**Pre-registration Details for a Multi-Lab Replication of the Action-sentence Compatibility Effect (ACE)**

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Participating labs will be listed in a separate document.

**Rationale**

The Action-sentence Compatibility Effect (ACE) is a motor compatibility effect first reported by Glenberg and Kaschak (2002). The canonical demonstration of the ACE is as follows. Participants read (or listen to) sentences describing directional action (e.g., *Meghan handed you the book* is an action *toward* you, and *You handed Meghan the book* is an action *away* from you). They are asked to judge if the sentence is sensible. The sensibility judgment is made by executing an action either toward or away from the body. Participants make this response using a response device (button box; computer keyboard) that has three buttons: a central button that is held down while the sentence is presented, a button near the body (for a *toward* response) and a button farther from the body (for an *away* response). Indicating that the sentence is sensible requires participants to either a) lift off from the central button and hit the button farther away from their body, or b) lift off from the central button and hit the button closer to their body. The ACE is an interaction of the directional action depicted in the sentence and the directional action required to respond to the sentence: participants execute the action more quickly (typically indexed by the time required to read the sentence and lift off from the central button) when the direction of the sentence action matches the direction of the response action.

The ACE was one of the first demonstrations of a relationship between language comprehension and motor processing, and this effect (and similar effects reported using slightly different paradigms; Zwaan & Taylor, 2006; Bub & Masson, 2010) has been important in building the case for an *embodied* approach to language comprehension (see Ibanez et al., in press, for a review). Papesh (2015) recently published a set of experiments that question the reproducibility of the ACE. There are nine experiments reported in the paper, only one of which shows a reliable ACE. We disagree with Papesh’s (2015) interpretation of the strength of the evidence she presents against the reproducibility of the ACE (in our view at least 7 of the 9 experiments contained elements that would have made the ACE unlikely to occur). Nonetheless, we believe that the best way to resolve questions about the reproducibility of the ACE is to conduct a pre-registered, multi-lab replication of the effect.

To that end, we have established a network of researchers (see list at the beginning of this document) who have agreed to participate in the pre-registered replication effort. We have agreed to replicate the effect using the version of the ACE task first reported in Borreggine and Kaschak (2006). This version of the task involves auditory presentation of the sentences, and the use of a computer keyboard to collect the responses (full methodological details below).

# **Methods**

**Participants**

The participants will be right-handed, Native English speaking undergraduate students drawn from the participant pool typically used by each research team’s lab. Handedness will be determined by administering the Edinburgh Handedness Inventory (Oldfield, 1971). Participating labs will be asked to declare their sample size to the organizers of this replication effort in advance of their data collection efforts. The minimum sample size for participation in this effort will be 60 participants; the maximum will be 120 participants. Each participant will give informed consent in accordance with the Institutional Review Board’s Human Subjects Committee.

**Materials**

Sentences from Borreggine & Kaschak (2006) were recorded by a female speaker. The sound files were trimmed and adjusted using Audacity (Audacity team, 2015). The sentences consisted of forty critical trials (20 toward and 20 away sentences) and forty ungrammatical trials (see Appendix A). Sentence lengths ranged from 1022 – 2065ms (mean = 1501.09ms; standard deviation = 211.68ms).

**Procedure**

Participants sat at a computer that had its keyboard oriented perpendicular to their bodies, with the number pad closest to them, and the escape key farthest away. The keys that the participants were to use for their responses were the P key (this was the START key, with a white label), the Tab key (covered with a grey label) and the “+” key (covered with a black label). The participants were first asked to go through a powerpoint presentation that explained the task instructions. The powerpoint slides are included as a separate pre-registered document. Once participants finished the slide show, the experimenter asked them a series of questions to make sure they understood the task instructions. The protocol for these questions is listed in a separate pre-registered document. Participants were told that they would be making sensibility judgments about the sentences that they would be hearing. If the sentence was sensible, they were to make the appropriate response. If the sentence was not sensible, they were to continue holding the start button until prompted to go on to the next trial’s start.

Once the participants completed the initial task training (powerpoint presentation, plus the experimenter’s questions), they were randomly assigned to one of four counterbalanced lists, with the constraint that there was to be an equal number of participants per list version. Each list consisted of four cue/response practice (with no audio) trials with feedback provided, 18 (9 sensible) cue/response trials with filler sentences, and then the 80 experimental trials. As it was the procedure in the original paper (Borreggine & Kaschak, 2006), the 18 practice sentence trials lead seamlessly into the critical trials in order to reduce a practice effect.

At the end of the experiment, participants were asked whether they are aware of the ACE or any related effects (i.e., if they learned about them in class).

**Data Analysis**

*Analysis for Individual Experiments*

Participants will be excluded from the study if a) they fail to follow task instructions (e.g., not following the proper procedure for executing the task response), b) they fail to complete the experiment, or c) their performance on the task falls below 75% accuracy. Items will be excluded from the analysis of a lab’s dataset if they show an error rate > 15% within that lab.

There are three dependent measures in this experiment: *lift off time* (time between the onset of the sentence and the release of the start button), *movement time* (time from the lift-off from the start button until the pressing of the response key), and *accuracy*.

Accuracy data will be analyzed using mixed models logistic regression, with Sentence Direction (toward/away), Response Direction (toward/away), and the interaction of Sentence Direction and Response Direction as predictors. The model will include Participants and Items as crossed random factors. We will run an initial model without random slopes for Sentence Direction, Response Direction, and the interaction term, and then assess whether any of the possible random slopes improve model fit.

The lift-off and movement times will be analyzed as follows. First, response times from any trials on which an error occurred will be excluded. Second, we will screen the remaining response times for outliers. Any response time that is more than 2 standard deviations from the mean of a given participant’s response times within a cell of the design (i.e., a combination of Sentence Direction and Response Direction) will be excluded. The remaining data will be analyzed using mixed models regression, with Sentence Direction, Response Direction, and the Sentence Direction by Response Direction interaction as predictors, and Participants and Items as crossed random factors. As with the accuracy data, model fits will be used to determine which random slopes are included in the final model.

Our predictions for the data analysis are as follows. First, we do not anticipate effects on the accuracy variable. Although it is possible that effects will emerge, performance on this measure tends to be quite high and differences across conditions are small. Second, the critical result will be an interaction of Sentence Direction and Response Direction (i.e., the ACE) on the response time measures. We anticipate that this effect will emerge on the lift-off time (as in Glenberg & Kaschak, 2002), and that there will be no effect on the movement times.

As an ancillary analysis, we will include the responses to our post-experiment questions (i.e., is the participant familiar with the ACE?) as a predictor in our mixed models analysis to determine if the effect differs between participants who do and do not know about the effect. We anticipate that most participants will not be familiar with the effect, and so it is unclear whether we will have enough participants who know about the effect for this to be a useful analysis.

*Meta-analytic Strategy*

As of the date of this pre-registration, the meta-analytic strategy is still being finalized. In the interest of time, our plan is to begin data collection, and finalize this aspect of the project in the near future. The meta-analytic strategy will be pre-registered prior to labs examining their data, and will be listed in a separate document.

*Equivalence Testing*

As of the date of this pre-registration, the equivalence testing strategy is still being finalized. In the interest of time, our plan is to begin data collection, and finalize this aspect of the project in the near future. The equivalence testing strategy will be pre-registered prior to labs examining their data, and will be listed in a separate document.

*Ancillary Analyses*

Although not of primary interest in our replication effort, we plan to take advantage of the opportunities afforded by this large data collection effort to explore different factors that might affect the magnitude of the ACE. As in previous work (e.g., Glenberg & Kaschak, 2002), we will test whether abstract and concrete transfer sentences show an ACE of the same magnitude. We will also check for item-level effects, to determine whether the magnitude of the ACE is affected by factors such as the effector being used to execute the action of the sentence (e.g., sentences that imply action with the hands, as opposed to sentences that imply action with the feet).

*Non-native English Speakers*

A group of labs participating in this project will deviate from the main design by collecting data on high-proficiency non-native English speakers. The procedure for this data collection effort will be identical to the procedure described here, except that participants will have their English proficiency measured after the end of the main experiment.

References

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1. Audacity(R) software is copyright (c) 1999-2014 Audacity Team. The name Audacity(R) is a registered trademark of Dominic Mazzoni. [↑](#footnote-ref-1)