**Relating phrase production and comprehension: animacy interactions with individual
variability suggest similar lexically-driven conflict resolution processes**

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Abstract

What cognitive processes might underpin sentence production and comprehension? Although access to vocabulary is likely shared across these tasks, the nature of potentially common mechanisms remains elusive, with current proposals arguing for common prediction processes or domain-general conflict resolution mechanisms. Here we explore this issue and specifically asks whether phrase production and comprehension may each recruit similar conflict-resolution mechanisms that are not solely explained by shared linguistic knowledge. To this end, we combined an experimental manipulation with separate individual measures assessing linguistic knowledge and performance in different kinds of conflict-resolution (e.g., response-related vs semantic conflicts). Previous evidence suggests that noun animacy and conceptual similarity modulate the difficulty in producing or understanding complex referential phrases matching visual stimuli. We reasoned that if the production and comprehension of these phrases recruit conflict resolution mechanisms that are similar in nature, individual performance in the same conflict-resolution measure should interact with animacy and similarity, i.e., poorer conflict performers should experience more difficulty in the high-difficulty than the low-difficulty experimental condition, compared to better performers. Mixed-effects models evaluated these predictions while accounting for linguistic knowledge. We found that only context-dependent lexical ambiguity resolution, as measured by a homograph task, interacted with experimental animacy and similarity. This result suggests that similar lexically-driven semantic conflict resolution mechanisms underpin phrase production and comprehension. Alongside current computational models, this finding raises the possibility that these mechanisms are domain-specific rather than domain-general. Implications for current models of production and comprehension are discussed.

1. Introduction

The relationship between stimulus understanding and overt behaviour is a central issue in cognitive psychology. A large body of research, for example, has investigated the common mechanisms underpinning action understanding and execution (Fuster, 2001; Hommel & Müsseler, 2001; Rizzolatti, Fogassi, & Gallese, 2001; Wolpert, Doya, & Kawato, 2003). In the domain of language, in contrast, sentence production and comprehension have been traditionally studied as distinct processes entailing disparate cognitive architectures. Sentence comprehension, for example, is argued to involve the incremental mapping of the input into probabilistic alternative meanings (Levy, 2008; M C MacDonald, Pearlmutter, & Seidenberg, 1994), whereas sentence production might involve mapping meaning into articulation across several encoding stages (Bock & Levelt, 1994; Bock, Loebell, & Morey, 1992; Griffin & Bock, 2000). Although some aspects of processing such as self-initiated word retrieval and motor sequence planning appear task-specific, other processes must be shared, such as accessing the lexical and conceptual knowledge that feeds into multiword comprehension and production. What other cognitive processes then might be common to sentence production and comprehension? This issue is critical to elucidate the architecture of the language system and the nature of the cognitive mechanisms operating in each task.

One theoretical account argues for shared on-line prediction processes within a single language architecture. Pickering and Garrod (2013), for example, propose a model in which prediction in comprehension and production is implemented by the production system, which acts as an internal simulator generating forward models of upcoming linguistic information (Pickering & Gambi, 2018; Pickering & Garrod, 2007, 2013). The predictions of upcoming utterance units are then checked against the actually produced or comprehended linguistic unit. Others also argue that production amounts to prediction but instead propose a dual-path recurrent network architecture with interconnected sequencing and meaning pathways (Bock, Dell, Chang, & Onishi, 2007; Chang, Dell, & Bock, 2006; Dell & Chang, 2014). The network learns

from linguistic experience and the acquired representations drive comprehension and production predictions (Dell & Chang, 2014, Chang et al, 2006).

Other accounts have highlighted common domain-general cognitive control processes across different word-based tasks and sentence comprehension. It has been shown, for example, that overlapping brain regions within the ventrolateral pre-frontal cortex (including Broca's area) are recruited by both the Stroop task and the comprehension of temporarily ambiguous sentences (January et al., 2009; Novick, Trueswell, & Thompson-Schill, 2005; Thompson-Schill, Bedny, & Goldberg, 2005). These results suggest possible common cognitive control mechanisms across tasks. Consistent with this suggestion, several studies have shown that conflict resolution training improves ambiguity resolution in sentence comprehension, and that interleaving Stroop trials with sentence comprehension trials also facilitates sentential ambiguity resolution (Hsu & Novick, 2016; Hussey et al., 2017; Kan et al., 2013; Thothathiri, Asaro, Hsu, & Novick, 2018). It is argued that domain-general control processes are shared across the Stroop and language comprehension tasks.

Despite this body of research, however, the specific nature of potential common mechanisms in sentence production and comprehension remains elusive. Behavioural evidence showing parallel effects across tasks or simple correlations between production and comprehension measures, for example, can point to similar or shared processes, but cannot unambiguously indicate whether such processes result from accessing shared linguistic knowledge or recruiting shared conflict-resolution processes. Moreover, despite adaptation across competitive word naming in the Stroop task and sentence comprehension, it remains unclear what aspects of cognitive control are shared. For example, adaptation from Stroop trials might be due to shared conflict detection or monitoring processes, inhibition/selection or any other such process (Botvinick, Braver, Barch, Carter, & Cohen, 2001; Friedman & Miyake, 2004; Miller & Cohen, 2001; Miyake et al., 2000). Importantly, it remains unclear whether sentence production and comprehension share any control-related mechanism.

The present work aims to present an initial examination into this issue and specifically asks whether sentence production and comprehension may each recruit similar conflict-related mechanisms that are not solely explained by shared linguistic knowledge. To this end, we adopted a novel approach in which an experimental animacy manipulation (in both production and comprehension) was used alongside separate individual measures assessing linguistic knowledge and performance in conflict-based tasks involving response-related vs. semantic conflict. This strategy allows us to test specific predictions emerging from prior findings suggesting similar conflict-related mechanisms. Indeed, conflict is thought to occur in phrases containing animate nouns that must be mapped into a verb's semantic/syntactic roles. Animate-target phrases such as *the man that the girl is hugging*, for example, are more difficult to comprehend than inanimate-target phrases such as *the teddy bear that the girl is hugging* because *man* and *girl* are more conceptually and functionally similar than *teddy bear* and *girl*, e.g., they are equally good candidates for the verb's agent or patient roles (Gennari & MacDonald, 2008, 2009; Humphreys, Mirković, & Gennari, 2016; Mak, Vonk, & Schriefers, 2002; Traxler, Morris, & Seely, 2002; Traxler, Williams, Blozis, & Morris, 2005). Thus, in animate-target phrases (e.g., *the man that the girl is hugging*), there is more conflict than inanimate-target phrases (e.g., *the teddy bear that the girl is hugging*) when establishing an interpretation (who is acting on whom). Similar levels of conflict are thought to occur in production when mapping the nouns into an active or passive structure (e.g., *the man that the girl is hugging* or *the man being hugged by the girl*), as discussed in detail below.

We, therefore, reasoned that if the production and comprehension of these referential phrases recruit conflict resolution mechanisms that are similar in nature, individual performance in the same conflict-resolution measure should play a similar role in explaining the animacy effect in each task. That is, for each production and comprehension, individuals with poor conflict resolution should experience more difficulty in the high-conflict phrases than the low-conflict ones, compared to individuals with better conflict performance, suggesting that a similar conflict

resolution ability may operate in phrase production and comprehension. In statistical terms, this expectation means an interaction between the same conflict-resolution measure and animacy conditions in each production and comprehension, beyond the influence of shared linguistic knowledge. To begin to constraint our understanding of conflict mechanisms across production and comprehension, our statistical models simultaneously explore the role of different conflict-related performance (e.g., response-related vs semantic conflict).

1.2. Animacy in relative clause production and comprehension

Complex referential phrases such as *the teddy bear that the girl is hugging....* have been extensively studied under the rubric of object relative clauses (Gennari & MacDonald, 2008, 2009; Humphreys et al., 2016; Mak et al., 2002; Traxler et al., 2002, 2005). These subordinate clauses modify the first noun (e.g., *teddy bear*), which is also the syntactic object or patient of the RC verb. See Figure 1. In reading and eye-tracking studies, comprehension difficulty in these structures is typically observed towards the end of the relative clause (henceforth, RC), particularly, at the verb and subsequent positions if any, because the ultimately correct interpretation cannot be achieved until the verb is integrated with the two preceding nouns (Gennari & MacDonald, 2008; Gibson, 1998; Staub, 2010; Traxler et al., 2002).

It has also been shown that higher conceptual similarity between the nouns further modulates comprehension difficulty, for example, *the **man** that the girl is hugging* is more difficult than *the **dog** that the girl is hugging*, as a dog is conceptually more distinguishable from a girl than a man and is less likely to be the agent of the action (Gordon, Hendrick, & Johnson, 2001; Gordon, Hendrick, Johnson, & Lee, 2006; Humphreys et al., 2016). Object RC comprehension difficulty is thus generally thought to occur because comprehenders experience some form of competition or interference between alternative semantic features or semantic-syntactic roles (e.g., who is acting on whom), all of which requires the selection of one alternative in favour of the other. In contrast, inanimate nouns (e.g., *teddy bear*) are generally poor agents, and thus do not elicit such competition (Trueswell, Tanenhaus, & Garnsey, 1994).

Figure 1: Examples of picture stimuli used in the production and comprehension tasks. Below the images, the text illustrates the heard stimuli in the comprehension task and the most typical spoken answers provided in the production task.

Production data on these relative clauses is less abundant, but it is well documented in corpus and experimental studies in several languages that speakers tend to avoid animate-target active structures, as shown in Figure 1, and instead produce passives such as *the man being hugged (by the girl)* (Gennari, Mirkovic, & MacDonald, 2012; Hsiao, Gao, & MacDonald, 2014; Hsiao & MacDonald, 2016; Montag, Matsuki, Kim, & MacDonald, 2017; Perera & Srivastava, 2015; Roland, Dick, & Elman, 2007). In English, the mean rate of passive choices in animate-target descriptions is around 95% (with individuals ranging from 60% to 100%). In contrast, the mean rate of passives for inanimate-targets is about 50% (with a range of 0% to 100%). It has been argued that speakers opt for passive RCs because they experience some form of interference or competition during planning between highly similar entities (e.g., man and girl), which makes uttering the two nouns in close proximity difficult, as required in an active RC and other phrase types (Allum & Wheeldon, 2009, 2007; Fukumura, van Gompel, Harley, & Pickering, 2011; Konopka & Kuchinsky, 2015; Smith & Wheeldon, 2004). To alleviate this competition, speakers select the task-required

target (*man*) and demote the alternative noun (*girl*) to a later position or omit it altogether, resulting in a passive structure with or without a *by*-phrase (Gennari et al., 2012; Humphreys et al., 2016; Maryellen C MacDonald, 2013). Consistent with this view, it has been shown that the more semantically similar the animate nouns are, the more passives are produced, and the more agents *by*-phrase are omitted (Gennari et al., 2012; Humphreys et al. 2016). Moreover, an eye-tracking production study showed that noun similarity modulated fixations before speech and at verb planning, where arguably syntactic/semantic roles are explicitly marked in the verb morphology (Humphreys et al., 2016). These similarity-based results therefore suggest that the choice of passive structure manifests an internal conflict during production planning.

Nevertheless, even when conflict isn't high, an inanimate-target phrase also involves a low-level conflict in selecting among alternative nouns and structures, and picture characters to talk about. Active RCs such as *the teddy bear that the girl is hugging* involve some conflict between the simultaneously planned nouns because of the overwhelming tendency in English to produce the agent animate noun first in the sentence and the tendency to talk about visually and conceptually salient animate characters (Arnold & Griffin, 2007; Bock & Warren, 1985; McDonald, Bock, & Kelly, 1993; Montag & MacDonald, 2014; Vogels, Krahmer, & Maes, 2013). It is known, for example, that entities in the visual display become less accessible for production when there are competing salient entities in the display (Arnold & Griffin, 2007; Fukumura et al., 2011). Similarly, before uttering an inanimate-target RC, participants fixate on both the animate and inanimate characters in the event (e.g., teddy bear and girl), whereas they mostly fixate on the target when uttering an animate-target RC (Humphreys et al., 2016). Thus, the inanimate noun or visual character may compete for the first phrase position with the more salient animate agent, even though these nouns are not conceptually similar. To alleviate this low-level conflict, as in animate target phrases, speakers select the target inanimate noun and demote the animate noun for later in the structure, resulting in a passive structure.

Taken together, previous comprehension and production research suggests that animacy and similarity in relative clauses elicit varying degrees of competition or conflict, with animate-target phrases eliciting more conflict than inanimate-target ones. This competition may occur at different time points in processing according to the nature of the task (planning for production and RC verb for comprehension). Moreover, competition might take place at different levels of representation in production, e.g., lemma selection, syntactic function assignment or even phonological encoding (Bock & Levelt, 1994; Bock et al., 1992). Thus, although the putative conflict in production is driven by conceptual aspects such as animacy and high conceptual similarity, it may percolate or be manifested in higher or lower levels of planning (e.g., conceptual vs. motor planning). Sentence production is notoriously difficult to study with timing measures, as much of planning and motor execution likely occur in parallel (Griffin & Bock, 2000; Melinger, Branigan, & Pickering, 2014).

1.3. The present study

To explore conflict-related mechanisms in phrase production and comprehension, we used picture-based RC production and comprehension tasks manipulating the target animacy and the degree of similarity between the RC animate nouns, resulting in different degrees of competition in understanding or formulating the RC. See Figure 2. As dependent variables, we obtained comprehension response times at the end of the RC verb, where difficulty is manifested, and we used the proportion of passive choices as a global index of production conflict. We also explored results in speech onset times (SOTs) but only across animate-target phrases. Note that the characteristics of the first word in a phrase such as frequency, word length and animacy are well-known to influence SOTs, resulting in longer SOTs for longer, less frequent and less salient inanimate nouns compared to animate ones (Bock & Warren, 1985; Griffin, 2001; Griffin & Bock, 2000; McDonald et al., 1993). Therefore, SOTs are a poor measure of semantic-syntactic conflict in phrase production when comparing across animate vs inanimate nouns, but they have been successfully used to measure production difficulty when comparing nouns of the same animacy

(Konopka & Kuchinsky, 2015; Martin, Crowther, Knight, Tamborello, & Yang, 2010; Smith & Wheeldon, 1999, 2004).

Figure 2: Schematic trial structure in the comprehension task (left panel) and the comprehension task (right panel) for a given experimental picture. The comprehension tasks required matching the heard phrase to the highlighted entity. The production task required uniquely identifying the highlighted entity with a verbal description, e.g., *the car the man is washing*.

Our individual measures consisted of two main groups—vocabulary knowledge and reading experience measures and conflict-related measures, all of which have been used in previous studies. Because vocabulary knowledge and reading experience are likely shared across production and comprehension and are already known to be good predictors of comprehension difficulty (Braze, Tabor, Shankweiler, & Mencl, 2007; Montag & MacDonald, 2015; Perfetti, 2007; Van Dyke, Johns, & Kukona, 2014), we evaluated the contribution of conflict-related predictors after knowledge and experience measures were included in our models, thus accounting for shared knowledge and experience. For conflict-related measures, we selected the Stop Signal task as a measure of motor inhibition and monitoring (Verbruggen & Logan, 2008) and the Stroop task, which is thought to involve semantic and response conflict (MacLeod, 1992; Milham et al., 2001). The Stop Signal task has been shown to correlate with inhibition of spoken responses and the Stroop task also plays a role in predicting verbal fluence (Amunts, Camilleri, Eickhoff, Heim, & Weis, 2020; Xue, Aron, & Poldrack, 2008). As measures of lexical semantic conflict, two context-dependent lexical ambiguity resolution tasks were taken from previous studies. These tasks have been extensively studied in psycholinguistics and elicit semantic conflict in selecting one

alternative meaning over another according to context (Gottlob, Goldinger, Stone, & Van Orden, 1999; Kawamoto, 1993; Kellas, Ferraro, & Simpson, 1988; Simpson, 1984, 1994; Simpson & Kang, 1994). This type of semantic conflict has also been associated with individuals' comprehension skills, e.g., poorer readers have poorer ambiguity resolution skills (M A Gernsbacher, 1993; M A Gernsbacher & Faust, 1991; M A Gernsbacher & Robertson, 1995; M A Gernsbacher et al., 1990; Hala, Pexman, & Glenwright, 2007).

These conflict tasks differ in various cognitive dimensions. For example, they differ in whether conflict is externally driven or internally generated, whether conflicting information interferes with motor responses and whether the task requires monitoring external perceptual cues (Braver, 2012; Chun, Golomb, & Turk-Browne, 2011; Friedman & Miyake, 2004). In the Stroop task, for example, conflict arises from interfering visual cues in the display—colour vs word—(to perform the task, participants need to focus on the font colour). When the font colour and the word are linked to two different colour responses, there is also response conflict. Because some trials do not necessarily involve word and colour conflict, participants may also monitor for its occurrence across multiple trials. Similarly, in the Stop Signal Task, an auditory cue interferes with an action already planned to stop it, and participants must monitor its occurrence across trials. Ambiguous words, in contrast, provide a measure of internal semantic conflict from a single linguistic cue. Indeed, ambiguous words automatically activate one or more meanings according to meaning frequency. If only the most frequent (dominant) interpretation is brought to mind, however, this meaning may conflict with the subordinate interpretation primed by the preceding context (Gorfein, Berger, & Bubka, 2000; Simpson, 1984, 1994; Simpson & Kang, 1994). For example, the dominant (frequent) meaning of *bank* is its reference to a financial institution, but when the word is presented after *river*, there is conflict between the dominant and the subordinate but contextually appropriate interpretation (Simpson & Kang, 1994; Gottlob et al., 1999). This conflict thus must be internally resolved and cannot be helped by monitoring ambiguity or

attending to the words' visual features, since to recognise an ambiguity one needs to access alternative interpretations.

Following previous studies, we expected to replicate the standard animacy effect in RC production and comprehension. Importantly, we predicted that if a similar conflict-related process underpins both phrase production and comprehension, variation in a given conflict task should interact with the animacy condition in both the production and comprehension tasks. Thus, individuals with poor conflict performance in a conflict task should experience more comprehension difficulty (longer RTs) for animate than inanimate target phrases, compared to those with better conflict resolution performance. Conversely, in the production task, participants with better conflict performance should produce more active RCs (i.e., fewer passives) than poorer performers in both animacy conditions, but less so in the more difficult animate-target condition. This is because better performers should be able to produce some active RCs for animate-targets as cost effectively and efficiently as producing passives, because they can more easily resolve the conflict at hand. For similar reasons, as suggested in section 1.2, they should be even more likely to produce actives in inanimate-target cases where the level of conflict is low, as they experience little effort in selecting the first noun of the structure or overcoming the tendency to focus on and talk about animate entities.

Given previous similarity-related findings, we also explored possible interactions with similarity across animate-target phrases using speech onset times, although the number of items was reduced by half in each participant. Since our statistical models simultaneously explored the role of different conflict resolution performance by assessing their ability to interact with animacy (or similarity), the results may also contribute to our understanding of the different processes that might operate in phrase production and comprehension. For example, motor inhibition or interference with visual features (as in the Stroop task) might play a role in one phrase task but not the other or both, given that both production and comprehension tasks require matching verbal and visual information and executing a hand or verbal response. Visually salient and similar

animate entities in the display might interfere with each other at various levels of representation, from perception to meaning and motor response, as has been argued for production (Arnold & Griffin, 2007; Bock & Warren, 1985; McDonald, Bock, & Kelly, 1993; Montag & MacDonald, 2014; Vogels, Krahmer, & Maes, 2013).

2. Experimental Methods

2.1. Participants

83 native English speakers (65 females, mean age=20.91, $SD=2.77$; 18 males, mean age=22, $SD=4.13$) from the University of York completed the two main experimental tasks and seven cognitive tasks. For technical reasons, the data of 12 of these participants was not usable, as was the data from 11 participants in the Stroop task and 2 participants in the lexical ambiguity tasks. Thus, for the analysis of production data, there were 71 participants (56 females, mean age=20.89, $SD=2.86$; 15 males, mean age=21.80, $SD=3.69$). Because we lacked prior data with the present design to compute statistical power, we aimed to at least double the number of participants from previous studies showing animacy effects. Our number of participants was also in line with previous individual differences studies in reading comprehension using mixed models (Kuperman & Van Dyke, 2011; Van Dyke et al., 2014).

2.2. Materials

For the main production and comprehension tasks, 84 grey-scale pictures were adopted from previous studies (Humphreys et al, 2016, Humphreys and Gennari, 2014), comprising 42 experimental pictures (see Supplemental Materials) and 42 filler pictures. Each experimental picture contained two events to be described with the same transitive verb (cf. Figure 1). The events contained either an animate or inanimate target character that was acted on by another character. Because relatively few verbs or actions can occur with animate and inanimate nouns in the object or patient position, some actions (e.g., push, carry) were repeated across pictures. Of a total of 25 distinct actions, 13 appeared in more than one picture with different actors (see Supplemental Materials). In the comprehension task, pictures were accompanied by object

relative clauses referring to a picture character. These phrases were in an active form (see Figure 1) and included nouns and verbs that participants in a previous production study have more often used to refer to the characters and actions depicted (Humphreys et al., 2016). For both experimental and filler trials, each stimulus phrase was recorded by a female native British English speaker in a sound-proof booth using Cool Edit software. The sound files were normalized to 68 dB SPL to minimise intensity differences throughout the recording session.

Similarity ratings previously obtained in Humphreys et al., (2016) were used in our analyses. These were obtained through web-questionnaires in which the picture items were presented. Participants were encouraged to focus not only on visual similarity but also on functional similarity, i.e., on what actions characters can take part in. In each picture, the two characters to be rated were highlighted with a red box and a similarity rating was given in a 7-point scale with 1 being “not at all similar” and 7 being “highly similar”. Ratings varied from 2.57 to 6.18 across animate target cases (mean= 4.30, median, 5.20). We used the median split to define the high- vs Low-similarity categories for our interaction analyses.

2.3. Phrase comprehension and production tasks

2.3.1. Design

For each of the 42 experimental pictures, two different characters—either an animate or an inanimate one—could be targeted to elicit a production or comprehension response, and thus could be accompanied by an animate- or inanimate-target description (animacy conditions). In Figure 1, for example, the targets for the right-side picture were either the teddy bear or the man being hugged. Animate- or inanimate-targets were allocated to two different lists (Latin-square design) so that a character was a phrase target only in one task, but all participants were exposed to both animate and inanimate target descriptions. Participants completed the comprehension task before the production task but were exposed to different lists in each task. For the comprehension task, all phrases were heard in an active object RC. If they had heard the animate-target reference in comprehension for a given picture (e.g., *the man being hugged*), they would

then be prompted to describe the inanimate target in the production task and vice versa. This arrangement allowed participants to become familiar with the targeted phrase structures but did not contain repetitions of the same targets across both production and comprehension. As suggested by previous studies, speakers often use simpler structures such as *the man on the left* to identify the relevant character in spoken descriptions, and thus, the comprehension task as well as the task instructions prompted participants to use full descriptions. These tasks were conducted on E-Prime 2. In each task, participants received 21 trials targeting animate entities and 21 trials targeting inanimate entities plus 42 filler items. The filler pictures were similar to the experimental pictures in that at least two entities interacted, but filler trials differ for each task (see below).

2.3.2. Procedure

Comprehension task: Participants were instructed to indicate whether the description they heard over the headphones was an accurate description of the character highlighted with a red square in the picture (see Figure 2). They pressed one of two buttons on a button box to indicate their response (*yes* or *no*). The experimental trials in a list required a *yes* response, but the filler trials elicited *no* responses, thus balancing the number of *yes/no* responses throughout the task. The order of trial presentation was random. The trial structure is shown in Figure 2. After a response was recorded, an intervening screen requested a key press to see the next trial. Filler trials in this task contained a variety of RC structures (e.g. *the boy playing with a ball; the woman that is washing the car, the nurse being pushed by the violinist*). To prevent strategic performance, a third of the fillers did not match the picture due to the action being wrongly described or the characters being reversed, so that participants could not simply guess the response from the nouns heard. Participants' reaction times (RTs) for each correct trial were computed by subtracting the audio length of the recorded sentence from the RT computed from the audio start. Because the RC stimuli ended with the critical verb and comprehension difficulty in RCs is typically observed at verb positions, where the nouns are integrated with the meaning of the verb, our RT measure captures

the intended role-to-argument mappings characteristic of RC comprehension difficulty (determining who is acting on whom) (Gennari & MacDonald, 2008; Gibson, 1998; Humphreys et al., 2016; Traxler et al., 2002; Warren & Gibson, 2002).

Production task: participants saw the same 42 pictures as in the comprehension task but in a different animacy condition. The additional filler items elicited a variety of structures (e.g. *the tree on the playground, the dog burying the bone in the sand*). The order of trial presentation ensured that a filler always occurred between experimental items, but experimental items followed a random order. Participants in this task were instructed to verbally describe the highlighted character and their responses were recorded using a microphone. Practice trials and instructions indicated to participants that they should give descriptions uniquely identifying the character and using the actions being performed. The trial structure was similar to that of comprehension (see Figure 2). Participants produced a verbal response and then pressed a key to move onto the next trial. After the main experimental tasks, participants completed several vocabulary and conflict-resolution tests described in detail below.

2.4. Individual measures

2.4.1. Vocabulary Measures and Text Exposure

We used the Vocabulary subtest from the Wechsler Abbreviated Scale of Intelligence (WASI) 2nd Edition (Wechsler & Hsiao-pin, 2011), and the Peabody Picture Vocabulary Test (PPVT) 4th Edition (Dunn & Dunn, 2007). As a measure of text exposure, we used the author recognition test (ART) (Acheson, MacDonald, & Wells, 2008; Stanovich & West, 1989). The two vocabulary measures were strongly correlated with each other (Pearson's $r = .58, p < 0.01$) as well as with text exposure (Pearson's $r = .52, p < 0.01$). To reduce the number of colinear predictors, we combined these three measures into one predictor (referred to as *Vocabulary + Text Exposure*) by averaging the corresponding z-scores.

2.4.2. Stop Signal and Stroop tasks

Stop signal task. This task was taken from Verbruggen and Logan (2008) as a measure of motor inhibition, and was conducted using an available dedicated programme (<https://ore.exeter.ac.uk/repository/handle/10871/13860>). In this task, participants' primary goal is to respond with two different keys to two different visual cues (square and circle) as fast as possible. Participants are instructed to withhold their response if they hear an auditory stop signal, which randomly occurs in one fourth of the trials. In an adaptive staircase tracking procedure, the time between the primary stimulus and the stop signal is increased or decreased, depending on whether inhibition was successful, resulting in a 0.5 probability of responding. This allows to estimate the time it takes to covertly stop a response—the stop-signal reaction time (referred to as *SSRT*). It is likely, however, that in addition to motor inhibition, the task captures other control processes such as monitoring.

Stroop Task. In this task, participants identify the font color of a word by pressing a button, while ignoring the word meaning. The responses were restricted to three font colors — yellow, green and blue. The task contained three main conditions: incongruent-eligible, incongruent-ineligible and congruent. In the incongruent-eligible trials, the word meanings and the font colors were incongruent, and the font colors were available response choices, for example, the words *green*, *blue* and *yellow* were written in blue, yellow or green fonts respectively. In the incongruent-ineligible trials, the words indicated a color that was not an available response, e.g., the words *red*, *orange* and *brown* were written in yellow, green or blue fonts. Thus, in eligible trials, there is conflict both in the motor response (the word indicates an available response in the response set) and in the semantic representations (both the word and the font refer to competing color representations). However, ineligible trials only involve conflict in semantic representations: the word and the font indicate different colors (e.g., brown and blue) but only one of the font colors was an available response. Congruent trials consisted of color words matching the font color. Congruent and incongruent trials (including both eligible and ineligible trials) were intermixed. Each participant completed 24 practice trials (6 incongruent-eligible, 6 incongruent-ineligible and

12 congruent trials), followed by 3 blocks of experimental trials, and each block consisted of 18 incongruent-eligible, 18 incongruent-ineligible and 36 congruent trials. Difference in RTs between incongruent-eligible or incongruent-ineligible trials and congruent ones were computed, but since these two measures were correlated with each other and eligible scores had better reliability (see Table 3), we only included eligible scores in our models.

2.4.3. Context-dependent lexical ambiguity resolution

Two tasks involving homographs and homonyms were based on previous studies, e.g., (Gernsbacher & Faust, 1991; Gottlob et al., 1999; Hala et al., 2007; Henderson, Snowling, & Clarke, 2013; Kawamoto, 1993; Simpson, 1994). A set of ambiguous words (20 homographs e.g., *row*, and 24 homonyms e.g., *bank*) were selected from existing studies and databases, along with unambiguous filler words (20 and 15 in each task respectively). Eight homographs involved a phonological change in pronunciation, whereas twelve homographs involved a change a syllable stress. See Table 1. Frequency of dominant and subordinate meanings were determined from British participants in existing word association norms (De Deyne, Navarro, Perfors, Brysbaert, & Storms, 2019). On average, 80% (SD = 19%) of the associations produced for a given homograph were dominant, whereas for homonyms the average was 76% (SD = 19%). A few homonyms showed similarly frequent meanings. In both homograph and homonym tasks, an ambiguous word was presented twice in two different contexts.

Table 1: Ambiguous words stimuli used in the homograph and the homonym tasks

Homograph Task			Homonym Task		
Dominant	Subordinate		Dominant	Subordinate	
prime	Prime	Target	prime	Prime	Target
guitar	fish	bass	bat	dress	ball
arrow	curtsey	bow	money	river	bank
help	machine	console	dog	log	bark
bird	swim	dove	ball	cave	bat
exit	awe	entrance	shoe	car	boot
smell	anger	incense	light	flower	bulb

wrong	sick	invalid	bus	football	coach
follow	pencil	lead	ice	medicine	cold
second	small	minute	moon	worm	earth
thing	disagree	object	window	cup	glass
vegetable	make	produce	bread	traffic	jam
work	predict	project	fire	game	match
decline	garbage	refuse	cheese	computer	mouse
boat	fight	row	hammer	finger	nail
math	submit	subject	envelope	music	note
cry	rip	tear	almond	screw	nut
mad	defeat	upset	hand	tree	palm
blow	turn	wind	tennis	noise	racket
hurt	wind	wound	finger	telephone	ring
close	suggest	intimate	shovel	ace	spade
			barn	drink	straw
			cup	plate	tea
			cross	clock	tick
			sea	hand	wave

Unbeknown to participants, the word lists was organized in blocks in both homonym and homograph tasks, so that the first occurrence of an ambiguous word was presented in a word context priming its dominant interpretation, whereas the second occurrence was presented in a word context priming their subordinate or alternate interpretation (see Figure 3). The context-words preceding the target word were semantically related to the dominant or subordinate meaning of the ambiguous words as determined by association norms. To prevent strategic performance focused on the repeated words, the filler pairs in both tasks had the same structure as the experimental items, i.e., the same target word was preceded by two different primes so that they would repeat throughout the experiment like the ambiguous words did. Speech onset times (SOTs) in the homograph task were obtained automatically with Praat and double checked manually by visually identifying the first sound of the word. Cases in which participants self-corrected after producing a pronunciation were excluded from the analyses.

Figure 3: Schematic trial structure of the homonym and homograph tasks in different contexts.

Homograph task procedure and obtained measures. Participants were instructed to read the words out loud into a microphone as quickly as they could. The instructions did not alert participants about the ambiguous nature of the stimuli or their alternative pronunciations, as the aim was to encourage rapid responses rather than conscious strategies or speed-accuracy trade-offs. Under these conditions, therefore, participants could read out the words and still follow instructions even if they outputted the dominant word pronunciation for the subordinate priming contexts. As demonstrated in previous studies, we assumed that the word presentation in the context of the subordinate meaning involves conflict between the dominant and subordinate meanings and pronunciations (Gorfein et al., 2000; Gottlob et al., 1999; Simpson, 1994), particularly if the dominant meaning has been recently encountered (Simpson & Kang, 1994). Moreover, even if the subordinate pronunciation is not produced in a subordinate priming context, the semantic conflict should still obtain due to the mismatch between prime and subordinate target meanings. In such cases, difficulty in accessing the appropriate phonological form under time pressure, given the already highly activated dominant pronunciation, leads participants to abandon the suppression of the dominant phonological form or motor plan in difficult trials.

Given that the task instructions did not request accurate word naming, the proportion of context-appropriate pronunciations across the 20 homographs occurring in dominant vs subordinate contexts was relatively low (mean = 43%, SD = 18%), indicating that in more than half

of the cases, participants did not produce the context appropriate pronunciation. This omission rate is not far from that of previous studies, even when their instructions emphasise both speed and accuracy (Gottlob et al, 1999 reports 36% correct for subordinate contexts). Nevertheless, SOTs in subordinate contexts were significantly slower than those in dominant contexts regardless of output pronunciation. As typically reported for this task, Table 2 shows strong significant SOT differences between the two pronunciations of the same word in each priming context. A pair of pronunciations for the same homograph word was classified as being context-inappropriate, if one of the priming contexts (e.g., the subordinate context) received an inappropriate pronunciation. If both dominant and subordinate contexts received the expected pronunciation, they were considered context-appropriate pairs. Note that participants had both types of pairs and all pairs received both pronunciation types by some participants.

Table 2: Descriptive statistics (mean, SD) and condition contrasts for the Homograph and Homonym tasks

Homograph Task	Dominant context	Subordinate context	Condition contrasts
a. Context-inappropriate pairs -SOT	568 (132)	655 (188)	$t_1(80)=1.66, p<0.001$; $t_2(19)=2.2, p<0.001$
b. Context-appropriate pairs - SOT	563 (142)	756 (218)	$t_1(80)=1.99, p<0.001$; $t_2(19)=2.09, p<0.001$
Homonym Task- Accurate RT	789 (283)	900 (242)	$t_1(82)=1.99, p<0.001$; $t_2(23)=2.06, p<0.001$

Note: t_1 and t_2 refers to comparisons across participants or items. Context-inappropriate pairs are those containing a mispronunciation in one of the priming contexts.

That both data subsets show the expected difference between SOTs in dominant and subordinate contexts confirms that despite uttering context-inappropriate phonological forms, there was difficulty and semantic conflict in all subordinate contexts. Moreover, the dominant and subordinate SOTs across context-appropriate and inappropriate pronunciations were highly correlated (dominant: $R^2= 72.4$; subordinate: $R^2=64.3$, both $ps <0.0001$). Therefore, as an index of

semantic conflict, which is present in all trials, we computed the difference in responding to the two presentations of the same ambiguous word (subordinate meaning – dominant meaning context), regardless of whether the subordinate pronunciation was context-appropriate (henceforth referred to as *homograph difference scores*). To account for the fact that some pronunciations were context-inappropriate, despite accuracy not being required by the task, we also included an accuracy-like measure in our analyses under the label *homograph expected accuracy*. It should be noticed nevertheless, that the difference scores from all pair types were highly correlated with the difference scores computed for each type of pronunciation pairs separately (context-appropriate: $R^2 = .69$; context-inappropriate: $R^2 = .77$, both $ps < 0.0001$), suggesting that regardless of how one computes the difference scores, they account for similar variance across participants.

Homonym task procedure and obtained measures. Participants in this task were instructed to indicate whether the two words presented sequentially on the screen had related meanings. As in the homograph task, participants were not alerted about the ambiguous nature of the stimuli. The first homonym presentation was expected to strengthen the dominant meaning so that the second presentation in the context of the subordinate meaning would involve conflict between the dominant and subordinate meanings (Duffy, Morris, & Rayner, 1988; Gottlob et al., 1999; Simpson, 1994). Cases in which participants responded incorrectly were excluded from response time analyses. The accuracy across the 24 pairs of dominant and subordinate presentations was 76% on average (SD=14%). As an index of semantic conflict, we computed the difference in responding to the two presentations of the same ambiguous word (subordinate meaning – dominant meaning) for correctly judged cases (henceforth referred to as *Homonym Difference Scores*). Accuracy was also used as a predictor (*Homonym Accuracy*).

2.4. Data pre-processing

In the comprehension task, responses to the experimental trials were coded for accuracy and only correct responses were analysed for RTs. Comprehension accuracy was at ceiling for

animate and inanimate conditions (98.6% and 98.8% respectively). One participant's data was removed for below-chance performance (<50% correct). For coding of the production data, if a description was skipped or did not include the targeted structure but was correct, e.g., *the girl sitting down, the man looking scared, the apple on the pole*, it was removed from the analyses (38 responses per condition were excluded from a total of 1491 responses in each condition). In the remaining responses, the accuracy of the descriptions was generally high (animate target, $M=100\%$, $SD=0.9$; inanimate target, $M=97\%$, $SD=6\%$), but there was a significant difference across conditions (Wilcoxon test: $z=4.5$, $p<.001$). Most errors in the inanimate-target condition were due to speakers often describing the wrong target, for example, the animate entity was described rather than the inanimate one, e.g., *the girl hugging the teddy bear* for the inanimate target description in Figure 1. As suggested above, this might be due to the tendency to focus on and use animate entities first in the structure. Only valid correct responses coded as active or passive phrases were included in the analysis.

SOTs for accurate animate-target phrases were obtained from the recorded audio files by identifying the beginning of the first sound relative to the beginning of the red square presentation (See Figure 2). Initial disfluencies, if any, were included in the SOT, i.e., the beginning of a fluent noun phrase (e.g., *the man*) was taken as the SOT, rather than initial hesitations. To minimize the influence of outliers, we first removed extreme values in all DVs (e.g., RTs and SOTs longer than 5s) and then, we removed values falling above 2.5 SD s from an individual's mean per condition (i.e. for animate and inanimate conditions separately). For words in the ambiguity resolution tasks, a similar procedure was followed for each of the relevant conditions (e.g., subordinate and dominant RTs or SOTs). These exclusions comprised less than 2.5% of the data. In the Stop Signal task, participants who had few correct stop trials (less than 40%) or 100% accuracy were excluded from further analyses (Band, van der Molen, & Logan, 2003). For the similarity-based analyses, a similar procedure was followed to remove outliers, except that due to reduced power in these exploratory analyses, extreme values larger than 5s were replaced with the condition mean.

Reliability. Split-half reliability scores for conflict-related measures were computed using the robust method of estimation described in Parsons et al. (2019), using 5000 random splits for each of the predictor scores (Parsons, Kruift, & Fox, 2019). For Stop Signal Reaction Times, we follow the procedure described in the *splithalfr* R-package (<https://cran.r-project.org/web/packages/splithalfr>). Note that reliability estimates are strongly influenced by the number of missing values (e.g., incorrect responses for RTs) and the way the exclusion criteria are applied, as has been demonstrated for the Stop signal task (Congdon et al., 2012; Soreni, Crosbie, Ickowicz, & Schachar, 2009). Therefore, it possible that our homonym reliability score is underestimated due to the fact that 24% of the data was not used to compute it.

Descriptive statistics for all individual measures and dependent variables used in our analyses are shown in Table 3 and their correlations are shown in Table 4. SOTs and RTs for the main experimental tasks in Table 4 were computed as the overall mean per participant (including animate and inanimate RCs) because by design, participants never comprehended and produced the same RC (cf. Figure 2). Comprehension RTs and production SOTs were correlated as expected by the fact that these time measures come from the same individuals and thus, emerge from the same linguistic knowledge and conflict resolution skills. However, this correlation does not indicate which of these factors underpin performance in more or less difficult cases (animacy manipulation), hence, our predictions target interactions. Importantly, mean SOTs or RTs per participant included as predictors in the corresponding comprehension or production models reported below did not result in significant interactions with experimental conditions and did not significantly alter any of the main interaction results (see attached OSF models).

Table 3: Descriptive statistics for individual measures and dependent variables

Measures	N	Mean	SD	Min	Max	Spearman-Brown	95% CI
Vocabulary + Text Exp. (z-scores)	83	0	.8	-1.8	2.6	-	-
Stroop Eligible Diff. Score (ms)	72	70	40	7	165	.59	[.40, .73]
Stroop Ineligible Diff. Score (ms)	72	45	33	-2.7	142	.45	[.23, .64]
Stop Signal RT (ms)	78	265	42	78	146	.88	[.80, .95]
Homonym Diff. Score (ms)	81	120	160	-273	449	.51	[.26, .69]
Homonym Accuracy (%)	81	76	17	0	100	.73	[.63, .8]
Homograph Diff. Score (ms)	81	134	128	-100	604	.79	[.68, .86]
Homograph Expected Accuracy (%)	81	43	18	10	90	.66	[.55, .76]
Comprehension RT (ms)							
Animate	83	547	627	-467	4640	.95	[.90, .98]
Inanimate	83	417	508	-498	3228	.96	[.92, .98]
Passive choice (%)							
Animate	71	81	22	19	100	.89	[.84, .93]
Inanimate	71	64	30	5	100	.92	[.89, .95]

Table 4: Spearman's correlations between variables

Predictors	1	2	3	4	5	6	7	8	9	10	11
Knowledge											
1 Homonym Acc.	-	.25*	.20+	.03	.05	-.03	-.09	.18	.17	.20+	.03
2 Homograph-EA	.25*	-	.35**	.00	.01	.06	.03	.38**	-.07	.09	.08
3 Vocab. +Text	.20+	.35**	-	.08	-.06	.02	.11	.31*	-.07	-.13	.10
RT score											
4 Stop Signal RT	.03	.00	.08	-	.14	.11	-.02	.11	.06	-.12	.12
5 Stroop diff. EL	.05	.01	-.06	.14	-	.58**	-.19	.00	.11	.26*	-.16
6 Stroop diff. INE	-.03	.06	.02	.11	.58**	-	.02	.04	.00	.18	-.10
7 Homonym diff.	-.09	.03	.11	-.02	-.19	.00	-	-.04	.07	-.05	.04
8 Homograph diff.	.18	.38**	.32**	.11	.00	.02	.04	-	.22+	.13	.22+
Dep. Variables											
9 SOT (prod.)	.17	-.07	-.07	.01	.11	.04	.07	.22+	-	.50**	-.05
10 RT (comp.)	.20+	.09	-.13	-.12	.26*	.18	-.05	.13	.50**	-	-.02
11 Passive rate	.03	.08	.10	.12	-.16	-.10	.04	.22+	-.05	-.02	-

Note: **= significant at the 0.01 level (2-tailed), *= significant at the 0.05 level (2-tailed), + = significant at 0.05 level (1-tailed). *diff*= difference, *EL* = eligible; *INE*= ineligible; *SOT* = speech onset time; *EA*= Expected accuracy.

2.5. Data Analysis

Analyses were conducted using linear mixed-effects models (LMEMs) in R (version 4.0.2, (Kuznetsova, Brockhoff, & Christensen, 2017; R Team Core, 2020). Continuous cognitive predictors were scaled prior to analysis (Iacobucci, Schneider, Popovich, & Bakamitsos, 2016). For analysis of dichotomous DVs (i.e. passive/active sentence structure), logistic regression models were used (with bobyqa optimizer and maximum iterations set at 100,000 for dichotomous dependent variables). All the mixed-effects models included the maximal random-effects structures allowed by the design (by-subject and by-item intercepts, by-subject and by-item random slopes for the animacy condition), except for the logistic model for passive productions, where the by-subject slope was dropped due to lack of convergence. The animate target condition was coded as 1 and inanimate target condition was coded as -1. Thus, a positive coefficient of the condition main effect would represent a higher value in the more difficult condition (i.e. animate). A similarity coding was used for High- vs Low-Similarity categories.

To examine whether different task predictors interacted with animacy, we entered the predictors and their interactions with conditions in an *a priori* selected order as shown in Table 4. In the first step, the model included all predictors linked to vocabulary and language experience to account for linguistic knowledge common to production and comprehension (i.e., Vocabulary + Text Exposure, Homonym accuracy and Homograph expected accuracy). Those variables with non-significant main effects or interactions were pruned before the second step. In a second step, conflict-based scores (Stroop Eligible scores, SSRT, homograph and homonym difference scores) were entered to investigate whether any of these conflict resolution tasks interacts with animacy after accounting for the effects of vocabulary and experience. Variables with no significant main effect or interaction were also removed to identify the simplest most explanatory model. Note that due to the variability in the number of participants who have data points for all of the measures entered into a given analysis, the number of participants considered in the models may vary. This variation was larger for the models including the Stroop scores as fewer participants completed

this task, namely 72. For this reason, once this predictor was evaluated with all others, we re-ran the model with the remaining predictors and a larger participant set, as exemplified below. The data and the R code used in the analyses including all steps can be found at https://osf.io/gjdvw/?view_only=675a8cc3d99143ad85a120f7058b377c.

3. Results

3.1. Animacy in phrase comprehension: Response time

Based on previous results, we expected that RTs would be longer for animate-target than inanimate-target phrases. Importantly, we expected that individuals with poorer conflict resolution performance would experience more difficulty in the animate-target condition after vocabulary and text exposure were accounted for in the model. Table 5 reports all steps of the analyses. In the final model, there was a significant main effect of animacy condition such that animate-target phrases took longer to comprehend than the inanimate-target phrases. Moreover, there was no main effect of Vocabulary + Text Exposure, but there was a significant interaction between this measure and Animacy: Participants with poorer vocabulary and less text exposure experienced more difficulty in the animate than the inanimate condition, compared to those with better vocabulary, who showed smaller differences between conditions (Figure 4). Importantly, as hypothesized, there were a significant main effect of Homograph performance and a Homograph*Animacy interaction. Individuals with poorer difference scores were generally slower than those with better scores and showed more difficulty in the animate-target than the inanimate-target condition (Figure 4). Homograph Difference scores were the only conflict resolution measure accounting for response times, over and above the role of vocabulary and text exposure.

Table 5. Results of LMEMs explaining comprehension RTs

	Estimate	SE	df	t-value	p-value
Step 1 ($N_{\text{subject}}=80$; $N_{\text{item}}=42$; $N_{\text{obs}}=3216$)					

(Intercept)	420.81	43.36	99.61	9.71	4.54e-16 ***
Animacy	123.05	27.90	45.68	4.41	6.22e-05 ***
Vocab. + Text Z-score	-61.68	52.53	79.78	-1.17	0.24
Homonym Acc. Z-score	4.30	41.79	79.80	0.10	0.92
Homograph Exp. Acc. Z-score	58.45	43.71	79.97	1.34	0.19
Animacy: Vocab. + Text Z-score	-51.33	21.03	78.69	-2.44	0.017 *
Animacy: Homonym Acc. Z-score	-6.46	16.72	78.58	-0.39	0.70
Animacy: Homograph Acc. Z-score	11.11	17.57	79.93	0.63	0.53
Step 2 ($N_{subject}=64$; $N_{item}=42$; $N_{obs}=2574$)					
(Intercept)	439.05	46.80	78.52	9.38	1.85e-14 ***
Animacy	126.09	29.59	45.83	4.26	0.00010 ***
Vocab. + Text Z-score	-84.34	44.56	63.69	-1.89	0.06296 .
Stop Signal RT Z-score	-9.00	41.87	63.96	-0.22	0.83
Stroop Diff. EL Z-score	45.82	43.20	63.86	1.06	0.29
Homonym Diff. Z-score	-1.94	43.01	63.93	-0.05	0.96
Homograph Diff. Z-score	141.98	41.74	64.01	3.40	0.00116 **
Animacy: Vocab. + Text Z-score	-57.75	18.85	62.36	-3.07	0.00322 **
Animacy: Stop Signal Z-score	13.32	17.80	63.31	0.75	0.46
Animacy: Stroop Diff. EL Z-score	18.46	18.34	63.16	1.01	0.32
Animacy: Homonym Diff. Z-score	19.62	18.33	63.81	1.07	0.29
Animacy: Homograph Diff. Z-score	42.41	17.77	63.97	2.39	0.01994 *
Step 3 ($N_{subject}=74$; $N_{item}=42$; $N_{obs}=2971$)					
(Intercept)	406.76	42.31	92.40	9.61	1.43e-15 ***
Animacy	118.97	27.55	46.04	4.32	8.27e-05 ***
Vocab. + Text Z-score	-49.17	39.36	73.87	-1.25	0.22
Stop Signal RT Z-score	-18.17	39.29	73.89	-0.46	0.65
Homonym Diff. Z-score	-13.62	37.97	74.11	-0.36	0.72
Homograph Diff. Z-score	147.13	39.65	74.01	3.71	0.00039 ***
Animacy :scale(Vocab.Text)	-48.90	16.63	73.04	-2.94	0.004377 **
Animacy: Stop Signal RT Z-score	9.08	16.54	72.54	0.55	0.58

Animacy: Homonym Diff. Z-score	13.56	16.15	74.87	0.84	0.40
Animacy: Homograph Diff. Z-score	39.71	16.75	73.74	2.37	0.020361 *
Final Model ($N_{subject}=80$; $N_{item}=42$; $N_{obs}=3216$)					
(Intercept)	420.71	41.39	100.7	10.17	$< 2e-16$ ***
Animacy	122.98	27.55	44.08	4.46	$5.54e-05$ ***
Vocab. + Text Z-score	-62.61	38.87	79.83	-1.61	0.11
Homograph Diff. Z-score	132.70	39.10	80.06	3.39	0.00107 **
Animacy: Vocab. + Text Z-score	-49.94	15.91	77.90	-3.14	0.00240 **
Animacy: Homograph Diff. Z-score	39.05	16.05	79.28	2.43	0.01722 *

Figure 4. Interactions of animacy with Vocabulary +Text Exposure (left panel) and Homograph Difference Scores (right panel) in explaining comprehension response times. Data points represent participants' means. Shading indicates standard errors. Smaller z-scores for the Homograph task indicate better performance, i.e., smaller differences between subordinate-dominant responses.

These results confirmed that animate targets are more difficult to process than inanimate ones, suggesting difficulty in determining who is acting on whom in the phrase. The role of vocabulary and language experience in comprehension performance is consistent with current

proposals suggesting that vocabulary measures do not only represent all-or-none knowledge, but also the quality of the lexical representations entertained. Meaning quality modulates the ability to keep similar meanings distinct from each other, increasing susceptibility to interference (Perfetti, 2007; Van Dyke et al., 2014). Importantly, among the several conflict resolution tasks included in this study, only performance in the Homograph task predicted unique variance beyond knowledge-related scores: participants with poorer performance (with large difference scores reflecting more difficulty in selecting or accessing the subordinate meaning) were slower at processing animate-target than inanimate-target phrases, whereas faster performers show smaller differences, hence the interaction with Animacy. This suggests that this type of conflict resolution may play a role in RC comprehension.

3.2. Animacy in production: Active vs. passive phrase structure choices

As indicated in the introduction, we follow previous accounts in using the tendency to produce passives as a global index of production difficulty. We therefore reasoned that since resourcing to passives rather than actives implies experiencing difficulty at some point within the utterance, the production of passive structures should increase for participants with relatively poor conflict resolution performance. Conversely, those with better performance should be able to produce actives with competitive nouns one after another in a way that is as cost-effective as producing passives, i.e., these participants should more easily deal with the conflict at hand, specifically, in the animate-target condition, and produce active structures. This tendency to produce actives for better performers should be more pronounced in inanimate-target cases, where there is a low-level conflict in overcoming the tendency to focus on and talk about animate characters/nouns.

Table 6 displays the step followed in the analyses, similar to those in comprehension. In the first step, where knowledge related measures were evaluated, we carried over to the next step the Vocabulary + Text Exposure measure, as this was the closest to a marginally significant interaction and was also correlated with the homograph expected accuracy measure—another close-to-significant measure (cf. Table 4). As previously shown, there was a main effect of Animacy

indicating that participants produced more passives for animate-targets (mean= 80%, SD=22%, median=89%), than inanimate-targets (mean= 64%; SD=31%, median=65%). There was also a marginal Animacy*Vocabulary + Text Exposure interaction indicating that participants with poorer vocabulary and text exposure showed larger differences between the two conditions than those with better vocabulary and text exposure, and participants with poorer vocabulary produced fewer passives (more actives) for inanimate targets. Importantly, there was also an Animacy*Homograph score interaction that showed the opposite pattern. As in our comprehension results, participants with poorer homograph performance (larger difference scores) tended to produce passives in the two animacy conditions whereas participants with better performance generally produced fewer passives (more actives) but showed larger differences between conditions, hence the interaction. Vocabulary and conflict resolution performance thus are associated with structure choices in different ways.

Table 6. Model results predicting passive choices

	Estimate	SE	z-score	p-value
Step 1 ($N_{\text{subject}}=70$; $N_{\text{item}}=42$; $N_{\text{obs}}=2816$)				
(Intercept)	1.11	0.29	3.78	0.000155 ***
Animacy	1.29	0.18	7.35	2.02e-13 ***
Vocab. + Text Z-score	0.29	0.34	0.86	0.39
Homonym ACC. Z-score	0.14	0.28	0.52	0.61
Homograph Exp. ACC. Z-score	0.14	0.30	0.46	0.64
Animacy: Vocab. + Text Z-score	-0.26	0.16	-1.61	0.11
Animacy: Homonym Acc. Z-score	-0.06	0.13	-0.44	0.66
Animacy: Homograph Acc. Z-score	-0.20	0.14	-1.40	0.16
Step 2 ($N_{\text{subject}}=54$; $N_{\text{item}}=42$; $N_{\text{obs}}=2168$)				
(Intercept)	1.13	0.30	3.73	0.000194 ***
Animacy	1.33	0.16	8.41	< 2e-16 ***
Vocab. + Text Exp. Z-score	-0.10	0.33	-0.32	0.75

Stroop Diff. EL Z-score	-0.12	0.28	-0.41	0.68
Stop Signal RT Z-score	0.29	0.29	1.02	0.31
Homonym Diff. Z-score	0.47	0.28	1.67	0.094037 .
Homograph Diff. Z-score	1.02	0.30	3.34	0.000840 ***
Animacy: Vocab. + Text Z-score	-0.22	0.15	-1.50	0.13
Animacy: Stroop Diff. EL Z-score	-0.09	0.13	-0.72	0.47
Animacy: Stop Signal Z-score	-0.08	0.14	-0.59	0.56
Animacy: Homonym Diff. Z-score	-0.08	0.13	-0.58	0.56
Animacy: Homograph Diff. Z-score	-0.66	0.16	-4.20	2.69e-05 ***
Step 3 ($N_{subject}=66$; $N_{item}=42$; $N_{obs}=2651$)				
(Intercept)	1.06	0.28	3.83	0.000127 ***
Animacy	1.43	0.14	10.23	< 2e-16 ***
Vocab. + Text Exp. Z-score	0.06	0.31	0.19	0.85
Stop Signal RT Z-score	0.29	0.27	1.06	0.29
Homonym Diff. Z-score	0.33	0.26	1.30	0.19
Homograph Diff. Z-score	0.81	0.28	2.86	0.004256 **
Animacy : Vocab. + Text Z-score	-0.27	0.13	-2.07	0.038409 *
Animacy: Stop Signal Z-score	-0.08	0.12	-0.66	0.51
Animacy: Homonym Diff. Z-score	0.03	0.11	0.29	0.77
Animacy: Homograph Diff. Z-score	-0.56	0.14	-4.07	4.64e-05 ***
Final model ($N_{subject}=70$; $N_{item}=42$; $N_{obs}=2816$)				
Animacy	1.39	0.14	10.15	< 2e-16 ***
Vocab. + Text Exp. Z-score	0.14	0.31	0.46	0.65
Homograph Diff. Z-score	0.81	0.28	2.87	0.004128 **
Animacy: Vocab. + Text Z-score	-0.24	0.13	-1.83	0.067256 .
Animacy: Homograph Diff. Z-score	-0.50	0.13	-3.75	0.000174 ***

Figure 5. Interaction of Animacy with Vocabulary + Text Exposure (left panel) and Homograph Difference scores (right panel) in explaining the proportion passives produced. Shading indicates standard error. Data points represent participants' means. Smaller Homograph difference z-score indicates better performance.

The fact that participants with poorer vocabulary and less reading experience tended to produce fewer passives in the inanimate-target condition compared to those with better vocabulary and experience is consistent with previous findings showing that less exposure to authored texts, which tend to contain more passives than oral language, correlates with production of fewer passives (Montag & MacDonald, 2015). Participants with poorer vocabulary and less reading experience may thus not entertain passives as a viable alternative structure, unless they find the planning difficult (hence the animacy difference). The homograph results on the other hand, were generally consistent with the expectation that participants with better conflict resolution performance should be better able to entertain actives as a viable alternative structure than those with poorer performance. Given that RTs in comprehension and structure choices in production are different types of measures, which were not correlated with each other, it is interesting that the same conflict resolution task interacts with both these measures. This result thus confirms our expectation that production and comprehension of these complex

phrases involves similar conflict resolution mechanisms beyond the influence of knowledge-related scores.

3.3. Conceptual similarity in phrase production and comprehension

Recall that due to SOTs sensitivity to first word characteristics such as animacy, frequency and word length, the comparison of animate vs inanimate target structures is unlikely to reflect purely semantic conflict. Indeed, by the nature of our design, our inanimate-target nouns were longer (e.g., *teddy bear*), lower in frequency and less conceptually salient than animate-target nouns. This would thus lead to longer SOTs for inanimate than animate targets, as indeed was the case (mean animate-target = 1584ms, SD=265; inanimate-target=1719ms, SD=351). However, when animacy, length and frequency are similar across phrasal nouns, as in our animate-target nouns, SOTs may reflect other aspects of planning such as semantic conflict, as shown by several studies (Konopka & Kuchinsky, 2015; Martin et al., 2010; Smith & Wheeldon, 1999, 2004).

We thus explored the role of similarity and individual measures in explaining production SOTs and comprehension times within animate-target phrases. Due to the small number of actives in production, only SOTs for passive structures were included. We followed the same step-wise procedure as exemplified above, as can be found in the linked files. The final model explaining SOTs revealed a main effect of similarity (Table 7, Figure 6). Importantly, among all the individual predictors included in the initial models, Homograph difference scores was the only predictor showing a correlation with SOTs and a marginal interaction with similarity conditions. Moreover, models predicting comprehension response times also revealed interactions with both Homograph and Homonym Difference scores, along with a main effect of vocabulary + Text Exposure but no Similarity. These results suggest that individual variation in the Homograph task not only interacted with animacy but also with similarity in both tasks, though marginally in production.

Table 7. Model results predicting passive choices and comprehension RTs from animate targets

Production SOT	Estimate	SE	<i>t</i> -score	<i>df</i>	<i>p</i> -value
Intercept	1594.52	63.12	96.86	25.26	<2e-16***
Similarity	90.43	41.19	44.14	2.20	0.03343*
Homograph Diff. Score Z-score	164.07	51.38	67.37	3.19	0.00214**
Homograph Diff. Score *Similarity	31.79	17.58	63.82	1.81	0.07524.
Comprehension RT					
Intercept	558.35	48.71	100.36	11.46	<2e-16***
Similarity	10.16	24.96	490.40	0.41	0.68
Vocabulary + Text Exposure Z-score	-116.91	45.15	79.09	-2.59	0.01143*
Homonym Diff. Score Z-score	27.89	43.92	80.01	0.64	0.53
Homograph Diff score Z-score	152.28	45.38	78.91	3.36	0.00122**
Homonym Diff. Score *Similarity	-48.02	24.68	484.69	-1.95	0.05225.
Homograph Diff. Score *Similarity	54.53	24.63	474.89	2.22	0.02726*

Figure 6: Interaction of Similarity with individual performance within animate targets in explaining comprehension RTs and SOTs. Shading indicates standard error. Data points represent participants' means.

4. Discussion

Combining an experimental hypothesis-driven approach with individual variability, the present study aimed to establish whether the same conflict resolution task interacted with experimental conditions in RC production and comprehension, while also revealing

characteristics of the conflict involved. Based on previous results, we expected that target-animacy and similarity would modulate production and comprehension difficulty and moreover, that this modulation would vary as a function of individual conflict measures, with better performers exhibiting less difficulty than poorer performers in the most difficult conditions. Thus, an individual's conflict-specific performance would make an equivalent contribution in interacting with animacy in production and comprehension, suggesting a similar conflict mechanism underpinning both tasks. Our results were consistent with these expectations. Animacy modulated both production and comprehension, consistent with previous reports: More passives were produced, and comprehension responses were longer for animate-target phrases, compared to inanimate-target phrases, suggesting that animate nouns elicited more difficulty.

Interestingly, only the homograph difference scores—the difference in uttering the same homograph in a subordinate vs dominant priming context—interacted with animacy and similarity in both production and comprehension, beyond the influence of linguistic knowledge and text exposure. Homograph difference scores interacted with the animacy condition in both comprehension times and passive rates, even though these two measures differ in nature. Individuals with better homograph performance showed a smaller animacy effect in comprehension RTs and a larger animacy effect in passive choices than individual with poorer performance (cf. Figures 4 and 5). Corresponding interactions were also found in exploratory analyses contrasting High and Low-similarity phrases within animate-target phrases, with better homograph task performance showing a smaller similarity effect in comprehension RTs and SOTs than poorer performers. These associations suggest that participants with better conflict resolution scores were faster in dealing with conflict in comprehension or production of animate-target cases and were more able to plan active structures with two nouns in sequence—a configuration that most speakers avoid and comprehenders find difficult, particularly with animate nouns (Gennari & MacDonald, 2009; Roland et al., 2007).

Overall, the relationship between individuals' performance and their RC production and comprehension suggests a similar kind of conflict resolution process underpinning the mapping of nouns into verb roles during both production and comprehension. Specifically, our results are the first to provide initial evidence suggesting that lexical ambiguity resolution involves processes that are similar in nature to those involved in sentence production and comprehension beyond the influence of standard measures of vocabulary and text exposure. These results imply that processes linked to semantic conflict resolution in the homograph task may underpin the role-to-noun mapping characteristic of sentence processing, particularly when the nouns involved are semantically similar and compete during phrase understanding or planning. Thus, any theory on the relationship between production and comprehension should not only account for knowledge-based commonalities, but also the presence of similar conflict resolution processes.

4.1. Implications for processes underpinning production and comprehension

As anticipated by most theoretical approaches, vocabulary knowledge and a measure of language experience were shown to interact with animacy in both tasks, suggesting a role for these measures across tasks. In both production and comprehension, Vocabulary + Text Exposure interacted with experimental conditions suggesting that participants with poorer vocabulary and exposure experienced greater comprehension difficulty and produce more passives in the animate-target than the inanimate-target condition. Although we did not have specific predictions about this measure, the role of vocabulary in comprehension difficulty is well documented, even in cases of working memory interference. It has been argued, for example, that this sort of conflict may derive from the quality of representations entertained (Braze et al., 2007; Perfetti, 2007; Van Dyke et al., 2014). Poor quality lexical representations may contain less distinctive semantic features that make them more likely to compete with other highly similar representations. Thus, semantic conflict would elicit more difficulty for participants with poor vocabulary than for those with better vocabulary.

Importantly, the present results provide an opportunity to begin to delineate the specific processing mechanisms beyond linguistic knowledge that might operate across phrase production and comprehension. The fact that comprehension times, production choices and marginally, speech onset times interacted with the same conflict-resolution suggests the possibility that aspects of context-dependent ambiguity resolution operate in the role-to-noun mapping processes characteristic of sentence processing, at least within the RC structures examined here. As reviewed in section 1.2., most current accounts of comprehension difficulty in object relative clauses (e.g., *the man/teddy bear that the girl is hugging*) posit some sort of competition or working memory interference when maintaining and integrating the animate nouns with the verb's roles—a conflict that is stronger for animate targets than inanimate ones (Gordon, et al., 2006; Gibson, 1998; Gennari and MacDonald, 2008, 2009; Humphreys et al., 2016, Traxler et al., 2002). Likewise, planning and uttering a phrase with two animate nouns elicit conflict in selecting the noun to be uttered first and indicating its agent or patient role in the structure (Allum & Wheeldon, 2009, 2007; Konopka & Kuchinsky, 2015; Smith & Wheeldon, 2004, Gennari et al., 2012; Humphreys et al, 2016). What aspects of the homograph tasks might relate to these phrase production and comprehension processes?

An indication of what specific processes might be relevant for these production and comprehension processes can be inferred from differences between our conflict resolution tasks, particularly those that showed relatively good reliability. Note that the homograph task did not only differ from the homonym task in engaging speech production rather than comprehension, but also in that the former targeted speed and the latter accuracy. Thus, the homonym task might better reflect vocabulary knowledge, as Table 4 suggests, rather than processing difficulty. Nevertheless, it does seem to index difficulty in our similarity analyses (Table 7, Figure 6), suggesting that difficulty in context-dependent interpretation may also reflect aspects of comprehension difficulty, as previously suggested (Gernsbacher, 1993), but not necessarily the difficulty between animacy conditions in comprehension or production.

The Stop Signal task in turn, differs from context-dependent ambiguity resolution in recruiting monitoring of perceptual cues and response inhibition. Since the Stop Signal task has been associated with inhibition in both manual and verbal tasks, it could have been expected to play a role in phrase production (e.g., SOTs), and moreover, to correlate with the homograph task (Cai, Oldenkamp, & Aron, 2012; Xue et al., 2008). Indeed, homograph tasks have been argued to involved the inhibition of an alternative meaning and phonological form (Johnson & Anderson, 2004; Simpson & Kang, 1994). Nevertheless, our version of the task did not require phonological selection and this selection was not often undertaken. Thus, although it remains unclear why the Stop Signal was not associated with any other measure, it is likely that our homograph task primarily involved internal semantic conflict arising from activating subordinate and dominant meanings through contextual priming: Once the primed meaning was activated upon processing the prime word (e.g., *fight*), reading the homograph (*row*) automatically activated its dominant boat-related meaning (see Figure 3), thus conflicting with the priming context and leading to longer naming times. This internal semantic conflict is consistent with the conflict between animate nouns operating in phrase production and comprehension in that alternative meanings are concurrently entertained, with one meaning being prioritised over the other.

Further indication of the specific processes involved in our ambiguity tasks comes from much prior ambiguity research and models of lexical ambiguity resolution. This research indicates that word characteristics such as frequency, imageability and spelling contribute to lexical ambiguity resolution processes, thus suggesting that semantic conflict resolution is intrinsically linked to lexical knowledge, and in particular, the associative links between orthography, phonology and meaning established through learning (Chen & Mirman, 2012; Gottlob et al., 1999; Simpson, 1984; Strain, Patterson, & Seidenberg, 1995). Connectionist models of word processing and ambiguity resolution, for example, suggest that meaning conflict takes place within an interactive lexical network, where the connection strength between semantic, orthographic and phonological nodes, together with the associative strength of the priming context, play a role in

biasing the network towards one or another meaning (Kawamoto, 1993; Seidenberg & McClelland, 1989; Strain et al., 1995). Individual-specific characteristics can also modulate the behaviour of the network (McLeod, Shallice, & Plaut, 2000; Plaut & Booth, 2000). Under this view, our ambiguity tasks involve fine-grained lexical knowledge concerning links between word forms and meanings, together with individual-specific characteristics modulating the ability to resolve lexical conflict within the lexical network. These observations highlight the internally-generated and lexical-semantic nature of the conflicts observed in our phrase and ambiguity tasks and raise the possibility that these semantic conflicts take place within a lexical domain-specific network, rather than at a level of representation shared with non-language tasks (domain-general processes).

Overall, the present results suggest that competitive processes between lexical meanings might operate in phrase production and comprehension. Within the context of production research, this finding is not particularly surprising because production is viewed as an inherently competitive process at various levels of linguistic representation (Dell & O'Seaghdha, 1994; Ferreira, 1996; Meyer, 1996; Shao, Meyer, & Roelofs, 2013; Slevc, 2011), and particularly, in the production of referential expressions (Allum & Wheeldon, 2009; Arnold, 2010; Arnold & Griffin, 2007; Fukumura & van Gompel, 2010; Fukumura et al., 2011; Konopka, 2012; Smith & Wheeldon, 1999, 2004). Competitive processes are also broadly compatible with models of sentence comprehension positing some form of competition or interference among alternative cues and interpretations (Lewis & Vasishth, 2005; Lewis, Vasishth, & Van Dyke, 2006; M C MacDonald et al., 1994; McRae, Spivey-Knowlton, & Tanenhaus, 1998). Beyond these competitive processes separately proposed for production and comprehension, the present results the possibility that phrase production and comprehension involve competitive mechanisms that are lexical-semantic in nature and domain-specific.

4.2. Implications for the relationship between production and comprehension

Previous prediction-based models of sentence production and comprehension have suggested a common language architecture for both tasks. The proposed models differ

substantially in their architectures, although they agree that production and prediction in comprehension are intimately linked. The covert-simulation model argues that in comprehension, the listener covertly imitates what has been heard and engages the production implementer to predict the next word (Pickering & Garrod, 2007, 2013, Pickering & Mani, 2018). The dual-path architecture, in contrast, implements word-by-word production and comprehension after learning in such a way that the same sequencing pathway is involved in the prediction of the next word in both comprehension and production (Chang et al., 2006; Chang & Dell, 2014). The sequencing pathway and its hidden layer modulate prediction by acting as the repository of what has been learned up to that point. Unlike the covert-simulation model, this architecture embodies the common knowledge base and prior experience underpinning production and comprehension. However, both models aim to account for prediction rather than processing difficulty and mostly specify the mechanisms taking place in relatively easier processes, e.g., when linguistic elements are highly predictable or primed from the context. It therefore remains unclear what mechanisms operate in difficult processing, e.g., in cases of conflict between production choices and interpretations, and importantly, whether conflict resolution mechanisms would be shared across sentence production and comprehension.

The present work addressed this possibility and suggests that lexico-semantic conflict resolution performance might underpin both phrase production and comprehension. To account for this possibility, existing production-comprehension models can be extended so that comprehension difficulty emerges from conflicting alternative expectations and/or the mismatch between predicted and perceptual input, as argued by probabilistic and computational models of comprehension (Levy, 2008; McRae et al., 1998). This putative extension requires that the notion of prediction is understood as probabilistic and experience-based, rather than an all-or-nothing process, e.g., one in which only highly probable elements are correctly anticipated.

Yet the biggest challenge for production-comprehension models is to specify how the production system would generate alternative predictions and account for production difficulty

as well. The dual-path model could potentially explain these processes because it can account for production choices as a function of prior learning (Chang, 2002; Dell, Chang, & Griffin, 2001). Note that the choice of active vs. passive in RC production is related to reading experience and the probability of the syntactic-semantic structures in the language, including animacy configurations (Gennari & MacDonald, 2009; Montag & MacDonald, 2015). Thus, the dual-path model has the potential to explain how learning from linguistic experience modulates the prediction of alternative continuations and how conflicting alternatives may elicit difficulty in both production and comprehension. This possibility is consistent with separate production and comprehension computational models that explain competition in various domains (Dell, Burger, & Svec, 1997; Dell, Chang, & Griffin, 1999; Dell, Juliano, & Govindjee, 1993; Fitz, Chang, & Christiansen, 2011; McRae et al., 1998), including inhibition mechanisms in production (Dell, Oppenheim, & Kittredge, 2008; Oppenheim, Dell, & Schwartz, 2010). It is, therefore, possible that probabilistic predictive processes operate in both production and comprehension, sometimes generating conflicting alternatives that are resolved according to available evidence in a context and prior language experience.

In sum, the present results suggest that conflict resolution in both sentence production and comprehension, as measured by the homograph task, stems from lexical-semantic conflict. Together with current evidence and proposed architectures of sentence production and comprehension, our results raise the possibility that some conflict resolution processes might be language-specific rather than domain general, resulting from the operating characteristics of the associative language network.

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