Using Mechanical Turk to Obtain and Analyze English Acceptability Judgments

Edward Gibson[1], Steve Piantadosi[1] and Kristina Fedorenko[2]

[1] Department of Brain and Cognitive Sciences, MIT

[2] Smith College, Northampton, MA

Send correspondence to:

Edward Gibson, MIT 46-3035, Cambridge, MA 02139, USA

Email: egibson@mit.edu

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Abstract

The prevalent method in syntax and semantics research involves obtaining a judgment of the acceptability of a sentence / meaning pair, typically by just the author of the paper, sometimes with feedback from colleagues. The weakness of the traditional non-quantitative single-sentence / single-participant methodology, along with the existence of cognitive and social biases, has the unwanted effect that claims in the syntax and semantics literature cannot be trusted. Even if most of the judgments in an arbitrary syntax / semantics paper can be substantiated with rigorous quantitative experiments, the existence of a small set of judgments that do not conform to the authors' intuitions can have a large effect on the potential theories. Whereas it is clearly desirable to quantitatively evaluate all syntactic and semantic hypotheses, it has been time-consuming in the past to find a large pool of naïve experimental participants for behavioral experiments. The advent of Amazon.com's Mechanical Turk now makes this process very simple. Mechanical Turk is a marketplace interface that can be used for collecting behavioral data over the internet quickly and inexpensively. The cost of using an interface like Mechanical Turk is minimal, and the time that it takes for the results to be returned is very short. Many linguistic surveys can be completed within a day, at a cost of less than $50. In this paper, we provide detailed instructions for how to use our freely available software in order to (a) post linguistic acceptability surveys to Mechanical Turk; and (b) extract and analyze the resulting data. We hope that the availability of these easy-to-use tools will result in many more language researchers evaluating their hypotheses using rigorous quantitative experiments.

1. Introduction

The prevalent method in syntax and semantics research involves obtaining a judgment of the acceptability of a sentence / meaning pair, typically by just the author of the paper, sometimes with feedback from colleagues. The results obtained using this method are not necessarily generalizable because of (a) the small number of experimental participants (typically one); (b) the small number of experimental stimuli (typically one); and (c) cognitive biases on the part of the researcher and participants (Schütze, 1996; Cowart, 1997; Edelman & Christiansen, 2003; Wasow & Arnold, 2005; Ferreira, 2005; Marantz, 2005; Featherston, 2007; Myers, 2009, Gibson & Fedorenko, 2010, in press). Whereas in some circumstances gathering non-quantitative language evidence may be warranted – e.g., when gathering data is difficult, such as when there is limited access to a single speaker of a dying language, who may only be available for testing for a brief time – in most situations, it is best to have multiple experimental materials, presented to multiple naïve experimental participants. Consequently, the above authors have argued that future research in syntax and semantics should adopt the following standards, common in all behavioral sciences, when gathering behavioral data such as acceptability judgments: (a) include many experimental participants, all of whom are blind with respect to the research questions and hypotheses; (b) include many experimental materials, in order to rule out effects due to idiosyncratic properties of individual experimental items (e.g., particular lexical items used in the critical sentences); (c) include distractor materials so that the experimental manipulations are not obvious to the participants; and (d) present counterbalanced lists of items to different experimental participants (in different random orders) to avoid effects of presentation order.

One common but fallacious argument that is sometimes given by researchers who argue

for continuing to use the traditional single-sentence / single-participant non-quantitative method is that it would be inefficient for the field to evaluate empirical claims in a rigorous quantitative manner. For example Culicover & Jackendoff (2010) say the following: "It would cripple linguistic investigation if it were required that all judgments of ambiguity and grammaticality be subject to statistically rigorous experiments on naive subjects…" (Culicover & Jackendoff, 2010, p. 234). However, contrary to Culicover & Jackendoff's claim, we think that the opposite is true: the field's progress is probably slowed by *not* doing quantitative research. There are two related reasons for our position. First, many judgments in published papers turn out not to survive experimental evaluation. Consequently, theoretical claims based on such bogus findings have no basis. And yet, some of these claims are propagated in the field for years, leading researchers on mistaken paths, and slowing real progress. We elaborate this observation below. And second, publishing papers that don't adhere to the methodological standards of neighboring fields like cognitive science and neuroscience has the undesirable effect that the results presented in these papers will be ignored by researchers in these fields, because these results are based on an invalid methodology. This second point is critical for attracting new quantitatively-trained researchers into the field of language research.

Gibson & Fedorenko (in press) provide many instances of judgments in published papers turn out not to survive experimental evaluation (see also Schütze, 1996; Wasow & Arnold, 2005; Featherston, 2007; and Bresnan & Nikitina, 2009 for further additional examples like these). For example, consider multiple-wh-questions and embedded mutiple-wh-clauses in English, where it has been shown experimentally that there is a subject / object asymmetry, such that the items in which the wh-subject (e.g., *who*) is clause-initial as in (1) are more acceptable than items in which the wh-object (e.g., *what*) is clause-initial as in (2) (see Kuno & Robinson, 1972;

Chomsky, 1973 for the original claim; see Arnon et al., 2006; Fedorenko & Gibson, submitted, for experimental evidence in support of this claim):

(1) a. Who bought what?

b. Mary wondered who bought what.

(2) a. * What did who buy?

b. * Mary wondered what who bought.

Whereas the contrast between (1) and (2) is supported by quantitative evidence, a further purported contrast is not. In particular, it has been claimed by Bolinger (1978) and Kayne (1983) that sentences like those in (2) become more acceptable with a third wh-phrase added at the end:

(3) a. ?* What did who buy where?

b. ?* Mary wondered what who bought where.

This empirical claim has resulted in several theoretical attempts to explain it, by postulating additional mechanisms, or making additional assumptions (e.g., Kayne, 1983; Pesetsky, 1987, 2000; Richards, 2001). It turns out, however, that when this intuition is evaluated using quantitative experimental methods, it does not hold. In particular, Clifton, Fanselow & Frazier (2006) evaluated the relative acceptability of examples like (1b), (2b) and (3b), and whereas they found a reliable difference between examples like (1b) on the one hand and (2b) and (3b) on the other, they found no difference between examples like (2b) and (3b).

More recently, Fedorenko & Gibson (in press) evaluated the same kinds of materials in supportive contexts, and replicated Clifton et al., critically finding no difference between examples like (2b) and (3b).

As a second example of an acceptability judgment from the literature that has not survived experimental evaluation, consider the purported contrast between (4) and (5), due to Chomsky (1986):

(4) What do you wonder who saw?

(5) * I wonder what who saw.

Chomsky (1986) claims that (5) is ungrammatical, but (4) is much better, perhaps grammatical. Chomsky provides a detailed theory of the purported contrast. But it turns out that examples like (4) are *not* more acceptable than examples like (5). In fact, the *opposite* turns out to be true here: (5) is actually *more* acceptable that (4), as demonstrated by Gibson & Fedorenko (in press).

The point of these observations is that there are many examples in published syntax and semantics articles where the reported judgments do not match those of typical native speakers of the language in question. Gibson & Fedorenko (in press) argue that the reason for this disparity is a combination of the weak experimental method (a single-sentence judged by a single-participant, the author of the research article) together with the existence of *cognitive biases*, such as (a) the experimenter will often have a confirmation bias favoring the success of the predicted result, with the consequence that he/she will tend to justify ignoring intuitions from speakers that do not fit the predicted pattern (Wason, 1960; Evans, Barston & Pollard, 1983; see

Nickerson, 1998, for a summary of many kinds of cognitive biases); and (b) the experimenter, and in some cases the people providing the judgments, will be unconsciously affected by the hypotheses in making their judgments about the relevant experimental materials. Furthermore, social factors may affect behavior in non-quantitative evaluations of hypotheses, so that, for example, people providing the judgments may be biased because they subconsciously want to please the experimenter. These are unconscious biases that affect all people, researchers included.[1]

It is critical to understand how serious this problem is for current research. Even if most of the judgments in an arbitrary syntax / semantics paper can be substantiated with rigorous experiments, the existence of a small set of judgments that do not conform to the authors' intuitions can have a large effect on the potential theories. The problem lies in not knowing which judgments are reliable, and which are not. A typical syntax / semantics paper that lacks quantitative evidence includes judgments for 50-100 sentences / meaning pairs, corresponding to 50-100 empirical claims. Furthermore, suppose that 90% of the judgments from such a paper are correct, which is probably a conservative estimate.[2] This means that in a paper with 70 empirical

[1] As discussed in Gibson & Fedorenko (in press), cognitive biases also affect these authors themselves, just like everyone else. Gibson & Fedorenko provide an example from the sentence processing literature in which Gibson (1991) offered judgments of a purported contrast which in fact did not exist, as demonstrated by later experimental work.

[2] It is difficult to estimate the percentage of judgments in a typical syntax / semantics paper that are correct. In one extreme, most quantitative acceptability judgment studies that have been run in the Gibson lab at MIT which investigate syntactic / semantic hypotheses in the literature have resulted in patterns of data that were not predicted by the existing literature (e.g., Fedorenko & Gibson, in press; Patel et al., submitted; Scontras & Gibson, submitted; Bergen, Fedorenko & Gibson, 2010). In contrast, Colin Phillips and some members of his group have told us that, in their experience, quantitative acceptability judgment studies usually validate the claims that they have tested in the literature. The difference in experience between Gibson's lab and Phillips' lab may reflect a selection bias in the researchers' approaches: one addressing perceived weaknesses in the syntax / semantics literature, and the other addressing perceived strengths. In order to get a better estimate of the percentage of judgments in an arbitrary syntax / semantics paper that withstand rigorous quantitative evaluation, one would have to sample random claims from many random papers, across a range of journals, and evaluate these. In the absence of an empirically-assessed estimate, we are forced to make rough estimates. The estimate from the Gibson research lab might suggest that the true proportion would be low, maybe 50% or 75%. On the other hand, the estimate from the Phillips lab might suggest that the true proportion may be higher.

claims, 63 of those 70 claims are correct. But which 63? There are 1,198,774,720 ways to choose 63 items from 70. That's over a billion different theories. In fact, the number of possible theories is even larger, because this result assumes that an experiment will either support or reject a hypothesis, whereas in many cases, the results may be in between, offering partial support or partial rejection of a hypothesis.

Amazon.com's Mechanical Turk

While it is clearly desirable to quantitatively evaluate all syntactic and semantic hypotheses, it has been time-consuming in the past to find a large pool of naïve experimental participants for behavioral experiments. The advent of Amazon.com's Mechanical Turk[3] now makes this process very simple. Mechanical Turk is a crowd-sourcing internet marketplace interface that can be used for collecting behavioral data quickly and inexpensively. Jobs ("Human Intelligence Tasks", HITs) are posted on the Mechanical Turk website (https://www.mturk.com/mturk/welcome) by *requestors*. The jobs are then performed by *workers*: people anywhere in the world, who want to get paid to do the posted jobs. Currently, the payment is through U.S.-based credit cards, so most of the workers and requestors are in the United States. We gathered demographic information on 519 Turk users for a recent experiment from September & October 2010 (see Piantadosi, Tenenbaum, Goodman, in prep.). Of these subjects, 58% were female. Users of Turk tend to be generally educated: only 2% do not have a

[3] Wikipedia explains the source of the name "Mechanical Turk" as follows: *The name Mechanical Turk comes from "The Turk" a chess-playing automaton of the 18th century, which was made by Wolfgang von Kempelen. It toured Europe beating the likes of Napoleon Bonaparte and Benjamin Franklin. It was later revealed that this "machine" was not an automaton at all but was in fact a chess master hidden in a special compartment controlling its operations. Likewise, the Mechanical Turk web service allows humans to help the machines of today perform tasks they aren't suited for.*

high school degree, 40% have only a high school degree and 41% completed up to a college degree. The remaining 17% report completing a graduate degree. In addition, most users spend less than 8 hours on Turk each week: 35% reported spending 0-4 hours on Mechanical Turk each week, 23% reported 4-8 hours, 17% reported 8-12 hours, and the remaining 25% spent more than 12 hours a week. The distribution of ages was largely unimodal, with a mean age of 34 and a range of 18 to 77 in our sample (participants younger than 18 were told they would not be able to participate). The form of the jobs to be performed on Mechanical Turk is typically anything that is difficult to do automatically, so that human labor is preferred, such as "identifying objects in a photo or video, performing data de-duplication, transcribing audio recordings, or researching data details" (https://www.mturk.com/mturk/help?helpPage=overview). Mechanical Turk is therefore perfect for testing hypotheses in behavioral psychology, including language.

Acceptability Judgment Surveys

Perhaps the most commonly used method in syntax and semantics research is the *acceptability judgment task* where participants are asked to judge the acceptability / naturalness of a sentence / meaning pair. The dependent measure in this task is a rating on some scale where the ends of the scale correspond to "acceptable" / "not acceptable", "natural" / "unnatural", "grammatical" / "ungrammatical", "good" / "bad", etc. In a non-quantitative (single-participant / single-item) version of the acceptability judgment task a two- or three-point scale is typically used, usually consisting of "good" / "natural" / "grammatical" / "acceptable" vs. "bad" / "unnatural" / "ungrammatical" / "unacceptable" (usually annotated with an asterisk "*" in the papers reporting such judgments), and sometimes including a judgment of "in between" / "questionable" (usually

annotated with a question mark "?").

In a quantitative version of the acceptability judgment task (with multiple participants and items) a fixed scale (a "Likert scale") with five or seven points is typically used. Alternatively, a geometric scale is sometimes used where the acceptability of each target sentence is compared to a reference sentence. This latter method is known as *magnitude estimation* (Bard et al., 1996). Although some researchers have hypothesized that magnitude estimation allows detecting more fine-grained distinctions than Likert scales (Bard et al., 1996; Keller, 2000; Featherston, 2005, 2007), controlled experiments using both Likert scales and magnitude estimation suggest that the two methods are equally sensitive (Weskott & Fanselow, 2008, 2009; Fedorenko & Gibson, submitted).

Although some researchers have criticized the acceptability judgment method because it requires participants to be aware of language as an object of evaluation, rather than simply as a means of communication (Edelman & Christiansen, 2003), there are two major advantages to this method: (1) it is an extremely simple and efficient task, which people can do quickly and reliably; and (2) results from acceptability judgment experiments are highly systematic across speakers, and correlate with other dependent measures, presumably because the same factors affect participants' responses across different measures (Schütze, 1996; Sorace & Keller, 2005).

Because of the simplicity of the acceptability judgment task, it is perhaps the easiest language task to implement for use on Mechanical Turk. The software that we provide here implements a Likert scale with five points. However, it is straightforward to adapt the html template that appears on Mechanical Turk in order to use a different scale (e.g., either a different number of fixed points on a Likert scale, or a magnitude estimation scale).

In the remainder of this paper, we describe four pieces of software, available at

http://tedlab.mit.edu/software/ which enable quick and easy use of Mechanical Turk for obtaining linguistic acceptability judgment data:

(1) `turkolizer.py`: A python program to create linguistic surveys from a turkolizer-formatted text file. This program takes lists of experimental and filler items for presentation in an acceptability judgment task, and organizes them in randomized, counterbalanced lists for presentation on Mechanical Turk. We also provide a sample turkolizer-formatted text file: `wh-question-expt.txt`

(2) `tedlab-turk-survey1.html / tedlab-turk-survey2.html`: Html templates for a 150-item survey on Mechanical Turk for items with one / two comprehension questions each

(3) `tedlab-turk-survey1-format.R / tedlab-turk-survey2-format.R`: R programs to format an output file from Mechanical Turk into an analyzable format assuming that there is one / two comprehensions question per experimental trial.

(4) `tedlab-turk-survey-analysis.R`: An R program to analyze the results from the survey using linear mixed effects regression methods.

We hope that the availability of these easy-to-use tools will result in many more language researchers evaluating their hypotheses using rigorous quantitative experiments, which would lead to strengthening the fields of syntax / semantics and building stronger connections between these fields and other areas of cognitive science.

2. Formatting items for presentation on Mechanical Turk

The *turkolizer* program takes an input file in turkolizer format (described below), and returns (a) a file to be uploaded on Mechanical Turk and (b) two files to help in decoding the acceptability judgment results that are returned from Mechanical Turk. A turkolizer file includes materials for any number of experiments, usually including one with the special name *filler*.

A fully-crossed factorial experimental design consists of an $n_1 * n_2 * \ldots n_m$ set of conditions, crossing the first factor's n_1 conditions by the second factor's n_2 conditions … by the *m*th factor's n_m conditions. Consider a two-factor example, examining the acceptability of wh-questions with two or three wh-phrases, from Fedorenko & Gibson (in press) (see also Kuno & Robinson, 1972; Chomsky, 1973; Bolinger, 1978; Kayne, 1983), where two factors are manipulated, and each factor has two conditions: subject-object order (subject-object, object-subject) and number of wh-phrases (3wh, 2wh). So, in this case, $n_1 = 2$ and $n_2 = 2$, resulting in a 2x2 design. The example in (6) presents one item in this experimental design, with all four conditions:

(6)

a. subject-object, 3wh: Peter was trying to remember who carried what when.

b. object-subject, 3wh: Peter was trying to remember what who carried when.

c. subject-object, 2wh: Peter was trying to remember who carried what.

d. object-subject, 2wh: Peter was trying to remember what who carried.

An experiment in turkolizer format[4] consists of a set of *sub-experiments*, each of which consists of a set of *trials*. One of the sub-experiments is typically designated as *filler*, with one

[4] The turkolizer format is very similar to the format in the program Linger, written by Doug Rohde, which can be downloaded at: http://tedlab.mit.edu/~dr/Linger/,

condition, also typically labeled *filler*. This sub-experiment contains distractor items for the other sub-experiments being run. Typically, there are at least twice as many filler items as items in a sub-experiment of interest.

In each sub-experiment, the *trials* have the format shown in Figure 1. The turkolizer format for the items in (6) is presented in Figure 2. A *trial* consists of three parts, each starting on a new line:

(a) The trial header. The trial header consists of four components, separated by spaces:

(i) the symbol "#";

(ii) the name of the experiment (e.g., “expt-name-1” in the example in Figure 1; “2WH3WH” in the example in Figure 2);

(iii) the item number within the experiment (a number from 1 to the number of items);

(iv) the condition name (e.g.,“condition-1-a” in the example in Figure 1; “3wh_SO”, “3wh_OS”, “2wh_SO”, and “2wh_OS” in the example in Figure 2). The condition names are not constrained in any way and could be any string of letters / numbers (e.g., “a”, “b”, “c”, etc.), but we find it is most perspicuous to use labels that reflect the experimental design (e.g., by using the values of the experimental factors, separated by underscores, as in Figure 2).

(b) The trial body. The trial body starts on the line following the trial header. It consists of any number of lines up until the trial question(s), or the next trial header (if there are no trial questions). Carriage returns are treated as carriage returns to be displayed as part of the item.

(c) The trial questions (optional for the purposes of turkolizer, but highly recommended from the standpoint of experimental design, as discussed below). The trial questions consist of a (possibly empty) set of questions about the trial body. The format for each trial question is as follows:

? Question? Answer

Each question is initiated and terminated by a question mark. Following the question is the correct answer value. The exact form of this answer needs to be present among the possible answers to be presented to participants (see Section 4 *Creating a presentation template on Mechanical Turk*).

We will present examples with Yes/No questions, so that the possible answers are always "Yes" or "No". As discussed in Section 4 below, the format of the answers needs to match the format of the answers in the Mechanical Turk presentation template, so "Yes" / "No" cannot be replaced with "Y"/"N" or "yes"/"no" for the template that we provide.

Every trial within and across sub-experiments that are being run together in one experiment must include the same number of trial questions.

Because the goal of Mechanical Turk participants is to finish the work as quickly and efficiently as possible (because they are paid by the job, not by the time spent), it is wise to include at least one comprehension question for each trial. This will ensure that participants are reading and understanding the materials before rating them for acceptability. When items are more complex, e.g., include a context of 1-3 sentences, then it is wise to include two or more questions per item to ensure that participants are reading and understanding all the relevant

elements of the context. In most cases, each participant will only see one version of an item – e.g., only one of the trials for the example in Figure 2. In such cases, it is ok to use the same comprehension question for all the conditions of an item. However, in cases where a participant sees all the conditions of an item, different questions should be used.

```
# expt-name-1 item-num condition-1-a
An experimental item
which can be over multiple lines
like this
? Question 1? Yes
? Question 2? No
```

Figure 1: The turkolizer format for a trial in an experiment.

```
# 2WH3WH 1 3wh_SO
Peter tried to remember who carried what when.
? Did Peter try to carry something? No

# 2WH3WH 1 3wh_OS
Peter tried to remember what who carried when.
? Did Peter try to carry something? No

# 2WH3WH 1 2wh_SO
Peter tried to remember who carried what.
? Did Peter try to carry something? No

# 2WH3WH 1 2wh_OS
Peter tried to remember what who carried.
? Did Peter try to carry something? No
```

Figure 2: The turkolizer format for the four conditions in example (1).

3. Creating lists of experimental items to be uploaded on Mechanical Turk

To run the Python program *turkolizer*, simply include the program `turkolizer.py` in the

current directory, and type `"python turkolizer.py"` in a UNIX shell[5]. The program will then ask for some information, as in the following example:

```
egibson$ python turkolizer.py

Please enter the name of the text file: myexperiment.txt
Please enter the desired number of lists: 80
Please enter the desired number of in-between trials: 1
Please enter the desired number of fillers in the beginning of
each list: 3

Processing the text file...

Number of experiments: 2

Experiment: filler
       - 40 items
       - 1 conditions
       - 40 trials
       - number of questions: 1
       - conditions:
['filler']

Experiment: 2WH3WH
       - 20 items
       - 4 conditions
       - 80 trials
       - number of questions: 1
       - conditions:
['2wh_OS', '2wh_SO', '3wh_OS', '3wh_SO']

Performing a check of the parameters...
Creating a latin square...
Creating LCM ( 4 ) lists...
Creating 80 lists...
Randomizing each list...
Creating two csv files...
------- DONE! -------
egibson$
```

First, the program will ask for the name of the turkolizer input file that needs to be

[5] If you don't use mac or linux, Cygwin (http://www.cygwin.com/) allows you to run unix shells on windows.

located in the current directory. In the above example, this file is named `myexperiment.txt`. The turkolizer program then asks for the number of lists that the user wants to generate. This is the number of participants that the user wants to run in the experiment on Mechanical Turk. Each presentation list that the program generates will be a different randomized order of the experimental items, across the different sub-experiments. The program takes one version of each item in a sub-experiment, such that there is the same number of items from each condition in a sub-experiment in each list that is generated, using a Latin Square design. Assuming that there are *k* items in a sub-experiment with *i* conditions, with *j* items in each condition (such that $i * j = k$), the first list in the Latin Square is generated by taking the first *j* items in condition 1, the next *j* items in condition 2, … and the last *j* items in condition *i*. The next list in the Latin Square is generated by taking the second *j* items in condition 1, the next *j* items in condition 2, … and the first *j* items in condition *i*, and so on for the rest of the lists in the Latin Square.

The number of presentation lists that the user should request should generally be a multiple of the least common multiple (LCM) of the number of conditions in each of the experiments, so that each experiment will be run on a balanced number of participants in each of the lists in its Latin Square.[6] For example, if you ran an experiment consisting of one sub-experiment with six conditions, another with four conditions, and a third with five conditions, then you should run some multiple of LCM (6, 4, 5) = 60 participants. In the simpler example above, there is a single sub-experiment with four conditions (along with a filler sub-experiment, which has only one condition). Thus, the number of lists that were run in this experiment was a multiple of four (80, in this case, thus giving 20 participants for each of the sets of items in the

[6] In practice, some participants are usually omitted from analysis, for one of several reasons (see Section 8, *Analyzing your results*). Such participants can be replaced, if fully balanced lists are desired.

Latin Square for the experiment).

Next, the program asks the user to enter the number of items from other experiments and fillers that the user wants to have between experimental items in any given sub-experiment. It is generally not a good idea to have items from the same sub-experiment following one another directly, because then the participant may be able to determine or make guesses about the kinds of phenomena that the sub-experiment is investigating (which is generally undesirable). Consequently, it is usually a good idea to separate items in a sub-experiment by filler items or items in other sub-experiment(s). In the example above, the number of between-items was entered as "1", so that no two items from the same sub-experiment would ever appear back-to-back within any list that is presented to an experimental participant. Hence, if you want to have at least *n* items separating two items from the same sub-experiment, then you must have enough fillers and/or sub-experiments to make this possible, otherwise an error message will be presented.

Finally, the user is asked to enter the number of filler items that they would like to initiate each presentation list. Initiating lists with filler items is motivated again by wanting the experimental participants to have as little knowledge as possible about the theoretical questions that the critical sub-experiment(s) is/are addressing. In the example above, the number of initial filler items is three.

If there are inconsistencies between the user's desired experimental set-up and the sub-experiments that are in the turkolizer input file (e.g., not enough fillers to suit the desires of the user; or an incorrectly formatted input file), then error messages will be output to the screen. Otherwise, the turkolizer program will now print some information about each of the sub-experiments to the screen, and will output three files to the current directory. If the input file was

named `myexperiment.txt`, then the output files will be named as follows:

```
myexperiment.turk.csv
myexperiment.decode.csv
myexperiment.correct.csv
```

The file `myexperiment.turk.csv` is a comma-separated-value (csv) file containing each of the randomized lists of trials. If the user requested *n* lists for their Mechanical Turk survey, then this file will contain *n+1* lines: one header line with the names for variables that are included in the Mechanical Turk template to be described in the following section, and one line for each randomized-order list.

The file `myexperiment.decode.csv` is a csv file containing information indicating which item in each experimental list is in which condition. The file `myexperiment.correct.csv` is a csv file that contains the correct answers to the comprehension questions. The last two files are used in decoding the responses from participants on Mechanical Turk (see Section 7, *Transforming the Mechanical Turk output into an easily analyzable format*).

4. Creating a presentation template on Mechanical Turk

Before you can upload your experiment onto Mechanical Turk, you will need to log in to https://www.mturk.com/mturk/welcome as a *requestor*[7]. Once you have set up an account for

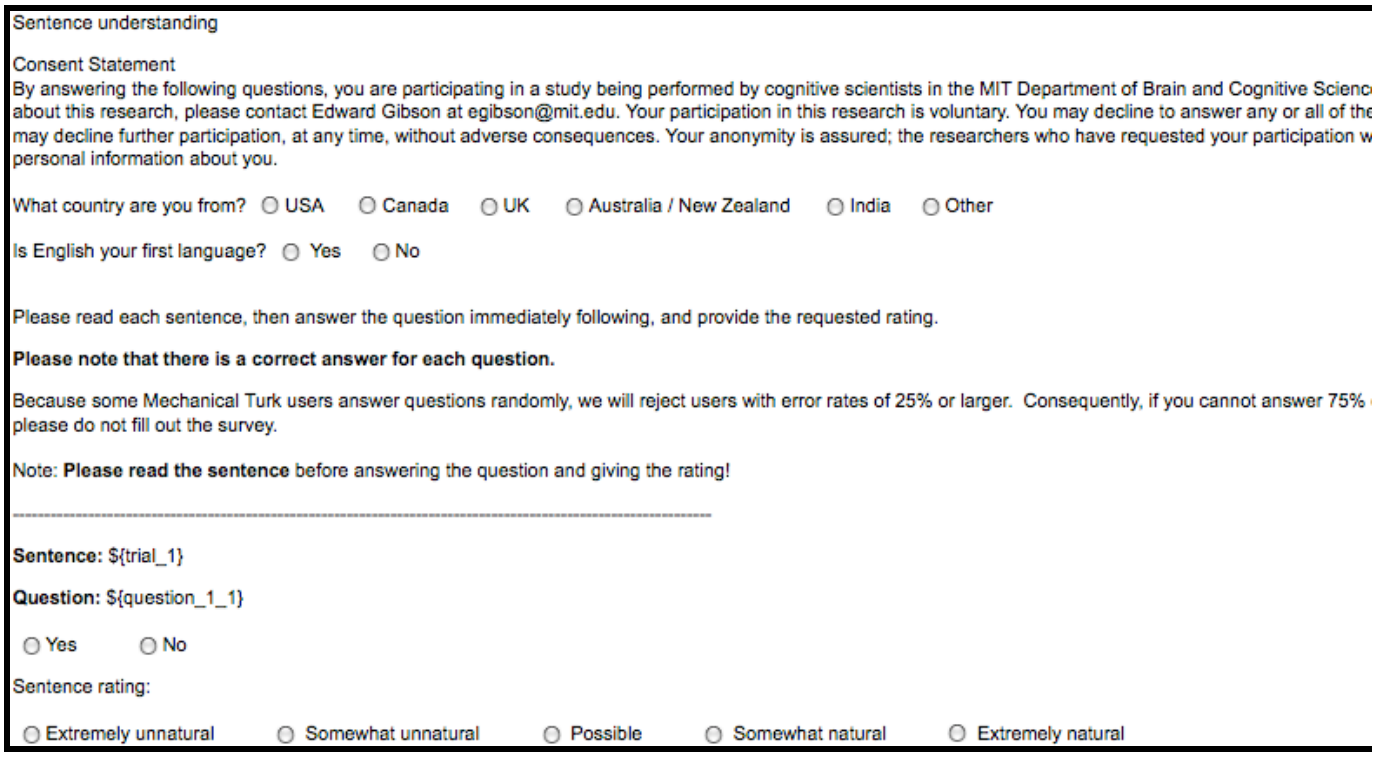
[7] Alternatively, if you log in as a *worker*, then you can perform jobs like the ones that we are describing here.

yourself and are logged in, you will need to design a template for your "HIT" (Human Intelligence Task). We have set up two templates at http://tedlab.mit.edu/software/ for users to download and edit for linguistic acceptability tasks. The first of these – `tedlab-turk-survey1.html` – is a template for a survey with 150 trials with one comprehension question each. The second of these – `tedlab-turk-survey2.html` – is a template for a survey with 150 items with two comprehension questions each. The beginning of the first of these templates is provided in Figure 3. Each of these templates is initiated by a simple consent statement which has been approved by MIT's Institutional Review Board (IRB). If you represent a university or institution, then you need to obtain approval for your proposed experiments before you run them on Mechanical Turk. There are two questions following the consent statement: (1) "What country are you from?" followed by a list of five English-speaking countries; and (2) "Is English your first language?". We generally restrict the location of the IP addresses of the respondents to our surveys to be from the US, so that the population is fairly uniform in their dialect (American English). People are then paid for their participation, as long as they can answer the comprehension questions following each item. We then generally restrict analyses to native English speakers from the US. Note that because we pay people no matter whether they indicate that they are native English speakers or not, participants have no motivation to pretend to be native English speakers.

Depending on whether you want a survey with one or two questions following each item in the survey, you should select the appropriate template for editing (if you want a survey with no questions or more than two questions, you can edit the current templates accordingly). Simply edit out the items that you do not need, and upload the resulting template at the "Design" section of the Mechanical Turk website (https://requester.mturk.com/bulk/hit_templates). If you

need more that 150 items, then simply follow the format for each item that is added. The current templates are set up with five possible acceptability rating values: "Extremely unnatural", "Somewhat unnatural", "Possible", "Somewhat natural", and "Extremely natural". In analysis, these ratings are translated to the numbers 1 (Extremely unnatural) – 5 (Extremely natural).

Note that the templates that we provide require that the only possible answer choices given to the participants are "Yes" or "No" (not "Y" and "N", or "yes" and "no", etc.). Thus, if other answers are required, then the templates need to be edited accordingly.


Sentence understanding

Consent Statement
By answering the following questions, you are participating in a study being performed by cognitive scientists in the MIT Department of Brain and Cognitive Scienc
about this research, please contact Edward Gibson at egibson@mit.edu. Your participation in this research is voluntary. You may decline to answer any or all of the
may decline further participation, at any time, without adverse consequences. Your anonymity is assured; the researchers who have requested your participation w
personal information about you.

What country are you from? ○ USA ○ Canada ○ UK ○ Australia / New Zealand ○ India ○ Other

Is English your first language? ○ Yes ○ No

Please read each sentence, then answer the question immediately following, and provide the requested rating.

Please note that there is a correct answer for each question.

Because some Mechanical Turk users answer questions randomly, we will reject users with error rates of 25% or larger. Consequently, if you cannot answer 75%
please do not fill out the survey.

Note: **Please read the sentence** before answering the question and giving the rating!

Sentence: ${trial_1}

Question: ${question_1_1}

○ Yes ○ No

Sentence rating:

○ Extremely unnatural ○ Somewhat unnatural ○ Possible ○ Somewhat natural ○ Extremely natural

Figure 3. A consent statement and instructions in a Mechanical Turk linguistic acceptability survey.

5. Uploading the materials on Mechanical Turk

Once the template is designed and saved, click on the "Publish" button on the Mechanical Turk website (https://requester.mturk.com/bulk/batches/new). Now select the appropriate template for use, and follow the Mechanical Turk instruction to upload your experimental item lists in the file `myexperiment.turk.csv` created in Section 3 (*Creating lists of experimental items to be uploaded on Mechanical Turk*). Select the appropriate rate of payment, and publish the survey on Mechanical Turk.

Depending on your rate of pay (anything over $2 / hour will probably generate very high demand for your survey), you should get your results within a few hours, or perhaps a day.

6. Downloading the results of your experiments from Mechanical Turk

Click on the "Manage" button on the Mechanical Turk website to see the progress of your survey. Once the survey is complete, click on the "Results" button on the website. You can approve or reject the results from each participant at this point, but we recommend first downloading the results, in order to see how the participants did in answering your comprehension questions, and approving / rejecting them based on their performance. Download the results of your survey by clicking the "Download CSV" button.

Once you have analyzed the response accuracy rates of participants (see Section 7), return to the "Manage" section of your Mechanical Turk webpage. Click on the results of the survey again. We recommend accepting results from each participant who completed at least 80% of the survey, and who answered the comprehension questions correctly at least 75% of the time. Because there are no memory demands on these rating surveys, this accuracy rate should be very easy for conscientious (English-speaking) participants to achieve. Very few participants

should be below 75% accuracy. If there are a substantial number, then there may be something wrong with the answers to your survey.

7. Transforming your Mechanical Turk output into an easily analyzable format

The output from Mechanical Turk consists of a csv file with a name like "`Batch_999999_result.csv`". This file consists of a header row consisting of names for each of its columns, followed by one row for each participant's values for each of the columns. Thus, if there are *n* participants in the survey, there will be *n+1* rows in the Mechanical Turk output file.

The first thing to do to the output file is to edit out the final two columns on the first row of the file, "Approve" and "Reject". Using a text editor, delete these words on the first row together with the commas preceding them.[8]

Once you have edited your turk-output file, you are now ready to process the results into a format that can be used for statistical analysis. You perform this preprocessing step using the R analysis program `tedlab-turk-survey1-format.R`, or `tedlab-turk-survey2-format.R`. Use `tedlab-turk-survey1-format.R` if you have one comprehension question per experimental trial. Use `tedlab-turk-survey2-format.R` if you have two comprehension questions per experimental trial.

[8] Don't try to edit this file using the program Excel: depending on your version of Excel, the turk-output file may have too many columns for Excel to load it properly. Use some other simple editing program, like "TextEdit" on Apple platforms, "Notepad" on windows, "Kwrite" on linux, or "emacs" on any platform.

Rename the relevant file to suit your experiment (e.g., `myexperiment-turk-survey-format.R`) and start R (e.g., by double-clicking on the program in your finder window on a Mac). You will need to have installed R on your computer to use this program. R is freely available from http://www.r-project.org/. We generally use a package called "lattice" for visualization, and a package "languageR" for analyses; both are available from CRAN (http://cran.r-project.org/), the Comprehensive R Archive Network. You can generally install packages using the R command `install.packages`. You can read about this and other functions in R by typing a question mark before the function name into the R console: `?install.packages`.

Once R is running, you can edit the file `myexperiment-turk-survey-format.R`. Three lines in this file need to be edited:

```
turk.output.file <- "Batch_xxxxxx_result.csv"
decode.file <- "xxx.decode.csv"
correct.file <- "xxx.correct.csv"
```

First, edit the turk.output.file name "`Batch_xxxxxx_result.csv`" so that it matches your turk output file name. Second, edit the decode.file name so that it is the name of the file for item decoding from Section 3 (e.g., `myexperiment.decode.csv` from Section 3). Third, edit the correct.file name so that it is the name of the file with the correct answers for comprehension questions from Section 3 (e.g., `myexperiment.correct.csv` from Section 3).

Now load the `myexperiment-turk-survey-format.R` into the R shell. In the R shell, type "`participant.summary.info`", which is the name of a variable which includes summary information about the participants in the experiment: (a) Answer.country: what country

they are from; (b) Answer. English: whether English is their native language; (c) Accuracy: their accuracy rate across the comprehension questions in the experiment; (d) NAPercent: their rate of leaving answers blank; and (e) ResponseCount: the number of responses that this participant was presented with. An artificial example is provided in Figure 4.

```
> participant.summary.info
      Participant  Accuracy   NAPercent ResponseCount Answer.country Answer.English
1  A10GDZ6LSVPO9C 0.9306931 0.009803922           102             USA            yes
2  A1338BOIT0IEBT 0.9019608 0.000000000           102             USA            yes
3  A149N3D2483WXS 0.9215686 0.000000000           102             USA            yes
4  A14X7JN1CL4I5K 0.9405941 0.009803922           102             USA            yes
5  A16JTXYL3MQ77P 0.8811881 0.009803922           102             USA            yes
6   A16Q77JGW17NA 0.8910891 0.009803922           102             USA            yes
7  A1APGSHXCIUAM5 0.7647059 0.000000000           102             CAN            yes
8  A1DU3I57BN5079 0.9509804 0.000000000           102             USA            yes
9  A1DXXMYU2HRU6N 0.9313725 0.000000000           102             USA            yes
10 A1GUGP8HBVU668 0.9019608 0.000000000           102             USA            yes
11 A1JRBA1EMMGWRJ 0.9313725 0.000000000           102             USA            yes
12 A1KL8HZHJ6AWC9 0.7128713 0.009803922           102             USA            yes
13 A1MRHIA5YGGBY4 0.9300000 0.019607843           102             USA            yes
14 A1NUA58PEFFN45 0.9702970 0.009803922           102             USA            no
15 A1OK4SKO6L7OND 0.9285714 0.588235294           102             USA            yes
16 A1OLRUT93TXWEP 0.9411765 0.000000000           102             USA            yes
17 A1QRJ6ZGZNMTRC 0.9117647 0.000000000           102             USA            yes
18 A1RWNYJA5X25YH 0.9215686 0.000000000           102             USA            yes
19 A1T4AT8PX9GNY5 0.9117647 0.000000000           102             USA            yes
20 A1X86TQB8KO6OR 0.9509804 0.000000000           204             USA            yes
```

Figure 4. Sample `participant.summary.info`. The participant ID number is provided by Mechanical Turk.

The final line in the R formatting code filters (a) participants that are not from the USA, such as participant 7 from Canada in Figure 4; (b) participants who are not native English speakers, such as participant 14 in Figure 4; (c) participants with accuracy rates below 75%, such as participant 12 in Figure 4; (d) participants with an NAPercent rate of 20% or higher, such as participant 15 in Figure 4; and (e) participants who filled out more than the total number of

responses on one survey, such as participant 20 in Figure 4, who has filled out the survey twice (which had 102 ratings), resulting in twice as many possible answers.

In practice, we find that few participants need to be filtered from an experiment, usually fewer than 5% or 10%. Some of the participants were artificially created in the above example in order to illustrate each filtering step.

8. Analyzing your results using regression analyses in R

Now you are ready to analyze your results using regressions in R. While a full discussion of R and statistical analysis methods is beyond the scope of this paper we will present very preliminary first steps in analyzing this type of data in R. We refer the reader to other sources for details on how to perform a more complete analysis of data: Gelman & Hill (2007) for regression; DeGroot & Schervish (1986) for statistics; and Venables & Ripley (2000) and Baayen (2008) for R.

In order to do begin to analyze your data, edit the file `tedlab-turk-survey-analysis.R`. We recommend putting all analysis scripts and data in a separate directory for each experiment, and editing analysis scripts rather than just typing into the R console. Having a script ensures replicability and creates a record of what you have done. In `tedlab-turk-survey-analysis.R`, we first define the appropriate factors for each experiment as fields in the data-frame for analysis. This is necessary because the turkolizer script requires factor names and values in a single field ("Condition"), but it is more convenient – for analysis purposes – to have one column for each factor, with different values for each factor value. This is done by editing the R code lines in Figure 5.

```
### this example set of factors assumes two factors: Factor1 and Factor2
### The values for Factor1 are Factor1_Value1 and Factor1_Value2
### The values for Factor2 are Factor2_Value1, Factor2_Value2, and Factor2_Value3

mydata$Factor1 <- NA
mydata[mydata$Condition == "Factor1_Value1_Factor2_Value1",]$Factor1 <- "Factor1_Value1"
mydata[mydata$Condition == "Factor1_Value1_Factor2_Value2",]$Factor1 <- "Factor1_Value1"
mydata[mydata$Condition == "Factor1_Value1_Factor2_Value3",]$Factor1 <- "Factor1_Value1"

mydata[mydata$Condition == "Factor1_Value2_Factor2_Value1",]$Factor1 <- "Factor1_Value2"
mydata[mydata$Condition == "Factor1_Value2_Factor2_Value2",]$Factor1 <- "Factor1_Value2"
mydata[mydata$Condition == "Factor1_Value2_Factor2_Value3",]$Factor1 <- "Factor1_Value2"

# set the order of factors for the regression (first is the baseline)
mydata$Factor1 <- factor(as.character(mydata$Factor1), levels=c("Factor1_Value1",
"Factor1_Value1"))
```

Figure 5. R code to be edited in order to define the appropriate factors to be analyzed in each experiment.

In order to analyze each sub-experiment using a regression, we first provide factor names for each condition in the sub-experiment. Suppose that sub-experiment 1 has two factors, Factor1 and Factor2. Furthermore, suppose that Factor1 has two values Factor1_Value1 and Factor1_Value2, while Factor2 has three values Factor2_Value1, Factor2_Value2 and Factor2_Value3. The code in Figure 5 creates one factor for each of the conditions in the sub-experiment, and associates the appropriate element in the data-frame with each value for that factor. All the user has to do here is replace the factor names and value names provided in the code in `tedlab-turk-survey-analysis.R` with the appropriate factor and value names for the conditions in their sub-experiments.

Once this step has been completed, the first – also, most important – step is to visualize the data. This helps to ensure that unexpected things have not happened in the course of the experiment (such as subjects answering the same way for all ratings) or during the conversion of

data to the correct format. It also gives you an understanding of what the general patterns in the data look like: how the statistics should come out. As mentioned above, we use the "lattice" library for visualization. With this library, simple ratings can be visualized for each condition by entering:

```
histogram( ~ Answer.rating | Factor1 * Factor2, data=mydata )
```

This command plots a histogram of Answer.rating for each combination of Factor1 and Factor2. To visualize the data without separating by both factors you can use:

```
histogram( ~ Answer.rating | Factor1 , data=mydata )
```

to collapse over Factor2, but not Factor 1, and

```
histogram( ~ Answer.rating, data=mydata )
```

to collapse over both factors.

A second useful command, `aggregate`, computes the mean rating for every value of any column of `mydata`. For instance to see the mean ratings by subject you could compute

```
aggregate(mydata$Answer.rating, by=list(mydata$WorkerId), mean)
```

This command returns a new data frame with one line for each value of WorkerId, corresponding to the mean of Answer.rating. To compute the mean by subject and condition, additional columns can be added to the "by" part of this command, as in

```
aggregate(mydata$Answer.rating, by=list(mydata$WorkerId,
mydata$Factor1, mydata$Factor2), mean)
```

Note that the result of `aggregate` can be saved into a new variable, forming a new data frame that can be manipulated further.

The most basic and conservative statistical tests you can do are nonparametric, meaning that they do not make assumptions about the types of distributions the data come from. Many of these are built in in R: one simple one is the Wilcoxon test, which can be called in R using `wilcox.test`, and is roughly used to compare means between conditions. However, we generally find that parametric tests – in particular, mixed effect regressions – work reasonably well on rating data, even though the rating data does not strictly meet all of the assumptions of the regression. These regressions can be called in R by first loading the "languageR" package (via "library(languageR)") and then running the following command:

```
l <- lmer( Answer.Rating ~ Factor1 * Factor2 + (1 | Participant) + (1
| Item), data=mydata)
```

This command creates a regression predicting the rating from the two factors and random intercepts for participants and items. The p values for this regression should be computed using

```
pvals.fnc(l)
```

which will return estimated p values for this regression.

Use of these methods should be done with care and require an understanding of the logic of regressions and ways of checking to be sure that the analysis does the "right" thing. Particular care must be used on rating data because it does not strictly satisfy the assumptions of the regression. For instance, the ratings are bounded, which contradicts the assumptions underlying the use of normal linear regression. There do exist more sophisticated regression models such as *ordinal regression* for these kinds of data, but as long as ratings are not near an extreme of the scale, linear regression works well. We refer readers to Gelman & Hill (2002) for an excellent introduction to regression models.

9. Concluding remarks

It is our hope that this software will enable syntax and semantics researchers to be able to test their hypotheses using the acceptability judgment task on Mechanical Turk quickly and easily. In our experience, the largest remaining bottle-neck in doing syntax and semantics research is constructing multiple instances of the relevant construction, which can admittedly be time-consuming, especially if they have to be normed for various factors like frequencies of critical words or constructions or plausibility. But of course Mechanical Turk can be used to

perform plausibility norming and syntactic frequency norming (by means of a sentence completion task). So even material construction is greatly speeded up by the existence of Mechanical Turk. The advent of Amazon.com's Mechanical Turk allows many empirical claims in syntax and semantics to be tested easily. We hope that it will further the adoption of quantitative methods, advancing the empirical standards of linguistics to those found in other psychological sciences.

References

Arnon, I., Snider, N., Hofmeister, P. Jaeger, T.F. & Sag, I.A. (2007) Cross-Linguistic Variation in a Processing Account: The Case of Multiple Wh-Questions. Proceedings of Berkeley Linguistics Society, 32.

Baayen, R.H. (2008). *Analyzing linguistic data: A practical introduction to statistics using R.* Cambridge University Press, Cambridge, UK.

Bergen, L., Fedorenko, E. & Gibson, E. (2010). Empirically measuring presuppositions. Tedlab presentation, Department of Brain and Cognitive Sciences, MIT.

Bates, D., Maechler, M. and Dai, B. (2008). lme4: Linear mixed-effects models using S4 classes. R package version 0.999375-27. http://lme4.r-forge.r-project.org/

Bolinger, D. (1978). Asking more than one thing at a time. In Hiz (Ed.), *Questions.* Dordrecht: D. Reidel.

Chomsky, N. (1973). Conditions on transformations. In S. Anderson & P. Kiparsky, eds., *A festschrift for Morris Halle*, pp. 232-86. New York: Holt, Rinehart & Winston.

Cowart, W. (1997). *Experimental syntax: Applying objective methods to sentence judgments*. Thousand Oaks, CA: Sage Publications.

DeGroot, M.H., Schervish, M.J., Fang, X., Lu, L. & Li, D. (1986). *Probability and statistics*. Addison-Wesley, Reading, MA.

Edelman, S. & M. Christiansen. (2003). How seriously should we take Minimalist syntax? *Trends in Cognitive Sciences* 7: 60-61.

Fedorenko, E. & Gibson, E. (In press). Adding a third wh-phrase does not increase the acceptability of object-initial multiple-wh-questions. *Syntax.*

Ferreira, F. (2005). Psycholinguistics, formal grammars, and cognitive science. *The Linguistic Review,* 22, 365-380.

Gelman, A. & Hill, J. (2007). *Data analysis using regression and multilevel/hierarchical models.* Cambridge University Press, Cambridge, UK.

Gibson, E. & Fedorenko, E. (2010). Weak quantitative standards in linguistics research. *Trends in Cognitive Science, 14, 233-234.*

Gibson, E. & Fedorenko, E. (In press). The need for quantitative methods in syntax and semantics research. *Language and Cognitive Processes.*

Kayne, R. (1983). Connectedness. *Linguistic Inquiry*, 14, 223-249.

Kuno, S. and Robinson, J. (1972). Multiple wh-questions. *Linguistic Inquiry, 3*, 463-487.

Marantz, A. (2005). Generative linguistics within the cognitive neuroscience of language. *The Linguistic Review,* 22, 429-445.

Myers, J. (2009). Syntactic judgment experiments. *Language and Linguistics Compass* 3, 406–423.

Piantadosi, S.T., Tenenbaum, J.B, Goodman, N. (in preparation). Representation languages for complex compositional concepts. Department of Brain and Cognitive Sciences, MIT.

R Core Development Team, (2008). R: A Language and Environment for Statistical Computing. Vienna, Austria: R Foundation for Statistical Computing. http://www.R-project.org

Schütze, C. (1996). *The empirical base of linguistics: Grammaticality judgments and linguistic methodology.* Chicago: University of Chicago Press.

Venables, W.N. & Ripley, B.D. (2000). *S programming*. Springer Verlag.

Wasow, T. & Arnold, J. (2005). Intuitions in linguistic argumentation. *Lingua,* 115, 1481-1496.