 5 incorrect responses on trials 12 through 14, and trials 20 and twenty-nine. Participant 790 emitted 9 incorrect responses beginning with their first two exposures to tool trials, and it was not until trial 19 that p790 began emitting correct responses more reliably. Participant 915 emitted 11 incorrect responses beginning with their first exposure to a tool trial. An uptick in correct responses for p915 was observed on trials 21, 24, and 25, but leveled off in the last two remaining tool trials of the experiment.

Figure 4 also shows the within condition percent of correct responses for all three participants. Participants 360, 790, and 915 were 100% correct on all no tool trials. On tool trials there was a decrement in percent of correct responses. Participant 360 scored the highest of the three with 67% correct, while p790 got 33% correct and p915 got 27% correct. Randomization tests indicated a significant difference between no tool and tool conditions for all three participants. The absolute difference between conditions for p360 was 0.33, p = 0.021, while the difference between conditions for p790 was 0.67, p = 0.001, and the difference between conditions for p915 was 0.73, p = 0.001. Based on these results, the null hypothesis that there is no difference between ambiguous instructions (no tool) and ambiguous-with-a-tool conditions was rejected for each participant.

Figure 7 shows the distribution of correct and incorrect response forms emitted per participant, per condition. Notice that (a) and (b) made up the majority of correct response forms. Participants 360 and 915 emitted correct response form (a) on 53% and
60% of the no tool trials respectively. Unlike the others, p790 emitted correct response form (b), almost exclusively, on 93% of the no tool trials. Provided a tool, no participants emitted correct response form (b) because the tools did not allow it. Instead, all three participants emitted either correct response form (a) or incorrect response form (ii). Participant 790 was the exception who emitted correct response form (c) on one trial.

That participants emitted response forms (a) and (ii) is consistent with an analysis of the available affordances while wielding a tool. Take the example array in Figure 2a with the flashlights: Both response forms (a) and (ii) involves the selection of the flashlight with the lanyard because it is the only flashlight that affords moving with a hook. The difference between (a) and (ii), however, is that (a) involves the movement of the flashlight attached to the lanyard into the empty bag (correct) while (ii) involves the movement of that same flashlight onto another book that is in the other bag (incorrect). Interestingly, without a tool, participants never made the equivalent response (ii) mistake of putting an object already on one thing, onto another thing of the same kind.

Discussion

Experiment 1 set out to determine whether the affordances of tools would function as contextual cues that disambiguate instructions that are ambiguous. Based on the visual analysis of Figure 4, in addition to the obtained p < 0.05 values for each participant, there appears to be a difference between executing ambiguous instructions with one’s hands versus with a tool. Interestingly, the effect observed was in a direction opposite to that which was expected. Rather than disambiguating instructions, the provision of tools afforded responses inconsistent with the stated instructions. This
suggests that the affordances of tools do not always disambiguate instructions. Instead, the affordance-based control of tools seems to have overridden the instructional control that was observed when participants used their hands.

A potential limitation of the current study was that the ambiguous instruction (no tool) arrays and the ambiguous-with-a-tool arrays were not wholly equivalent. Tool arrays were designed such that participants could only manipulate one of the two objects specified in an instruction (e.g., Figure 2a). An unfortunate consequence of this design was that for some of the arrays the tool was not the only object that constrained affordances for action. At least five of the 15 ambiguous-with-a-tool arrays constrained participants’ actions on the basis that one of the specified objects to be moved could not fit into another object. Figure 6 is an example of those 5 arrays. The instruction corresponding to that array was “Put the tea in the glass on the notebook.” The tool provided was a clip that only afforded the movement of the tea bag in the glass. The tea box, in addition to the tool, also constrained participant responding in that it was too large to fit into the glass on the notebook. Contrast this with ambiguous instruction (no tool) arrays like the one shown in Figure 2b, which allows participants to move either rock into either hat. It may be the case that the structure of these 5 arrays controlled incorrect responses on tool trials and inflated the results of Experiment 1. Experiment 2 was devised as a control study to determine whether the structure of these 5 arrays controlled incorrect responding.
Experiment 2

All methods and materials were the same as in Experiment 1. The only exception was that there was no provision of a tool on trials that usually included a tool. This was to test whether it was something about the structure of the ambiguous-with-a-tool arrays that evoked incorrect responses. The two conditions participants were exposed to were characterized as condition A, ambiguous instructions (no tool), and condition B, ambiguous-without-a-tool instructions (control). Conditions A and B were the same as in Experiment 1, except participants were not provided with tools on B trials. The null hypothesis was no difference between conditions A or B. If that null is rejected, and there is an observed difference between conditions, then incorrect responses are possibly under the control of the structures of the stimulus arrays. If there is a failure to reject the null, and there is no observed difference between conditions, then we can say that “the tools in Experiment 1 afforded incorrect responses” with more confidence.

Method

Methods, materials, dependent measures, design, and data analysis were the same as in Experiment 1, with the exception that no tools were provided.

Participants. Three UNR undergraduates were recruited through the Psychology Department’s SONA System and self-identified as being fluent in English. These participants were not the same as those who participated in Experiment one.

IOA. The IOA for Experiment 2 was 100 percent. Additionally, there were no experimenter errors when arranging the stimulus arrays for presentation.
**Procedure.** The procedure was the same as Experiment 1, except participants were given a modified version of the computer-read instructions. The instructions read:

In this study I will give you instructions. Your job is to follow those instructions by moving objects with your hands. After you complete each instruction, the experimenter will give you a new instruction, with a new set of objects. Lastly, I cannot repeat any instructions. Any questions?

The part of the Experiment 1 instruction referring to the provision of an instrument (i.e., a tool) was removed.

**Results**

Figure 7 includes cumulative records and percentages correct within conditions for each participant. “No tool” represents trials on which participants were presented with ambiguous instructions and manipulated objects with their hands. “Control” represents ambiguous-without-a-tool trials. Participants 998 and 912 responded correct on all no tool trials while p303 emitted two incorrect responses on no tool trials 21 and thirty. On control trials, p303 emitted three incorrect responses on trials 9, 22, and twenty-nine. Participant 998 emitted two incorrect responses on control trials 29 and 30, and p912 responded correct on all control trials. Critically, no incorrect responses were emitted in the presence of the five arrays that were structured differently than the no tool arrays.

Figure 7 also shows the percent of correct responses for each participant. Like those in Experiment 1, participants 998 and 912 responded 100% correct on ambiguous instruction (no tool) trials. Participant 303 was the exception who got 87% correct on no tool trials. On ambiguous-without-a-tool instructions (control), participants emitted more
correct responses than those who used a tool in Experiment 1. Participants 303, 998, and 912 got 80% correct, 87% correct, and 100% correct on control trials respectively.

Randomization tests indicated no significant difference between no tool and control conditions for any participants. The absolute difference between conditions for p303 was 0.07, $p = 1$, while the difference between conditions for p998 was 0.13, $p = 0.394$, and the difference between conditions for p912 was 0, $p = 1$. These results indicate a failure to reject the null for each participant, so there was no apparent difference between conditions for these participants.

Figure 8 shows the distribution of correct and incorrect response forms emitted per participant, per condition. Response forms emitted on ambiguous instruction (no tool) trials were similar to those emitted by participants in Experiment 1 (Figure 5). As for the ambiguous-without-a-tool (control), there was more variability in response forms, compared to Experiment 1 (Figure 5), because participants were not wielding a tool.

**Discussion**

Experiment 2 was conducted for the purposes of determining whether the tools in Experiment 1 afforded incorrect responses, or whether the nature of the stimulus arrays afforded incorrect responses. Based on the randomization tests in conjunction with a visual analysis of the data, there is no apparent difference between conditions in Experiment 2. This is to say that the structure of the arrays (control), which were accompanied by a tool in Experiment 1, did not evoke incorrect responses more often than what was observed on ambiguous instruction (no tool) trials. In contrast to the results of Experiment 1, participants in Experiment 2 emitted more correct responses on
ambiguous-without-a-tool (control) trials than participants who wielded a tool in Experiment 1.

Experiment 2 provides additional evidence supporting the conclusion that the affordance-based control of tools overrides the instructional control observed when participants use their hands. The provision of a tool modulates the nonverbal actions of the listener in relation to his/her environment, and based on the results of Experiments 1 and 2, interferes with the verbal actions of the listener. Without-a-tool participants reliably “listen with understanding” (à la Hayes & L.J. Hayes, 1989), but with a tool participants emit responses inconsistent with the actions specified in the instructions.

Experiment 3

Experiment 3 was designed to test whether listeners would emit incorrect responses with a tool, even when instructions were unambiguous. This was tested by adding the contextual cue “that is” to all ambiguous-with-a-tool instructions, which rendered them unambiguous-with-a-tool instructions. “Put the flashlight on the book in the bag,” for example, was reworded to include “that is”: “Put the flashlight that is on the book in the bag.” The prediction was that the addition of “that is” would not only disambiguate which object to manipulate, but it would also disambiguate the affordances of the tool (i.e., its possibilities for action) consistent with the instruction.

Method

Methods, materials, dependent measures, design, data analysis, and procedures were the same as in Experiment 1, with the exception that ambiguous-with-a-tool instructions were reworded as unambiguous-with-a-tool instructions. The unambiguous-
with-a-tool condition (B) was compared to condition A, the same ambiguous instruction (no tool) condition used in Experiments 1 and two.

**Participants.** One UNR undergraduate was recruited through the Psychology Department’s SONA System and self-identified as being fluent in English.

**IOA.** The IOA for Experiment 3 was 100% and there were no experimenter errors when arranging stimulus arrays for presentation.

**Results**

Figure 9 includes the cumulative record and percentages correct within conditions for p224. “No tool” trials were the same as in Experiments 1 and 2 while “UT” represents unambiguous-with-a-tool trials. All of p224 responses were correct on both no tool and UT trials. Randomization tests indicated no significant difference between no tool and UT conditions. The absolute difference between conditions was 0, p = 1. These results indicate a failure to reject the null hypothesis that there is no difference between conditions.

Figure 10 shows the distribution of correct and incorrect response forms emitted per condition. Without a tool p224 emitted either correct response forms (a) or (b). The provision of a tool (UT) constrained that responding to correct response form (a) only. Compared to Experiment 1, p224’s responses were limited to response form (a) not just because of the tool, but also because of the addition of the contextual cue “that is.”

**Discussion**

Experiment 3 tested whether a listener would emit incorrect responses with a tool, even when instructions were unambiguous. Results indicate that the addition of the
contextual cue “that is”remediates the emission of incorrect responses with a tool, which was observed in Experiment 1. When instructions are unambiguous, tools do not afford actions inconsistent with the uttered instructions. This is to say that the contextual cue “that is” functioned to disambiguate the affordances of the tool that were consistent with the instructions.

**Experiment 4**

Experiment 4 was designed for the purposes of replicating the effects observed in Experiment 1. That first Experiment included only 3 participants, and so as not to design other experiments for which there may be no effect, an attempt at direct replication was pursued. Additionally, the randomization test p-values used in Experiments 1 through 3 make statistical inferences based on that which the experimenter did in terms of random assignment and observed as a result. Statistical inferences about the larger population are not warranted in the case of randomization tests, but non-statistical inferences can be made on the assumption that behavior is lawful (Edgington, 1966). That is, “control your conditions and you will see order” (Skinner, 1956, p. 223). Experiment 4 was an attempt to do just that: control conditions as they were in Experiment 1 to see if order would emerge.

**Method**

All methods were the same as in Experiment 1.

**Participants.** Five UNR undergraduates were recruited through the Psychology Department’s SONA System. Four out of the 5 participants self-identified as being fluent in English. Participant 412 identified English as a second language and self-identified as
“maybe” being fluent in English. All other interactions with p412, including her responses to the post-test survey, indicated that she was fluent in English. Four of the participants self-identified as being right-hand dominant and one of the participants (610) self-identified as being left-hand dominant.

**IOA.** The IOA for Experiment 4 was 98% and there were no experimenter errors when arranging stimulus arrays for presentation.

**Results**

Figure 11 includes cumulative records and percentages correct within conditions for each participant. “No tool” indicates trials on which participants executed ambiguous instructions with their hands and “Tool” indicates trials on which participants executed ambiguous instructions with a tool. The dashed vertical line on p412’s cumulative record represents an interruption in the alternation of treatments and the downward facing arrows on p412 and p341 data represents trials on which participants used their hands in conjunction with the tool. The interruption in the alternation of treatments for p412 was a prompt to use the tool and not their hands on trials when given a tool.

Visual analysis of the cumulative records indicates that all participants, with the exception of p506, emitted correct responses on all no tool trials. Participant 506 emitted 2 incorrect responses on no tool trials 18 and twenty-two. As for tool trial responses, p610 was the only participant to respond correctly on all tool trials. Participant 506 emitted 4 incorrect tool responses on trials 1, 13, 17, and twenty. Participant 194 did not emit an incorrect response on tool trials until trials 15 and 16, which was followed by incorrect responses on trials 22, 25, 27, and thirty. Participant 412 emitted 8 incorrect
responses with a tool, with the first incorrect response immediately following the interruption in the alternation of treatments on trial five. Prior to that interruption, p412 got both tool trials correct when using her hands instead of the tool provided. Other incorrect responses for p412 occurred on trials 10, 12, 14, 17, 20, 22, and 26. Between those incorrect trials, p412 emitted the most correct tool responses—indicated by the arrows—when she used her hands in conjunction with the tool (e.g., pinching the flashlight between the hook and her thumb). Participant 341 emitted the most incorrect responses on tool trials 4, 5, 6, 8, 9, 12, 17, 18, 20, 21, 25, and twenty-nine. One of the 3 correct responses emitted was with p341’s hands in conjunction with the tool.

Figure 11 also shows percentages correct for which all participants, except p506, got 100% correct in the no tool condition. Participant 506 got 87% correct within the no tool condition. On tool trials, p610 was the only participant to get 100% correct. Participant 506 got 87% correct, p194 got 60% correct, p412 got 47% correct, and p341 got 20% correct. Randomization tests indicated no significant difference between no tool and tool conditions for p610 or p506. The absolute difference between means was 0, p = 1, for p610; and 0.13, p = 0.631, for p506. Randomization tests did, however, indicate a significant difference between conditions for all other participants. The absolute difference between means was 0.40, p = 0.013, for p194; 0.53, p = 0.002, for p412; and 0.80, p = 0.001, for p341.

Figure 12 shows the distribution of correct and incorrect response forms emitted per participant, per condition. The distribution of Figure 12 response forms is similar to the one observed in Experiment 1 (Figure 5), as there is a split between correct response
forms (a) and (b) on no tool trials and a split between response forms (a) and (ii) on tool trials. The only exception is p610, whose majority of responses emitted were form (a). Participant 610 emitted only two (b) responses on trials 2 and 3 at the beginning of the experiment. Participant 610 also reported in the post-test survey that: “I tried my best to stay consistent, and always interpret the sentence the same way.” If p610 derived this as a rule after her first couple tool trials, which force response form (a), then this could possibly explain the anomalous 100% correct within the tool condition.

**Discussion**

Experiment 4 set out to determine the reliability of the effects observed in Experiment 1 by attempting a replication. With the exception of p610 and p506, the effects of Experiment 1 were replicated and appear to be reliable under the circumstances described in the method. Arguably, p506 could be considered a replication based on the decrement in correct responses on tool trials, but according to the randomization tests there was no significant difference between no tool and tool conditions. Although p610 did not replicate, their data indicate a potential path for future research: to invoke the derivation of rules, regarding consistency in responding, to see how rules affect that responding. For p610, the rule to stay consistent may have been the reason for the correct responses observed on tool trials.

The results from p412 are particularly interesting because the ATD for that participant includes elements of a reversal design. Up until trial 4 the participant was using her hands instead of the tool provided. When the experimenter intervened by prompting p412 to use the tool instead of her hands, she emitted her first incorrect tool
response. Immediately following that incorrect tool response on trial 5, p412 then went back to using her hands, but this time in conjunction with the tool, on trial 6 which she got correct. This pattern continued, as p412 made incorrect responses when using the tool and correct responses when reverting back to the use of the tool in conjunction with her hands. This result is interesting because it conforms with the explanation that tools that constrain possibilities for action cause a decrement in correct responding. When using the tool in conjunction with her hands there was no constraints on responding, for p412 could manipulate either of the stimuli specified in the instruction. Participant 412 got tool trials correct when constraints on responding were absent but got tool trials incorrect when constraints on responding were present. Therefore, the presence of constraints on responding by the tool appear to be the cause of the decrement in correct responding on tool trials. Experiment 5 sought to determine the viability of this explanation.

**Experiment 5**

The purpose of Experiment 5 was to determine whether the decrement in correct responses, on tool trials in Experiments 1 and 4, were due to the provision of tools alone or to the provision of tools that constrain the nonverbal actions of listeners. The tools in Experiments 1 and 4 constrained the nonverbal actions of listeners, so the tools provided in Experiment 5 were made compatible with either of the stimuli specified in an instruction. For example, “Put the flashlight on the book in the bag” (Figure 2a) was arranged such that both flashlights could be manipulated with a hook (i.e., both flashlights would have a lanyard).

Tool trials that afford either action are similar to trials on which participants use
their hands: they can put the flashlight that is on the book in the empty bag or put the lone flashlight on the book that is in the bag. As such, it was expected that there would be no difference between ambiguous instruction (no tool) trials and trials with a tool. If there is a decrement in correct responding on tool trials, then it might be said that tools—regardless of whether they constrain possibilities for action—interfere with instructional control.

**Method**

Materials, procedures, dependent measures, design, and data analysis were the same as Experiment 1, except tools did not constrain participant responding to one stimulus.

**Participants.** Five UNR undergraduates were recruited through the Psychology Department’s SONA system and self-identified as being fluent in English. Four of the participants self-identified as being right-hand dominant and one of the participants (242) self-identified as being left-hand dominant.

**IOA.** The IOA for Experiment 5 was 98% and there were no experimenter errors when arranging stimulus arrays for presentation.

**Results**

Figure 13 includes the cumulative records and percentages correct within conditions for each participant. “No tool” indicates the presentation of ambiguous instructions that participants executed with their hands and “Tool” indicates the condition in which participants executed ambiguous instructions with a tool that did not constrain responding to a single stimulus. Participant 151 made one incorrect response on no tool
trial 6 while p839 made no incorrect responses in either condition. Participant 313 made one incorrect response on tool trial 30 and p976 made one incorrect response on tool trial sixteen. Participant 242 made 2 incorrect responses on tool trials 23 and twenty-eight.

As for percentages correct, p151 was the only participant to emit an incorrect response on no tool trials with 93% correct. All other participants were 100% correct on no tool trials. Participant 151 and p839 were 100% correct on tool trials while p313, p976, and p242 got 93%, 93%, and 87% correct respectively. Randomization tests indicated no significant difference between conditions for any participants. The absolute difference between conditions was 0.06, p = 1, for p151; 0, p = 1, for p839; 0.06, p = 1, for p313; 0.06, p = 1, for p976; and 0.13, p = 0.492, for p242.

Figure 14 shows the distribution of correct and incorrect response forms emitted per participant, per condition. On both no tool and tool trials participants emitted response forms (a) and (b), with p151, p242, and p976 emitting response form (c) on no tool trials and p151 and p976 emitting form (c) on tool trials. Figure 14 tool trial response forms are in contrast with the tool trial response forms observed in Experiments 1 (Figure 5) and 4 (Figure 12), as there was only one instance of incorrect response form (ii) in Experiment five. Furthermore, Figure 14 shows that when participants wielded a tool that did not constrain affordances for action, participants responded the same as when they executed instructions with their hands (no tool).

Discussion

The results of Experiment 5 indicate that there is no difference between no tool and tool conditions when tools do not constrain the nonverbal actions of listeners.
Experiment 5 strengthens the claim that there is a decrement in correct responses to instructions when tools constrain that which a listener can do. When those constraints on responding are absent, as they were in this Experiment and Experiment 2, participants emit little to no incorrect responses on tool trials.

**General Discussion**

Whether tools confer an advantage or disadvantage upon the execution of instructions by listeners can begin to be answered. Experiment 1 set out to determine whether the affordances of tools might function as contextual cues that specify that which ambiguous instructions do not. Results were in a direction opposite to that which we expected. Rather than constraining the listener’s possibilities for action, and therefore, specifying which objects to move to which locations, tools constrained listener responding and afforded actions inconsistent with instructions. In comparison to no tool trials, instructional control was inhibited when participants wielded a tool.

Experiment 2 asked a counterfactual: What if all of the conditions of Experiment 1 were held constant, with the exception that the participants in Experiment 2 are not provided a tool on any trials? Results showed that without-a-tool listeners did not make the errors that were observed on tool trials in Experiment 1. Experiment 2 is revealing because the absence of the effects observed in Experiment 1 were concomitant with the absence of a certain variable: *tools that constrain possibilities for action*. This is to say that tools that constrain responding could be the variable that inhibits instructional control. If tools that constrain possibilities for action are present, then a decrement in correct responses to instructions is probable.
While Experiments 1 and 2 provided evidence for the inhibiting effects of tool affordances on following ambiguous instructions, Experiment 3 determined whether tool affordances inhibited instruction following when instructions were unambiguous. Experiment 3 was limited by its inclusion of only one participant, but it nevertheless provided evidence that the inclusion of two inconspicuous words—“that is”—could restrict the variability in behavior observed in Experiments 1 and 2. When instructions were ambiguous, participants exhibited multiple response forms, but when unambiguous, the participant in Experiment 3 exhibited only one response form and the affordances of tools did not result in a decrement in correct responding. The words “that is” are contextual cues that specified not only the relations between stimuli, but also the nonverbal actions consistent with the rest of the instructions. Words such as “that is” are secondary verbal behavior that Skinner (1957) called autoclitics, as they modify the effectiveness with which listeners respond to a speaker’s instruction, command, warning, or advice. The stimulus control engendered by the *thats, its, buts, ifs, and, therefore* of verbal behavior require more research, and Experiment 3 may be a start.

The final two Experiments, 4 and 5, strengthened the claims made based on Experiments 1 and 2 by showing that (1) the inhibition of instruction following by tool affordances is a reliable effect and (2) that tools must constrain listeners’ possibilities for action for the decrement in correct responding to be observed. Experiment 5 showed that absent any constraints on responding by a tool, participants do not make the same mistakes observed when there are constraints on responding by a tool. Therefore, when tools constrain possibilities for action in the context of ambiguous instructions, nonverbal
actions inconsistent with those instructions are observed. This is in contrast to the observation that when participants execute ambiguous instructions with their hands—where there are no constraints on responding—they do not make the same mistakes.

Altogether, Experiments 1, 2, 4, and 5 point to one variable as the cause of errors when following instructions with a tool. Tools that constrain affordances to one of two stimuli specified in an instruction results in nonverbal actions that are incongruent with that instruction. When there are no constraints on responding, such as in the no tool condition, instructional control is operative and effective. Figure 15 shows all of the individual data from Experiments 1, 2, 4, and 5 partitioned by the presence of constraints and absence of constraints. It makes apparent the difference in behavior due to tools that constrain possibilities for action. When tools constrain possibilities for action, affordance-based control is operative and in competition with instructional control.

Affordance-based control is nonverbal behavior under the control of the environment relative to the perceptual system of the organism in question—in this case a human listener. In the current investigation, affordance-based control was observed when possibilities for action in relation to the organism were constrained, and as a result, the nonverbal behavior emitted was inconsistent with the instruction stated. Instructional control, in the current investigation, is the control of nonverbal behavior by verbal contextual cues that specify spatiality and locality. Instructional control was observed when constraints on responding were absent, and nonverbal behavior was a function of the verbal contextual cues that specified the behavior to be emitted.

The competition between affordance-based control and instructional control is
when tools constrain responding to a stimulus that is not the one specified, according to the listener, by the instruction. For instance, if instructions were interpreted as specifying response form (b), but the tool constrained responding to response form (a), then the result might be a combination of response forms (a) and (b). This may in fact be the case, for the only incorrect response form emitted with a tool was (ii), which is a conglomerate of forms (a) and (b). In Figure 2a, putting the flashlight that is on the book into the empty bag is response form (a), while form (b) is putting the lone flashlight on the book that is the bag. Form (ii) is their conglomerate, where participants select the flashlight on the book as if they were to engage in an (a) form, but put it on the book that is in the bag as if they were now engaging in a (b) form.

**Conclusion**

The observed inhibition of instruction following by affordance-based control is a preliminary finding that requires replication not just across people of different populations in different contexts, but also across instructions, tools, and stimuli. The effect appears to be lawful when the conditions are right, but even so, the effects of tools on nonverbal behavior when alone—deriving rules, setting goals, or meandering to oneself—remains unknown. Future research should direct its attention to the potential effects of tools on solving problems (i.e., ones with verbal features), setting goals (i.e., prospective control), and thinking (i.e., covert verbal behavior). If the affordance-based control of tools is operative, it may inhibit other forms of behavior or even facilitate one’s problem solving, goal setting, or thinking.

A possible limitation of the current investigation was the potential for differential
carry-over effects due to the alternation of treatments within subjects. This is to say that the results observed herein could have been due in part to the effects of tool trials on no tool trials or vice versa. Future replications should randomly assign participants to separate groups, whereby participants would only be exposed to one of the conditions (e.g., tool trials) to determine its effect on the behavior of instruction following. Furthermore, future research should investigate the implications of Experiment 3, a study limited by its inclusion of only one participant. That verbal contextual cues such as “that is” can control nonverbal behavior so effectively is an area of limited investigation. If this secondary, autoclitic verbal behavior results in nonverbal behavior like that observed in Experiment 3, then it is deserving of more inspection.

Language, tools, and language in conjunction with tools is an area of study ripe for exploration within operant behavior science. It engages the study of the perceptual systems of organisms (Jacobs, Isenhower, & Hayes, 2016), the study of affordances relative to that organism’s verbal behavior (Killeen & Jacobs, 2017a; 2017b), and the study of tools in conjunction with verbal behavior that transforms the stimulus functions of objects (Stewart, Barrett, McHugh, Barnes-Holmes, & O’Hora, 2013). The study of listening with tools challenges operant behavior scientists to determine the conditions under which people do and do not speak with meaning and listen with understanding. Humans regularly solve their problems by emitting verbal behavior and implementing tools, so a basic understanding of those processes might inform operant behavior science’s goal of predicting and controlling behavior for the betterment of the human condition.
References


Science & Business Media.


Killeen, P. R., & Jacobs, K. W. (2017a). Coal is not black, snow is not white, food is not a reinforcer: the roles of affordances and dispositions in the analysis of behavior. *The Behavior Analyst, 40*(1), 17-38.


Figure 1: Depiction of the stimulus array presented to participants in Chambers et al. (2004). Top left is a whistle with a lanyard on a folder (target); top right is an empty folder (incorrect stimulus); bottom left is a whistle on a plate (distractor); and bottom right is an empty box (correct stimulus). The instruction was to “Put the whistle on the folder in the box.” All images were retrieved from https://pixabay.com/, where images are free of copyrights under Creative Commons CC0.
Figures 2a & 2b: Picture of the stimulus arrays accompanied by the ambiguous instructions: “Put the flashlight on the book in the bag” and “Put the rock in the hat on the picture.” Above the 2a array is the tool, a handheld hook. Top left is a flashlight with a lanyard on a book; top right is an empty bag; bottom left is a book in a bag; bottom right is a flashlight. As for 2b, the top left is a rock in a hat; top right is a hat on a picture; bottom left is a rock; bottom right is a picture.
Figure 3: Schematic of correct and incorrect responses given the generic instruction, “Put the [x] in the [y] on the [z].” x, y, and z represent stimuli presented to participants. Blank spaces, represented by an empty line, indicate the variable that was initially selected and moved. Bolded font, within the arrays only, represents the terminal arrangement of stimuli based on the initial selection and movement of variables.
Figure 4: Experiment 1 cumulative records of data by trial and percent correct within conditions. *p < .05. **p < .01. ***p < .001
Figure 5: Experiment 1 distribution of correct and incorrect response forms emitted per participant, per condition.
Figure 6: Picture of the stimulus array accompanied by the ambiguous instruction: “Put the tea in the glass on the notebook.” Above the array is the tool, a clip. Top left is a tea box; top right is an empty glass on a notebook; bottom left is a tea bag in a glass; bottom right is a notebook. Note that if participants used their hands, responding would be constrained because the tea box does not fit into the glass on the notebook.
Figure 7: Experiment 2 cumulative records of data by trial and percent correct within conditions.
Figure 8: Experiment 2 distribution of correct and incorrect response forms emitted per participant, per condition. “Control” stands for the ambiguous-without-a-tool condition.
Figure 9: Experiment 3 cumulative records of data by trial and percent correct within conditions. “UT” stands for unambiguous-with-a-tool.
Figure 10: Experiment 3 distribution of correct and incorrect response forms emitted per condition. “UT” stands for unambiguous-with-a-tool.
Figure 11: Experiment 4 cumulative records of data by trial and percent correct within conditions. Arrows represent trials on which participants used their hands in conjunction with a tool. The vertical dotted line on p412 represents an interruption in the alternation of treatments, where the experimenter prompted the participant to use the tool and not their hands. *p < .05. **p < .01. ***p < .001
Figure 12: Experiment 4 distribution of correct and incorrect response forms emitted per participant, per condition. “Incorrect (o)” stands for an “other” response form not encompassed by forms i, ii, and iii.
Figure 13: Experiment 5 cumulative records of data by trial and percent correct within conditions.
Figure 14: Experiment 5 distribution of correct and incorrect response forms emitted per participant, per condition. “Incorrect (o)” stands for an “other” response form not encompassed by forms i, ii, and iii.
Figure 15: Percent correct within conditions across Experiments 1, 2, 4, and 5. Affordances constrained, on the left-hand side, includes participants from Experiments 1 and 4. No constraints, on the right-hand side, includes participants from Experiments 2 and 5. *p < .05. **p < .01. ***p < .001
Appendix

Tables 1 and 2 below display the instructions and their corresponding stimulus arrays. A more comprehensive look at the instructions, stimuli, stimulus locations, tools, and pictures of the stimulus arrays can be accessed and downloaded for viewing here:

https://osf.io/9suwq/.
Table 1

Practice Round Instructions & Stimulus Arrays from Experiments 1-3

<table>
<thead>
<tr>
<th>No tool</th>
<th>Tool</th>
</tr>
</thead>
<tbody>
<tr>
<td>Touch the stapler.</td>
<td>Cut the paper.</td>
</tr>
<tr>
<td>Open the tupperware.</td>
<td>Pinch the hat.</td>
</tr>
</tbody>
</table>

Note. Tools are pictured above each array, but were handed to participants separate the array on all trials.
<table>
<thead>
<tr>
<th>No tool</th>
<th>Tool</th>
</tr>
</thead>
<tbody>
<tr>
<td>Put the baseball in the glove on the target.</td>
<td>Put the screw in the glass on the cloth.</td>
</tr>
<tr>
<td>Put the rock in the hat on the picture.</td>
<td>Put the sugar cubes in the glass on the plate.</td>
</tr>
<tr>
<td>Put the toothbrush in the cup on the coaster.</td>
<td>Put the paper in the strainer on the whiteboard.</td>
</tr>
<tr>
<td>Put the CD in the case on the cloth.</td>
<td>Put the tea in the glass on the notebook.</td>
</tr>
<tr>
<td>Put the lid on the container in the box.</td>
<td>Put the flashlight on the book in the bag.</td>
</tr>
<tr>
<td>Put the VHS tape on the magazine in the basket.</td>
<td>Put the water on the tile in the box.</td>
</tr>
<tr>
<td>Put the necklace on the trophy in the box.</td>
<td>Put the glove on the trophy in the carton.</td>
</tr>
<tr>
<td>No tool</td>
<td>Tool</td>
</tr>
<tr>
<td>---------</td>
<td>------</td>
</tr>
<tr>
<td>Place the straw in the bottle on the plate.</td>
<td>Put the beans on the plate in the pot.</td>
</tr>
<tr>
<td>Place the spoon in the coffee on the pan.</td>
<td>Place the ball in the container on the sock.</td>
</tr>
<tr>
<td>Place the ruler in the folder on the tray.</td>
<td>Place the money in the glass on the shirt.</td>
</tr>
<tr>
<td>Place the eraser in the container on the book.</td>
<td>Place the stick in the bottle on the notepad.</td>
</tr>
<tr>
<td>Place the toothpaste on the dish in the pot.</td>
<td>Place the wire on the receipt in the jar.</td>
</tr>
<tr>
<td>Place the spoon on the washcloth in the bowl.</td>
<td>Place the bracelet on the plate in the bag.</td>
</tr>
<tr>
<td>Place the clip on the mail in the binder.</td>
<td>Place the candle on the envelope in the ring.</td>
</tr>
<tr>
<td>Place the whistle on the folder in the box.</td>
<td>Place the tape on the can in the container.</td>
</tr>
</tbody>
</table>

Note. Tools are pictured above each array, but were handed to participants separate the array on all trials. Unambiguous instructions are not listed, but were constituted by the addition of "that is" or "that are" before the first prepositional phrase of each ambiguous-with-a-tool instruction.