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The Crowbar Sabotaged the Machine: Effects of Verb Intentionality and Syntactic Structure on

Fixation Times During Reading

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Abstract

Research conducted by linguists has indicated that inanimate entities are incompatible with verbs that connote intentionality because inanimate entities lack the facilities to complete intentional actions. However, there are currently no studies that have analyzed this inappropriate relationship in real-time. To address this gap, the current eye-tracking experiment investigated the infelicitous nature of this relationship, as well as how it may be modulated by different syntactic structures. The experiment implemented a 2 x 2 within-subjects design, in which the independent variables were verb type (neutral versus intentional) and syntactic structure (main clause versus relative clause), and the dependent variables were gaze duration, regression path duration, and total time. The data were consistent with previous research, for there was greater processing difficulty when the verb was intentional than neutral, as well as when it appeared in the main clause compared to when it was in a relative clause. Crucially, there was an interaction, in which the processing difficulty imposed by intentional verbs was reduced when the verbs were embedded within a relative clause. The current experiment is the first to provide online evidence of the inappropriate relationship between inanimate entities and intentional verbs.

Keywords: eye-tracker, inanimate entities, intentional verbs, relative clause

The Crowbar Sabotaged the Machine: Effects of Verb Intentionality and Syntactic Structure on
Fixation Times During Reading

In many languages, it is common for animate nouns, such as humans and animals, to be the subjects of action verbs (Wolff, Jean, & Li, 2009). For example, sentences 1a and 1c have an animate subject, and the action verbs are “destroyed” and “killed,” respectively. Interestingly, some languages, such as English, allow inanimate nouns to be the subject of sentences, even if they are completing actions (Schlesinger, 1989; Wolff et al., 2009; Wolff, Jeon, Klettke, & Yu, 2010). For instance, sentences 1b and 1d have inanimate nouns—a crowbar and a gun—completing actions.

(1a) The man destroyed the machine.

(1b) The crowbar destroyed the machine.

(1c) The man killed the governor.

(1d) The gun killed the governor.

In English, it is acceptable to have inanimate nouns as the subject of action verbs because inanimate nouns can participate in causal expressions due to their ability to alter the state of the receiver (Wolff et al., 2010). As a result, inanimate nouns can be classified into two main categories based on the way they obtain their force and invoke change. Projectiles (e.g. balls and bullets) and instruments (e.g. tools and weapons) typically receive their energy from a human agent or some other external force (Alexiadou & Schäfer, 2006; Grimm, 2007; Lowder & Gordon, 2012; Schlesinger, 1989; Wolff et al., 2009, 2010). Meanwhile, the second class of inanimate nouns generate their own energy, and this includes natural forces, such as hurricanes and storms, and machines, such as computers and vehicles (Fillmore, 1968; Alexiadou & Schäfer, 2006; Grimm, 2007; Lowder & Gordon, 2015). Although inanimate objects may

generate their power differently, linguists have observed that inanimate nouns can be the subject of action verbs.

Even though English allows inanimate entities to be the subjects of sentences, previous research has observed that the acceptability of inanimate entities as subjects depends crucially on properties of the verb (Dillon, 1974; Grimm, 2007; Schlesinger, 1989). According to Schlesinger (1989) and Grimm (2007), when the verb connotes intentionality, planning, or involving cognitive processes, inanimate entities cannot be subjects of these verbs because they lack the ability to complete these actions. For example, sentences 2a and 2c are completely acceptable because the inanimate objects—the crowbar and the gun—are able to complete those actions (destroy and kill, respectively) on their own. Meanwhile, sentences 2b and 2d are infelicitous because the verbs “sabotage” and “assassinate” connote intentionality, and inanimate objects lack the facilities and capabilities to meaningfully carry out these intentional acts (Grimm, 2007). Similarly, according to Dillion (1974), verbs that express evil, unlawful, or wrongdoing acts, such as sabotage and assassinate, tend to require a [+ volitive] noun phrase, making them have an intentional connotation (p. 224).

(2a) The crowbar destroyed the machine.

(2b) The crowbar sabotaged the machine.

(2c) The gun killed the governor.

(2d) The gun assassinated the governor.

The purpose of the current experiment is to examine the processing of inanimate sentence subjects with verbs that differ in their degree of intentionality. In addition, the experiment examines how this effect is modulated by different syntactic structures. Examining the effects of syntactic structure is particularly important, as previous research has indicated that information

embedded within subordinate clauses tends to not be as deeply processed as information in the main clause (Baker & Wagner, 1987). This may occur because information in subordinate clauses is structurally separated from the main clause. Furthermore, Lowder and Gordon (2012) have illustrated that the processing difficulty associated with integrating an inanimate subject with an action verb is significantly reduced when the verb is embedded within a subordinate relative clause (3b) versus when it appears in the main clause of the sentence (3a). Therefore, sentence processing may be significantly altered by various syntactic structures.

(3a) The revolver shot the burglar in the bedroom.

(3b) The revolver that shot the burglar was in the bedroom.

Although linguists have observed that inanimate entities are incompatible with verbs that connote intentionality, this implication stems solely from offline measures, as opposed to online measures. Typically, linguists rely on offline measures, such as comprehension questions and act-out tasks, which gauge the effects of a manipulation after it has been processed. In contrast, psycholinguists implement online methods, such as eye-tracking, electroencephalography (EEG), and functional magnetic resonance imaging (fMRI), allowing psycholinguists to examine the effects of a manipulation as they are being processed in real time. One popular online method used by psycholinguists is eye-tracking because it provides millisecond-by-millisecond information on eye movements, fixation times, and saccades as a participant reads, creating a window into the cognitive processes as they naturally unfold. For example, Lowder and Gordon (2015) employed eye-tracking technology and found that acts of nature, such as hurricanes and tornadoes, are processed like animate agents even though they are inanimate. Similarly, eye-tracking measures have revealed greater processing difficulty for inanimate objects than animate ones (Lowder & Gordon, 2012). Interestingly, the literature only contains offline evidence for

the infelicitous nature of verbs that connote intentionality and their relationship with inanimate subjects; therefore, this experiment addresses this gap by providing online evidence via eye-tracking technology.

The purpose of the current experiment is to examine how fixation times during reading are affected by manipulations of verb intentionality and syntactic structure. The hypothesis is that when the verb is intentional (e.g., sabotaged), as opposed to neutral (e.g., destroyed), fixation times will be significantly longer since the relationship between inanimate entities and intentional verbs is infelicitous. Further, it is hypothesized that there will be significantly shorter fixation times when the verb of interest is embedded within a relative clause (RC), compared to when it is in the main clause, because readers will pay less attention to it. Crucially, an interaction is expected, such that the effect of verb intentionality on fixation times during reading will be significantly reduced when the verb is embedded in an RC compared to when the verb appears in the main clause of the sentence. This experiment is important because it is the first to produce online evidence encompassing the relationship between inanimate subjects and intentional verbs, and it adds to the preexisting literature surrounding how syntactic structures modulate sentence processing.

Method

Participants

Thirty-one introduction to psychology students at the University of Richmond participated in exchange for course credit. All participants reported normal or corrected-to-normal vision. Two participants were excluded for being non-native-English-speakers, and three were removed for attentive reasons. As a result, the final sample size was 26 native-English speaking participants.

Materials

Each participant was presented with 40 experimental items, 80 filler sentences, and 4 practice sentences. Of the 40 experimental items, participants received 10 items from each condition: neutral verb and main clause (4a), intentional verb and main clause (4b), neutral verb and RC (4c), and intentional verb and RC (4d). Intentional and neutral verbs did not significantly differ in length or log frequency (SUBTLEX_{US}, Brysbaert & New, 2009). Four counterbalanced lists were constructed so that participants only received one version of each experimental item. The full set of experimental items is listed in the Appendix. To ensure that the participants were reading the sentences and paying attention, true/false comprehension questions were created that appeared after each item (e.g., True or False: The manager received the crowbar). Half of the questions were false, while the other half were true.

(4a) The crowbar destroyed the machine within seconds and was given to the manager as proof.

(4b) The crowbar sabotaged the machine within seconds and was given to the manager as proof.

(4c) The crowbar that destroyed the machine within seconds was given to the manager as proof.

(4d) The crowbar that sabotaged the machine within seconds was given to the manager as proof.

Procedure

Participants were situated in front of an Eyelink 1000 system that tracked their eye movements and a monitor that displayed the sentences. Their forehead and chin rested against padded bars that reduced head movements. At the beginning of each trial, participants were told

to look at a fixation point that appeared on the left edge of the monitor, marking the location of where the first word of an item would appear. When the gaze was steady, the experimenter presented the sentence. The first four sentences were always the practice items, while the other 120 sentences were randomly shuffled. Once the sentence was read, participants pressed a button on a handheld console. After pressing this button, a true or false comprehension question appeared and remained on the screen until participants responded. The mean accuracy of the comprehension question was 97%. After completing the experiment, participants were debriefed.

Analysis

For each experimental item, two regions of interest were created: a verb region and a noun region. The verb region consisted of the verb of interest and the subsequent word, which was always “the.” Meanwhile, the noun region contained the receiver of the action and the following preposition (e.g., “for,” “at,” “within,” etc.). In (4), for example, the verb region was “destroyed the” or “sabotaged the,” and the noun region was “machine within.”

For both regions, three eye-tracking measures were examined. Gaze duration, an early processing measure, was calculated by adding all the initial fixations in the region. Also known as go-past time, regression path duration was the sum of all fixations on a region before the gaze was averted to the right of the region. Regression path duration served as an indication of integration difficulty because it captures rereading behavior. Total time, which is a global difficulty measure, was the sum of all fixations in a region. For each measure and both regions, fixations less than 80 milliseconds and greater than 800 milliseconds were removed from the analyses. Additionally, the mean and standard deviation of all measures were calculated for the two regions in the four conditions, and any values that were more than three standard deviations

from the mean were removed. Each dependent measure was analyzed using a 2 x 2 repeated-measures ANOVA in SPSS.

Results

Verb Region

Reading times are presented in Table 1. Analysis of all measures on the verb of interest revealed main effects of syntactic structure such that reading times were quicker when the verb was in a relative clause than in the main clause. The effect was marginally significant in gaze duration, $F(1,25) = 4.10, p = .054$, and it was significant in regression path duration, $F(1,25) = 30.16, p < .001$, and total time, $F(1,25) = 84.75, p < .001$. Additionally, the main effects of verb type were significant in gaze duration, $F(1,25) = 11.04, p = .003$, regression path duration, $F(1,25) = 15.32, p = .001$, and total time, $F(1,25) = 21.61, p < .001$, such that fixation times were longer for intentional verbs than neutral verbs.

Crucially, these main effects were qualified by an interaction between syntactic structure and verb type. The interaction was significant in regression path duration, $F(1,25) = 7.31, p = .012$. The pattern of the interaction indicates that the effect of verb type in the main clause condition (131ms) was approximately five times greater than in the relative clause condition (27ms). This interaction is represented in Figure 1.

Noun Region

An analysis of gaze duration revealed no significant main effect of syntactic structure. However, the main effect of syntactic structure was significant in regression path duration, $F(1,25) = 12.25, p = .002$, and total time, $F(1,25) = 15.82, p = .001$, such that fixation times were quicker when the verb was in a relative clause than in the main clause. Moreover, there was a significant main effect of verb type for gaze duration, $F(1,25) = 5.39, p = .029$, so that fixation

times were longer for neutral verbs than intentional verbs. In contrast, the significant main effect of verb type for regression path duration, $F(1,25) = 6.99, p = .014$, showed that fixation times were longer for intentional verbs than neutral verbs. Analysis of total time did not show a significant main effect of verb type. Lastly, there were no significant interactions between verb type and syntactic structure.

Discussion

Even though English allows inanimate entities to be subjects of action verbs, verbs that connote intentionality are incompatible with inanimate subjects. The current experiment is the first to demonstrate in real-time the processing difficulty associated with the integration of an inanimate entity with an intentional verb. In contrast, the integration of an inanimate subject with a neutral verb did not cause early or sustained processing difficulties. Furthermore, when the verb of interest was embedded within an RC, reading times were significantly quicker than when they appeared in the main clause. Importantly, the integration difficulty of an inanimate subject with an intentional verb was mitigated when the verb of interest was located in an RC. As a result, the data supported the hypotheses.

These findings are consistent with previous linguistic accounts that have examined the infelicitous relationship between inanimate subjects and verbs that connote intentionality. Previous research that has implemented offline measures indicated that intentional verbs induce processing difficulties when their subjects are inanimate nouns because inanimate nouns lack the facilities to complete intentional actions (Dillon, 1974; Schlesinger, 1989; Grimm 2007). The data from the current experiment revealed that the integration of inanimate nouns with intentional verbs led to difficulties in processing, for fixation times were significantly longer for the intentional verb conditions compared to the neutral verb conditions. Furthermore, this study

is consistent with the preexisting literature encompassing how syntactic structures modulate sentence processing (Baker & Wagner, 1987; Lowder & Gordon, 2012), for, when intentional verbs were embedded within an RC, processing difficulties were significantly reduced, compared to when the verbs were in the main clause. As a result, not only is the current experiment consistent with previous research, but it also is the first to provide online evidence of the infelicitous relationship between inanimate subjects and intentional verbs, as well as how this relationship is modulated by varying syntactic structures, through an eye-tracker.

Despite the significance of the current study, one major limitation is the small sample size. The current experiment originally planned to have 40 participants; however, due to unforeseen circumstances caused by the coronavirus, the experiment had to end earlier than anticipated, resulting in a sample of only 26 participants. Given this, a future experiment should use this exact same design but have a sample size of 40 participants. Although the sample size was not desirable, the current experiment is crucial, for it is the first to provide online evidence of the infelicitous relationship between inanimate subjects and intentional verbs.

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Table 1

Eye-tracking results.

Region of Interest	Condition	Measure (in Milliseconds)		
		Gaze Duration	Regression Path Duration	Total Time
Verb	Neutral-Main	355	543	906
	Intentional-Main	402	674	1022
	Neutral-Relative	329	466	625
	Intentional-Relative	361	493	745
Noun	Neutral-Main	330	527	655
	Intentional-Main	310	544	643
	Neutral-Relative	331	413	535
	Intentional-Relative	320	502	553

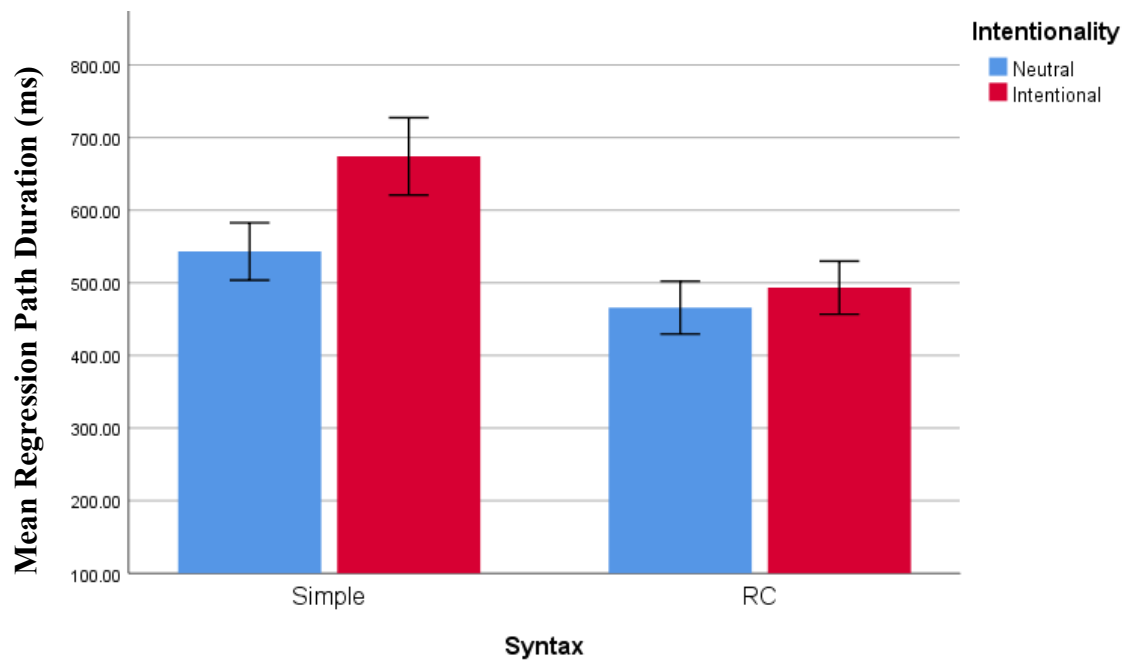


Figure 1. Mean regression path duration on the verb region. Error bars represent 95% confidence intervals.

Appendix

- 1) The bullet (killed/murdered) the president at the rally and was bagged as evidence.
The bullet that (killed/murdered) the president at the rally was bagged as evidence.
- 2) The stick (hit/beat) the horse for several minutes and was left behind in the stable.
The stick that (hit/beat) the horse for several minutes was left behind in the stable.
- 3) The bomb (scared/persecuted) the crowd at the stadium and was followed by panic.
The bomb that (scared/persecuted) the crowd at the stadium was followed by panic.
- 4) The crowbar (destroyed/sabotaged) the machine within seconds and was given to the manager as proof.
The crowbar that (destroyed/sabotaged) the machine within seconds was given to the manager as proof.
- 5) The gun (killed/assassinated) the governor at the theater and was found in the trash can.
The gun that (killed/assassinated) the governor at the theater was found in the trash can.
- 6) The wall (prevented/forbade) the ants from entering the area and also kept out spiders.
The wall that (prevented/forbade) the ants from entering the area also kept out spiders.
- 7) The revolver (alarmed/bullied) the cowboy in the saloon and was pulled from the holster.
The revolver that (alarmed/bullied) the cowboy in the saloon was pulled from the holster.
- 8) The axe (injured/butchered) the woman in the kitchen and became central to the investigation.
The axe that (injured/butchered) the woman in the kitchen became central to the investigation.
- 9) The scissors (trimmed/styled) the hair at the salon and were left on the edge of the sink.

The scissors that (trimmed/styled) the hair at the salon were left on the edge of the sink.

- 10) The wrench (tightened/built) the table for the living room and was placed back into the toolbox.

The wrench that (tightened/built) the table for the living room was placed back into the toolbox.

- 11) The paint (covered/vandalized) the bridge on the far side of town and could be seen from across the river.

The paint that (covered/vandalized) the bridge on the far side of town could be seen from across the river.

- 12) The chisel (carved/created) the sculpture for the gala and was returned to the storage closet.

The chisel that (carved/created) the sculpture for the gala was returned to the storage closet.

- 13) The handgun (killed/executed) the man within seconds and was disposed of in the river.

The handgun that (killed/executed) the man within seconds was disposed of in the river.

- 14) The shotgun (wounded/ambushed) the citizens of the village and was found in the fields.

The shotgun that (wounded/ambushed) the citizens of the village was found in the fields.

- 15) The dynamite (demolished/attacked) the building around the corner and was heard a mile away.

The dynamite that (demolished/attacked) the building around the corner was heard a mile away.

- 16) The oven (baked/prepared) the casserole for dinner last night and now needs to be cleaned.

The oven that (baked/prepared) the casserole for dinner last night now needs to be cleaned.

17) The key (unlocked/invaded) the office on the top floor but now seems to be missing.

The key that (unlocked/invaded) the office on the top floor now seems to be missing.

18) The syringe (injected/treated) the patient at the hospital and was immediately discarded.

The syringe that (injected/treated) the patient at the hospital was immediately discarded.

19) The camera (recorded/observed) the ceremony at the church and now needs to be charged.

The camera that (recorded/observed) the ceremony at the church now needs to be charged.

20) The glue (fastened/crafted) the replica of the monument and dried in just a couple hours.

The glue that (fastened/crafted) the replica of the monument dried in just a couple hours.

21) The microscope (revealed/diagnosed) the disease affecting the patient but is now malfunctioning.

The microscope that (revealed/diagnosed) the disease affecting the patient is now malfunctioning.

22) The binoculars (magnified/inspected) the birds in the forest and were put back in the case.

The binoculars that (magnified/inspected) the birds in the forest were put back in the case.

23) The cart (moved/arranged) the boxes in the warehouse and is no longer being used.

The cart that (moved/arranged) the boxes in the warehouse is no longer being used.

24) The piano (played/performed) the song in the concert hall and was admired by the spectators.

The piano that (played/performed) the song in the concert hall was admired by the spectators.

25) The spatula (flipped/cooked) the pancake in the kitchen and was placed in the dishwasher.

The spatula that (flipped/cooked) the pancake in the kitchen was placed in the dishwasher.

26) The razor (shaved/groomed) the man in the bathroom but was starting to get a bit dull.

The razor that (shaved/groomed) the man in the bathroom was starting to get a bit dull.

27) The rifle (shot/hunted) the deer in the woods and was louder than we had anticipated.

The rifle that (shot/hunted) the deer in the woods was louder than we had anticipated.

28) The telescope (surveyed/discovered) the stars in a distant galaxy and was mentioned by the scientists.

The telescope that (surveyed/discovered) the stars in a distant galaxy was mentioned by the scientists.

29) The spear (pierced/pursued) the buffalo on the plains and proved to be a very useful weapon.

The spear that (pierced/pursued) the buffalo on the plains proved to be a very useful weapon.

30) The hammer (pounded/constructed) the roof of the house and was needed for several other jobs.

The hammer that (pounded/constructed) the roof of the house was needed for several other jobs.

31) The pencil (scribbled/planned) the speech for the congresswoman and was left on the desk.

The pencil that (scribbled/planned) the speech for the congresswoman was left on the desk.

32) The hose (watered/tended) the garden early this morning but remained on for too long.

The hose that (watered/tended) the garden early this morning remained on for too long.

33) The pen (marked/graded) the essay written by the student and began to run out of ink.

The pen that (marked/graded) the essay written by the student began to run out of ink.

34) The wagon (transported/stole) the painting from the museum and was abandoned on the side of the road.

The wagon that (transported/stole) the painting from the museum was abandoned on the side of the road.

35) The calculator (assisted/cheated) the accountant on the taxes and is being replaced by a newer model.

The calculator that (assisted/cheated) the accountant on the taxes is being replaced by a newer model.

36) The purse (carried/smuggled) the drugs into the prison and was not searched by the guards.

The purse that (carried/smuggled) the drugs into the prison was not searched by the guards.

37) The whip (struck/assaulted) the donkey on the trail but was quickly confiscated by one of the guides.

The whip that (struck/assaulted) the donkey on the trail was quickly confiscated by one of the guides.

38) The paddle (bumped/spanked) the child in the playroom but did nothing to correct his bad behavior.

The paddle that (bumped/spanked) the child in the playroom did nothing to correct his bad behavior.

39) The needle (poked/sewed) the dress in the parlor but fell to the floor and could not be found.

The needle that (poked/sewed) the dress in the parlor fell to the floor and could not be found.

40) The knife (scraped/sculpted) the statue in the studio and was covered in dark clay.

The knife that (scraped/sculpted) the statue in the studio was covered in dark clay.