Published in final edited form as:
J Exp Psychol Learn Mem Cogn. 2014 May ; 40(3): 797–810. doi:10.1037/a0035576.

The Exception Does Not Rule: Attention Constrains Form Preparation in Word Production

Pádraig G. O'Séaghdha and **Alexandra K. Frazer**
Lehigh University

Abstract

Form preparation in word production, the benefit of exploiting a useful common sound (such as the first phoneme) of iteratively spoken small groups of words, is notoriously fastidious, exhibiting a seemingly categorical, all-or-none character, and a corresponding susceptibility to 'killers' of preparation. In particular, the presence of a single exception item in a group of otherwise phonologically consistent words has been found to eliminate the benefit of knowing a majority characteristic. This has been interpreted to mean that form preparation amounts to partial production, and thus provides a window on fundamental processes of phonological word encoding (e.g., Levelt et al., 1999). However, preparation of only fully distributed properties appears to be non-optimal, and is difficult to reconcile with the sensitivity of cognitive responses to probabilities in other domains. We show here that the all-or-none characteristic of form preparation is specific to task format. Preparation for sets that included an exception item occurred in ecologically valid production tasks, picture naming (Experiment 1), and word naming (Experiment 2). Preparation failed only in the commonly used, but indirect and resource-intensive, associative cuing task (Experiment 3). We outline an account of form preparation in which anticipation of word-initial phonological fragments uses a limited capacity, sustained attentional capability that points to rather than enacts possibilities for imminent speech.

Keywords

phonological preparation; word production; odd-one-out; sustained attention

Imagine a game show in which contestants get points for the speed of spoken responses. In one round of the competition, participants are given good odds that the responses, names of common things, will begin with a particular phoneme. Will participants capitalize on these favorable odds and respond faster to matching terms? Common sense, and the well-attested sensitivity of people to probabilities and pay-offs in many domains (e.g., Aslin, Saffran & Newport, 1999), say yes. But extensive research in a corresponding experimental paradigm has reported no benefit of the probabilistic information. Rather, participants benefited only when they knew with certainty that an answer possessed the designated property (e.g., Roelofs, 1999). This article examines this counter-intuitive finding, and shows that it holds only for an experimental procedure, associative cuing, that requires indirect retrieval of

Pádraig G O'Séaghdha, Department of Psychology and Cognitive Science Program, Lehigh University, 17 Memorial Drive East, Bethlehem, PA 18015, pat.oseaghdha@lehigh.edu.

target names. For simpler, more direct tasks, picture and word naming, the common sense expectation holds. We propose that anticipation of partial sound properties of response words may prefer certainty but that it can deal with uncertainty. Moreover, an inference from the previous research, that studies of form preparation provide a privileged window on underlying processes of phonological encoding, may be invalid. Instead, we propose that form preparation in picture and word naming indicates what phonological components can be usefully anticipated prior to encoding. Useful anticipation is of course correlated with the requirements of phonological production, but more importantly may be modulated by attentional constraints that apply to preparation for speech as well as other forms of action. If so, preparation may provide only an indirect reflection of phonological encoding processes.

All-or-none Form Preparation

A review of previous form preparation literature shows both how the conclusion that preparation for word production is all-or-none came about, and that there are good reasons to question it. The form preparation task involves repeated iterative production of members of small sets of words that share a specific component of form in the preparation condition but not in the control condition. The method was devised as a tool for the exploration of the initial steps of phonological encoding in word production (Meyer, 1990, 1991). In an *associative cuing* procedure, participants learned small sets of associatively related word pairs and then were prompted, randomly and repeatedly, to produce the second members of the pairs in response to the first members. The target words shared certain phonological properties in the *homogeneous* condition. They shared nothing in particular in the *heterogeneous* control condition. Meyer (1991) found benefits for homogeneous word beginnings, but not for homogeneous endings, supporting theories of word production in which initial ingredients are selected before later ones (e.g., Levelt, Roelofs & Meyer, 1999; O'Séaghdha & Marin, 2000; Sevald & Dell, 1994; see also Fournier, Gallimore, Feiszli, & Logan, 2013). Because of its demonstrated utility, form preparation has been applied to additional questions, including the nature of syllable representation (Cholin, Schiller & Levelt, 2004), and the isolability of distinctively morphological units (e.g., Chen & Chen, 2006; Janssen, Roelofs & Levelt, 2002; Roelofs & Baayen, 2002). Although our research has implications for this extended literature, the focus of this article is on the simpler case of preparing phonological word beginnings.

Whereas all of the homogeneous set members shared the manipulated properties in Meyer's (1990, 1991) original studies, later studies introduced variability among set items in order to investigate more precisely what properties were functional in phonological encoding. For example, Roelofs (1999) used the associative cuing method to examine whether form preparation operated at a phonological or at a phonetic level. Using an odd-one-out procedure, he showed that when one of the items in a set differed by a single phonological feature from the others (e.g., including one unvoiced */p/* onset in a variable set with two voiced */b/*s), there was no preparation benefit relative to the heterogeneous condition. To show that failure of form preparation in this *variable* condition was not limited to associative cuing, Roelofs replicated the experiment with a picture naming format (Roelofs, 1999, Experiment 3). The absence of form preparation for variable sets is consistent with the idea that whole segments are fundamental or *proximate* planning units (O'Séaghdha, Chen & Chen, 2010) in production of words in European languages, but importantly for the present article also points to the counterintuitive conclusion that preparation requires unanimity among set items, and may fail entirely without it. Throughout this article, we adopt the terms *constant* to refer to sets in which manipulated properties are fully distributed (e.g., all */b/* onsets), and *variable* to refer to sets that contain an exception or odd-one-out (e.g., one non-*/b/* among several */b/*s).

Other studies showing the all-or-none form preparation pattern held the phonology of word beginnings constant in the homogeneous condition while manipulating set variability via a second property. For example, Roelofs and Meyer (1998) tested the hypothesis that a metrical frame must be in place in order for form preparation to proceed. They varied metrical properties, such as number of syllables and placement of stress, of Dutch target words that all shared their initial segments in the homogeneous condition. Thus, in a *constant* homogeneous condition, target words might all begin with */ma/*, be trisyllabic, and have stress on the second syllable (e.g., *maRIne* (navy), *maTErie* (matter), *maLAise* (depression), *maDOna* (madonna)). In a *variable* homogeneous condition, the three words also began with */ma/* but two had second syllable stress and two had third syllable stress (e.g., *maLAise* and *maDOna* replaced by *manuSCRIPT (*manuscript) and *madeLIEF* (daisy)). According to Roelofs and Meyer (1998, p 927): "If metrical structures are stored and must be retrieved for advance planning, preparation should be possible only if the number of syllables and the stress pattern are the same throughout the response set but not if they are variable." The hypothesis was sustained, with the benefit of shared phonology present only when the placement of stress was also constant among the items. Thus, preparation was all-or-none, with variation in one relevant dimension (stress placement) obviating any benefit in another (shared word beginnings) even though the word beginning was constant over items.[1] Studies such as this one provided compelling corroboration of the view that form preparation is extremely sensitive, is vulnerable to many 'killers', but thereby provides deep insights into fundamental processes of phonological encoding.

A study by Damian and Bowers (2003) and several responses to it illustrate that the all-or-none behavior of form preparation soon transitioned from investigative tool to the status of convenient fact. Damian and Bowers varied spelling consistency while holding phonology constant to examine whether there is cross-talk between orthography and phonology in word production. They found that including one item with a different written initial letter in phonologically constant homogenous sets (e.g., *kennel, coffee, cushion*) led to complete loss of form preparation relative to constant, orthographically consistent sets (e.g., *camel, coffee, cushion*). Notably for the present purpose, the control condition in this study was a variable onset condition (different phoneme and spelling for one of three items, e.g., *camel, gypsy, cushion*), not a fully heterogeneous control, thus taking the all-or-none view of form

[1]Several other studies have combined the odd-one-out and dual criterion logics to study larger components of form. For example, Cholin et al., (2004) studied the functionality of syllables, and Janssen Roelofs, & Levelt (2002) explored the representation of morphemes. These studies show degrees of preparation rather than all-or-none preparation, suggesting that preparation was not subject to the all-or-none restriction.

preparation as given. Many subsequent studies have followed this practice (e.g., Alario, Perre, Castel & Ziegler, 2007; Cholin et al., 2004; Janssen et al., 2002; Roelofs, 2006).

Although Damian and Bowers (2003) provided very clear data across several experimental formats, they conceded that "orthographic effects on speech production processes might seem surprising (perhaps even implausible)" (p. 128), and others shared this assessment. In response, both Roelofs (2006) and Alario et al. (2007) presented new studies that cast doubt on the generality of orthographic-phonological cross-talk in word production (see also Bi, Wei, Janssen, & Han, 2009; Chen & Chen, 2006).

Form Preparation Tasks

Both Roelofs (2006) and Alario et al. (2007) drew attention to the potential importance of task properties in determining the presence or absence of form preparation. Roelofs (2006) examined orthographic inconsistency in picture naming and word naming, as well as in the original associative cuing format, using essentially the same design as Damian and Bowers, but in Dutch. Orthographic variability limited form preparation in word naming, but not in picture naming or associative cuing. Roelofs suggested that the contrast between his results and those of Damian and Bowers for the associative task might be due to the relative orthographic shallowness of Dutch, whereas the failure of preparation in the word naming task was a result of the salience of orthography in reading. However, marginal form preparation in the reading task may have been underestimated due to the choice of a variable rather than a fully heterogeneous baseline. Thus Roelofs (2006) can be interpreted as showing differential task behavior across languages, or more simply as a failure to replicate the Damian and Bowers (2003) orthographic inconsistency result in Dutch.

Alario et al. (2007) focused on picture naming which is widely considered to be more ecologically valid than associative cuing for the study of production. Alario et al. suggested that the memory demands of associative cuing (orthographic inconsistency hampering target retrieval and so leading to abandonment of preparation) were responsible for the orthographic inconsistency effect of Damian and Bowers (2003). They found no sensitivity to orthography in a picture naming format in French despite that language's orthographic depth. Alario et al. also modified the Damian and Bowers (2003) design by analyzing only the consistent items, which were identical across conditions. This excludes potential variability introduced by orthographically or phonologically inconsistent items. Instead the dependent measure was whether naming responses to exactly the same pictures were affected by the presence of the discounted items, whether consistent, inconsistent or unrelated. However, like Roelofs (2006) this design perpetuated the practice of treating a variable condition as equivalent to a fully heterogeneous baseline, thus assuming complete preparation failure in variable sets. We show below that this practice can be problematic.

Relevant to this point, we have shown in a related project that form preparation does not fail just because of the occurrence of inconsistent items (O'Séaghdha & Frazer, 2013). O'Séaghdha and Frazer developed a new *interloper* procedure, in which extraneous items appeared unpredictably during a typical word naming form preparation test with constant homogeneous sets. On most trials, targets were simply read and named. On interloper trials, the task was exactly the same except that the words were not part of the response set. The relevant findings here are for the case where the interlopers were exception items, inconsistent with the constant sets. For the set items, preparation of constant initial phonemes was reduced but still significant in the presence of the extraneous inconsistent items. Given that preparation survived the presentation of extraneous inconsistent items in constant sets, it should also be possible in variable sets. A speaker merely needs to segregate the exception and thereby focus on the majority component.

Attention and Form Preparation

If form preparation entails formation and maintenance of an intention toward the shared components in small sets of words, it is inherently attentional. Accordingly, the demands of the different task formats may influence whether form preparation is effective. To date, however, in the specialized literature on word production, the role of attention in preparation has not been distinguished from its role in actual production. Previous research has focused on how attention impacts different stages of word production, including phonological encoding. Ferreira and Pashler (2002) used a standard dual-task design, combining a picture-word paradigm (name the picture while ignoring a distractor word) with a tone discrimination task. Semantic but not phonological manipulations of distractor properties propagated to the secondary task. Ferreira and Pashler concluded that lexical retrieval does, but phonological encoding does not require central attention. However, Roelofs (2008) drew a different conclusion from a dual tasking study with form preparation as the primary task.

In this study, Roelofs (2008) used a picture naming version of form preparation (with constant homogeneous sets) together with a secondary perceptual decision task, deciding whether an arrowhead pointed left or right. Form preparation was present in the primary picture naming task, and the effect propagated to the secondary task during the time window of phonological encoding (0 and 300 ms SOAs). Roelofs interpreted these results as evidence, contrary to Ferreira and Pashler (2002), that phonological encoding draws on general attentional resources (see also Cook & Meyer, 2008; Roelofs & Piai, 2011). This conclusion however depends on the standard interpretation of form preparation as incipient production of target words (Roelofs 1997; Levelt et al., 1999). We next review how this interpretation came about and gained wide acceptance.

In the first publication on the subject, Meyer (1990) outlined an informal attentional account of form preparation, suggesting that there is a strategic focus on the shared phonological fragment, which is replenished throughout the productions of a homogeneous set. A much more specific account was proposed in the computational framework of the WEAVER++ model of word production (Roelofs, 1997; Levelt et al., 1999). Partly based on the all-or-none pattern of preparation observed in studies such as Roelofs (1999) and Roelofs and Meyer (1998), Roelofs and colleagues proposed that preparation involves insertion of the component shared by all homogeneous items in the production pathway, suspension of production at that point of phonological encoding, and resumption of production from the suspension point when a specific target is engaged. The role of attention was therefore limited to maintaining activation of the suspended fragment. This *suspend-resume* account thus a) conflates preparation and production by defining preparation as incipient production,

NIH-PA Author Manuscript

NIH-PA Author Manuscript

and b) asserts that what can be inserted in the production pathway must be fully distributed over set items. This conception of preparation as partial production underlies Roelofs's (2008) interpretation of the effect of form preparation on a secondary task as evidence that phonological encoding captures central attentional resources.

However, if preparation is attentional, it is not necessary to assume that it entails partial production. Instead, as in Meyer's (1990) original conception, preparation may be viewed as a distinct goal-setting process that points to and activates attended production ingredients, but need not commit to producing them (O'Séaghdha et al., 2010). That is, the anticipated component may receive selective attention but need not yet be selected for production. Moreover, the assumption that preparation requires full distribution of the attended component may not be warranted. There is little direct evidence for the restriction of preparation to constant sets outside the resource intensive and ecologically suspect associative cuing task. Therefore, the restriction of preparation may reflect task specific properties of associative cuing rather than an inherent limitation on the preparation of a majority phonological component.

Based on these considerations, we hypothesized that form preparation is implemented by attention in working memory. Because it is oriented to the action of producing words, such attention may be constrained by a selection bottleneck (Ferreira & Pashler, 2002) and has very limited capacity (see McElree, 2001), so that attention to a phonological component may be challenged by other task requirements. Crucially, selective attention is not equivalent to selection for production. Instead, just as pre-motor activity is functionally and anatomically distinct from motor action (Rosenbaum, 2010), preparation and production are anatomically distinguishable in speech production (e.g., Eickhoff, Heim, Zilles, & Amunts, 2009; Hickok & Poeppel, 2007). We theorize that form preparation prefigures but does not engage actual speech production.

To assess this proposal, we examined whether preparation of variable word sets succeeds despite the presence of exception items in the three commonly used form preparation tasks, picture naming, word naming, and associative cuing. In doing so, we implemented two adjustments to recent practice in this field. We segregated the responses to the exception items from the consistent ones (see Alario et al., 2007). And because our interest is in the extent of preparation for variable sets, we employed a fully heterogeneous baseline. In addition, we tested over two blocks in order to increase the power and sensitivity of the design. By implementing these changes, we optimized the conditions for assessing form preparation in each task.

Experiment 1: Picture Naming

Previous research has indicated that preparation may not occur for variable sets that contain an exception item. However, most of the evidence for this conclusion comes from the indirect associative cuing task. Our literature review and analysis suggest that it is worth examining whether the assertion that form preparation is impossible in variable sets holds for other tasks. In Experiment 1, we used a more ecologically valid production task, picture naming.

Experiment 1 tested variable homogeneous sets (three consistent and one inconsistent item) against fully heterogeneous sets (4 diverse items). The shared component among consistent items was the onset consonant. There were four base sets in which the excluded/exception items were rotated out in different versions (see Design). To capture adjustments in preparation as a result of experience, the experiment included a full replication in a second block. To provide maximum sensitivity, we used a true heterogeneous baseline, and we segregated responses to exception items from the others. This design is equipped to reveal form preparation if it occurs. If the all-or-none restriction is correct, there will be no preparation in this experiment. If preparation in variable sets is possible, and is moderated rather than eliminated by variability, the extent of preparation will be evident.

Method

Participants—Sixteen Lehigh University undergraduate students participated in fulfillment of a research option in Introduction to Psychology. All participants were native speakers of English.

Materials—Four sets of four CVC nouns sharing onset consonants were selected from the English Lexicon Project database (Balota et al., 2007). The consonants were */b/, /g/, /m/*, and */t/*. Sets were directly equated for naming latency in the Balota et al. norms, rather than by indirect fluency predictors such as lexical frequency (see Table 1). The selected words were monosyllable nouns from a restricted naming latency range (571 to 689 ms) that was one standard deviation above and below the mean of all monomorphemic, monosyllabic nouns in the database. Candidate homogeneous items shared only the initial consonant which was always followed by a long vowel and a consonant. The items were also selected to be easily picturable and to be distinct in reference. Table 1 shows these base items in the standard form preparation design arrangement of homogeneous (vertical columns) and crossed heterogeneous (horizontal) sets.

Pictures were obtained from a free online stock photo website, stock.xchng (http://www.sxc.hu/). Some words are more transparently referential than others, but with only four words per set it was easy to select images that effectively cued the intended words. Images were cropped as necessary and resized to 310 × 310 pixels using MS Paint, then saved as .bmp files for use with E-Prime 1.2.

The homogeneous conditions were always presented in *variable* sets (see Table 2). That is, each set comprised 3 consistent items and one inconsistent exception item. Items were rotated through four versions, with subgroups of participants assigned to each version, so that each item was omitted from the variable homogeneous set in one version and was correspondingly deployed as the exception item in another set. For example, in one version, *beach* was placed in the /g/ set and replaced by *tail* in the /b/ set (see Table 2). Across versions, the exception items for each homogeneous set included two exemplars of one onset and one each of two other onsets, thus maximizing diversity. The variable versions had no relevance for the heterogeneous groups which stayed the same in all versions (see Table 1).

Design—The design follows that of many previous experiments with variable homogeneous sets (e.g., Roelofs, 1999). The factors of theoretical interest were Context (Homogeneous, Heterogeneous), and Block (two blocks). The Homogeneous sets contained both consistent and exception items. In the analyses, we segregated the exception responses from the consistent ones. The primary interest is in the behavior of the consistent items, but the behavior of the exception items is also relevant.

In addition, there were two counterbalancing design factors. Sequence was counterbalanced such that half of the participants received heterogeneous sets first and half received homogeneous sets first. There were four versions of each homogeneous set (see Materials), with a different item rotated out of the consistent remainder in each version, and so there were four Versions of the materials. Sequence was included in analyses but is not theoretically relevant or informative and so will not be reported. Likewise version had no systematic effects. Because it involved only rotation of exception items, version was not included as a factor in analyses.

Because it was difficult to implement constrained randomization of picture presentation in E-Prime 1.2, we conducted this experiment in tandem with the following word naming experiment. We transcribed the randomizations generated for Experiment 2 into Experiment 1, using exactly the same design and randomizations in the two experiments. The order of items was random except that the same item was never repeated consecutively. Only the presentation order of the four sets in each condition was randomized independently of the Experiment 2 randomizations for each participant in Experiment 1.

Apparatus—The experiment was conducted on a Dell Optiplex Computer with a flat panel monitor and programmed in E-Prime 1.2. Voice onset times were recorded with a microphone connected to the computer through an SR Box. Audio recordings were also made of the experimental sessions using a Creative Technology *NOMAD Jukebox* recording device.

Procedure—Participants were introduced to the procedure and apparatus. An experimenter explained that the task was to become familiar with the names of small sets of pictures, and then to produce those names as quickly and accurately as possible when cued by the pictures during the testing phase. Prior to testing, participants were briefly familiarized with all 16 pictures and their names through a previewing procedure. Each picture was displayed in the center of the screen with its assigned name printed below together with an illustrative sentence. For example, the picture *beach* had the caption "BEACH as in: In the summer, people go to the beach." After silently reading the sentence, participants named the picture aloud. The experimenter provided any necessary clarification or correction and moved to the next item. Participants also completed two practice sets, one homogeneous and one heterogeneous with items not used in the experimental trials.

For each test set, four variable homogeneous (three consistent and one exception) or heterogeneous pictures, without their names, were first displayed on the screen. The position of the exception item was unpredictable. Participants named the four pictures aloud once before proceeding to the testing phase. During the testing phase, participants were instructed to name each picture aloud as quickly as possible when it appeared on the screen. On each trial, a fixation point appeared in the center of the screen for 100 ms, followed by a 250 ms blank screen accompanied by a warning tone. The picture then appeared on screen for up to 1150ms or until a response was detected by the voice key. Following a response, there was a blank interval of 1250 ms before the next trial. If there was no response, the message "Too Slow" was presented for 500 ms accompanied by a different 250 ms warning tone, and was followed by a 1000 ms blank screen. Each of the four pictures was named four times. Participants were informed when the first block was complete and initiated the second block themselves. The session lasted approximately 30 minutes.

Results

Errors were defined as productions where the participant did not produce the correct target or produced a word incorrectly (8.35% word production errors), did not speak loudly enough for the voice key to register a response, where the voice key was tripped by extraneous noise, or where the initiation time was unrealistically short (<150ms) (2.07% for these non-speech errors combined). These responses (10.42% in total) were removed from the data. Overall means and standard deviations of the remaining valid response times, with word production error rates, are displayed in Table 3 by block and context, with exception items segregated from the consistent homogeneous set members. To highlight changes in responding over time, a more detailed breakdown of responses to the first, second, third, and fourth appearances of exception items in each block, together with responses to corresponding quartiles of the consistent item responses, is shown in Figure 1a. To reduce noise, the first response in each trial was excluded. In the first block, there was a small difference between the homogeneous and heterogeneous conditions, and latencies to exception items were distinctly slow. Responses were faster at the beginning of trials in the second block, but slowed down as the trials progressed. In the second block, there was a clearer preparation effect for consistent items in the homogeneous condition relative to the heterogeneous, and the exception items were responded to faster than the heterogeneous baseline. Notably, the 29 ms change in response to exception items (from −17 to + 12) was both larger than the 13 ms change in response to consistent items (from 6 to 19 ms) and changed polarity, suggesting that exception items were processed in a fundamentally different way in the two blocks. The presence of exception items may have limited preparation of consistent words in the first block, but in the second block they appear to have been assimilated into a more complex preparation. We suggest that this preparation was of the form "expect the majority onset OR the specific exception word."

The key assumption in the literature is that there is no preparation of consistent items in sets containing an exception. Although many studies did not segregate exception items from consistent ones, it is clearly preferable to do so. We therefore conducted a 2 Block x 2 Context (homogeneous, heterogeneous) x 2 Sequence (homogeneous first or heterogeneous first) ANOVA with exception items excluded in the homogeneous condition. There was no overall effect of block, $F1\ (1, 14) = 1.24$, $p = .285$, $F2\ (1,15) = 1.67$, $p = .215$. Pictures were named more quickly in homogeneous contexts (563 ms) than in heterogeneous contexts (576 ms), $F1\ (1, 14) = 18.15$, $p < .001$, $F2\ (1, 15) = 18.12$, $p < .001$, $min\ F'(1, 29) = 9.07$, $p < .01$. Although the context effect descriptively increased over blocks (see Table 3 and Figure 1a), the interaction between block and context was not significant by subjects, $F1$ (1, 14) = 1.03, $p = .327$, and was only marginal by items, $F2$ (1, 15) = 4.27, $p = .057$. We conclude that form preparation of consistent items is present in the variable homogeneous condition, contrary to the previous literature.

Existing understandings of form preparation assume that exception items disable form preparation and so are no different than consistent ones in variable sets. The apparent shift in responses to exception items across blocks (see Figure 1a) is inconsistent with this interpretation. To test the exception responses, we repeated the previous analysis but replaced the consistent data with the exception data in the homogeneous condition. In contrast to the first analysis, there was a main effect of block [$F1$ (1, 14) = 4.61, $p < .05$, $F2$ (1,15) = 5.45, $p = .034$, but *min* F' (1, 29) = 2.50, $p = .12$], showing a slight speed-up in the second block. Context was not significant, $F1$ (1, 14) < 1, $F2$ (1, 15) < 1. But crucially, the context effect varied by block, $F1$ (1, 14) = 7.66, $p = .015$, $F2$ (1, 15) = 19.95, $p < .001$, *min* F' (1, 24) = 5.53, $p = .027$. We interpret this to mean that the response to exception items shifted significantly, from 'odd-one-out' to 'favored insider' between the first and second blocks. Together with the primary finding of form preparation in the variable homogeneous condition, the change in response to exception items over blocks is difficult to reconcile with the *suspend-resume* view that form preparation is limited to a single partial preparation in the production pathway.

Although we advocate that exception items should routinely be segregated from consistent ones in form preparation data analyses, it is interesting to consider the alternative analysis. We note that the contrast between blocks would be sharper (no context effect in the first block and a substantial effect in the second) if we followed the usual practice of aggregating all set items together. Under this procedure, the exception item wiped out the weak context effect in the first block. In contrast, the response to the exception was not very different than that to the other homogeneous condition items in the second block. An analysis of these aggregate data showed a significant context effect [$F1$ (1, 14) = 9.71, $p = .008$; $F2$ (1, 15) = 11.50, $p = .004$; *min* F' (1, 29) = 5.26, $p = .03$. The modulation of the context effect over blocks was marginal by subjects, F (1, 14) = 2.21, $p = .16$, but significant by items, $F2$ (1, 15) = 10.90, $p = .005$[2], *min* F' not significant. The effect of context in the second block with the exception item included (17 ms) was robustly significant [$F1$ (1, 14) = 7.00, $p = .019$, $F2$ (1, 15) = 23.78, $p < .001$, *min* F' (1, 22) = 5.41, $p = .03$]. Thus, both the overall analysis and the second block analysis disconfirmed the all-or-none assumption even when exception items were included in the homogeneous condition data. Our disconfirmation therefore does not depend on the choice of analysis.

Test for Local Disturbances—One interpretation of the relative costs incurred by exception items, especially in the first block, is that the exception items had to contend with and overcome incompatible form preparation. If so, exception items could also negatively affect responses to consistent items that followed them and weaken form preparation for the consistent items. To test this possibility, we organized the homogeneous context data into

[2]The weaker effect by subjects is a byproduct of sequence counterbalancing where half the participants received homogeneous contexts first and half the heterogeneous contexts first.

three Location categories: 1) exception items; 2) items immediately following exception items (Post); and 3) the remaining consistent items (Other) (see Figure 2). Contrary to the prediction, responses to items in the aftermath of exception items were if anything facilitated. An analysis of these data showed a significant effect of location, $F1$ (2, 28) = 5.63, p = .009, that was not modulated by block. Post-hoc tests on the aggregate data (using the Bonferroni correction) indicated that the difference between the Exception (578) and Post (556) means was marginal (p = .057), perhaps due to high variability in the exception responses, but the 10 ms difference between the Other (566 ms) and Post (556) means was significant, p = .014. Thus, if anything the item following an exception item was advantaged relative to other homogeneous context items. This may be because an exception was always followed by a consistent item, and so the preparation could be confidently expressed. This analysis is consistent with the presence of sustained rather than fluctuating attention to majority initial phonemes.

Discussion

Experiment 1 showed form preparation of consistent items in variable homogeneous contexts in a picture naming task, contradicting the all-or-none characterization of form preparation in previous reports. Considering only the consistent items in homogeneous contexts, the effect was descriptively but not statistically larger in the second block than the first. The response to exception items was clearly different in the two blocks, with relative costs in the first block modulating to a benefit almost equivalent to that for consistent set items in the second block. The more detailed descriptive examination of changes over quartiles of the data (Figure 1a) confirmed that these patterns were quite stable within blocks. These findings contradict the claim that preparation of consistent items is impossible in variable sets that include exceptions. The most salient aspects of the data are the difference in responses to consistent and exception items in the first block, and the preparation of both consistent and exception items in the second block (see Figures 1 and 2). The expansion of expectation in the second block to encompass the exception item as well as the majority onset implies a kind of dual attention that is difficult to account for in a *partial production*, suspend-resume account of preparation. We return to this important point in the General Discussion.

We noted that the contrast between the first and second blocks would have been sharpened if we had not segregated the exception responses from the consistent ones. In fact, the preparation effect in the first block would be nonexistent. This may have contributed to the insensitivity of previous experiments with only one testing block. For example, Roelofs (1999, Experiment 3) found no preparation in a single-block, picture naming experiment when one item had a different onset. However, this explanation does not work for our second block data where consistent and exception item latencies were similar. Here, inclusion of exception items with consistent ones left a substantial and significant form preparation benefit. Experiment 1 showed clear form preparation despite the presence of an exception item in an ecologically valid picture naming task format. This disconfirms the all-or-none view of form preparation and requires reconsideration of the assumptions underlying that view. In Experiment 2, we replicated the experiment in a word naming format that reduces cognitive demands relative to picture naming.

Experiment 2: Word Naming

In Experiment 1, in contrast to some previous research, we observed form preparation in variable homogeneous contexts in which one item always diverged from the designated form preparation property. Experiment 2 replicated Experiment 1 except that the task format was word naming. The primary goal was to establish whether variable context form preparation generalizes beyond the picture format. Word naming has been used in some previous form preparation studies, (e.g., Roelofs, 2006; Chen & Chen, 2006). Because the target words are always directly available, word naming makes very low demands on retrieval. Accordingly, there may be less motivation to focus on the composition of sets in word naming, or to strategically anticipate whether the next item will be a set item or the exception word. Nonetheless, Roelofs (2006) found comparable form preparation with constant sets in picture naming (31 ms) and word naming (38 ms). This suggests that word naming and picture naming are equivalent with respect to the phonological phase of encoding (see Nozari, Kittredge, Dell, & Schwartz, 2010 for converging evidence). Therefore, if form preparation in variable sets is a general phenomenon it should be present in word naming.

Method

Participants—Sixteen Lehigh University undergraduate students from the same source as Experiment 1 participated.

Materials and Design—The same materials were used as in Experiment 1, except that the cues were words instead of pictures. The design was the same as Experiment 1 and used the same randomization of items (see Experiment 1 Method). Only the order of sets within each block, which varied freely in each experiment, was different.

Procedure—The procedure was the same as in Experiment 1 except that the format differed. Instructions were updated throughout to reflect this difference. In the preview phase, participants saw only words and sentences. They named the words. At the beginning of each test, they received four words on screen and named the words. The test procedure was exactly the same as in Experiment 1 except that the targets were words rather than pictures. The words were presented in bold Courier New 18 font, centered on the screen.

Results

Errors were coded in the same way as in Experiment 1. Reflecting the simplicity and directness of the task, the error rate was low (2.56% of which 1.32% were word production errors – wrong word or incorrectly produced word). These responses were removed from the data which are shown in Table 3 and in Figure 1b. As in Experiment 1, there was a form preparation benefit for consistent items in the homogeneous condition. Figure 1b shows that the benefit is present in all quartiles except the first sector of the first block. Exception items pattern like in Experiment 1, but both the cost in Block 1 and the benefit in Block 2 relative to the heterogeneous condition are more moderate. We first assessed form preparation of the consistent items. There was no effect of Block, $F1\ (1, 14) < 1$, $F2\ (1, 15) = 1.16$, $p = .299$, perhaps because the directness of the task leaves little room for improvement with practice.

Responses were significantly faster in the homogeneous (428ms) than in heterogeneous (438ms) contexts, [*F1* (1, 14) = 6.28, *p* = .025; *F2* (1, 15) = 21.23, *p* < .001; *min F′* (1, 22) = 4.85, *p* = .039] showing a form preparation benefit for variable sets. As in Experiment 1, the effect was numerically larger in the second block (14 ms) than the first (7 ms), but statistically the effect was not modulated by Block, *F1* (1, 14) <1, *F2* (1, 15) = 1.95, *p* = .183.

As shown in Figure 1b, there is little evidence of distinctive responses to exception items within or across blocks. An analysis of exception vs heterogeneous conditions showed no context effect, *F1* (1, 14) < 1, *F2* (1, 15) < 1, and no modulation of the context effect over blocks, Fs < 1. Thus, the exception condition was not distinguishable from the heterogeneous baseline, and, unlike in Experiment 1, there was no appreciable change between blocks. Accordingly, there was no variation in responses following exceptions and so the additional positional analysis we provided for Experiment 1 was not repeated here.

Discussion

Experiment 2 confirmed the presence of form preparation of word-initial consonants in variable sets in a word naming task format. The effect was comparable to the picture naming effect in Experiment 1, and was very stable (see Figure 1b). Unlike in Experiment 1, the exceptionality of the exception items appeared to be virtually ignored (see Figure 1b).

The difference in reactivity to exception items between Experiment 1 and Experiment 2 can be understood as following from the task demands of word naming and the nature of the exception items. Given that there was only one exception item per set and that it occurred repeatedly in each set, it was easy to read it off each time it was presented. In contrast, if exception items are unknown interlopers, there is a clear cost in word naming (O'Séaghdha & Frazer, 2013). Also, we note that the effect size in the first block of this experiment (7 ms) was substantially less than the 26 ms effect O'Séaghdha and Frazer (2013) obtained for constant homogeneous sets in the first block of an experiment with the same words. Thus, although exception items were not themselves a locus of special difficulty, their presence nonetheless impacted the degree of form preparation for consistent words.

Experiment 3: Associative Cue Format

Experiments 1 and 2 clearly showed form preparation in variable homogeneous sets, contradicting the widely held assumption that form preparation is not possible in these conditions. Nonetheless, because there is a substantial history of preparation failure in just these circumstances in the cued-associates version of the form preparation task, it seems likely that form preparation with variables sets is indeed problematic in this task. One reason why this might be the case is that associative cuing is more resource demanding than picture or word naming, both in a general sense and in the specific respect that it requires indirect retrieval of targets based on associative cues. Previous studies, however, have not usually tracked performance over blocks, have not examined the behavior of exception items, or have aggregated exception items with consistent ones in reporting the context effect. These considerations could result in lack of sensitivity to small preparation effects. Thus, given the significant preparation effects in picture naming and word naming, a complete investigation of variable set form preparation requires a comparison of results under equivalent conditions in the associative cuing task. Experiment 3 used exactly the same design as the preceding experiments except that the procedure was associative cuing.

Given the findings of Experiments 1 and 2, if there is variable set form preparation in Experiment 3, it is more likely to emerge in the second block when responses are more fluent. In addition, if variable set form preparation is prevented by the difficulty of the associative task, responses to exception items could nonetheless reveal striving toward preparation. Thus, we were interested in whether there was any evidence of form preparation, especially in the second block, and in whether responses to exception items were slower than to set items, especially in the first block. In short, we investigated how the data profile in the associative-cue format compared to that in the picture and word naming versions of form preparation.

Method

Participants—Sixteen participants were drawn from the same source as for the other experiments.

Materials and Design—The same materials and design were used as in Experiments 1 and 2, except that the target words were cued by semantically related associates (see Table 1). Associates were selected to unambiguously elicit the targets, to minimize both phonological and semantic overlap with one another, and to minimize phonological overlap with the target words.

Procedure—The procedure was the same as in Experiment 1, except that participants learned small sets of prompt and response words, and then produced the response words as quickly as possible when cued during the testing phase. The familiarization procedure was the same as in Experiment 2. Each target word was displayed in the center of the screen with a sentence in which the target word was used beneath.

In the learning phase for each set of items, the four cue-target pairs were first displayed vertically. Participants were instructed to read the target words aloud. Then, to promote learning, each cue word was presented alone for 1000 ms and accompanied by the corresponding target for an additional 1000 ms. In the test phase, only the cue words appeared on the screen, and participants produced the corresponding targets.

Results

Errors (11.37%, of which 8.62 % were word production errors) were removed from the data. Overall means and standard deviations of the remaining valid response times as well as by condition word production error rates are displayed in Table 3 by Block and Context, and the more detailed quartile latencies are shown in Figure 1c. Latencies were much slower than in the other experiments, reflecting the difficulty of the task. In contrast to Experiments 1 and 2, there appeared to be no preparation effect, and there was no modulation of responses to exception items in either block of the experiment. Consistent with the all-or-none pattern in the previous literature, participants in this task may have focused on individual target retrieval in all conditions, making no strategic use of the majority phonological onset.

Analysis of variance on the consistent homogeneous and heterogeneous data confirmed that there was no context effect $F1$ (1, 14) < 1, $F2$ (1, 15) = 2.76, p =.118, and no change in the context effect over blocks, $F1$ (1, 14) < 1, $F2$ (1, 15) = 1.66, p = .217. The only significant effect was a main effect of Block, $F1$ (1, 14) = 81.08, p < .001, $F2$ (1, 15) = 47.92, p < .001, *min* F' (1, 28) = 30.12, p < .001, indicating that participants became substantially faster in the second Block (716ms) than they were in the first (748ms). We interpret this to reflect an improvement in the ease of retrieving the targets from associative cues. The fact that the block effect was significant here, but not in the other experiments, reflects the much greater task difficulty. Despite the more fluent retrievals in the second block, however, there was no indication of an emerging form preparation effect. It is notable that responses are faster at the beginning of the second block but slow down as the block proceeds in all three experiments. An analysis of Exception and Heterogeneous items confirmed that there was no context effect, $F1$ (1, 14) < 1, $F2$ (1, 15) < 1. Thus, there was no indication of reactivity to exception items. Participants neither prepared nor unsuccessfully attempted to prepare in this experiment.

Discussion

Consistent with the previous literature on form preparation with the associative cuing task, we found no form preparation in variable homogeneous contexts in which one of the four set items did not share the designated property. In contrast to Experiments 1 and 2, there was no indication of a preparation benefit to the majority, and in contrast to Experiment 1, there was no evidence of a cost to the exception items in the first half of the experiment (Figure 1c). In short, participants in Experiment 3 appeared to be oblivious to the homogeneity manipulation. Thus, there must be something about the associative cuing format that works against variable set preparation. Contrary to current accounts, however, the failure is task specific, not reflective of a general limitation on word form encoding.

Given the positive effects in Experiments 1 and 2, the lack of striving for preparation in this experiment is striking. Although the lack of cost for exception items in Experiment 3 suggests that there was no preparation rather than that preparation occurred but did not prove useful in target production, we decided to check this in a follow-up experiment. We used the 'interloper' method of O'Séaghdha & Frazer (2013) in which words with specified relations to the potential preparation occasionally and unpredictably appeared among the cues. These interlopers were signaled by a distinct green font. On cue trials, targets were retrieved just as in Experiment 3. On interloper trials, the task was simply to name these extra-set words as quickly as possible. In contrast to findings with constant sets in word naming (O'Séaghdha & Frazer, 2013), there was no benefit to interlopers that shared the same onset as the majority homogeneous targets. This indicates that the absence of form preparation in Experiment 3 was not due to fluctuation of attention when the cue was presented. Rather, preparation was simply nonexistent.

From the beginning of the study of form preparation, concerns have been aired about the validity of the associative cuing task (Meyer, 1990), specifically whether the benefit reflects

NIH-PA Author Manuscript
NIH-PA Author Manuscript

retrieval rather than or in addition to preparation processes. These concerns were addressed conceptually by Meyer, and have been allayed by demonstrations of consistent cross-task performance (Roelofs, 1999, 2006), but reemerged in the context of the debate about possible orthographic influences on form preparation (Damian & Bowers, 2003; Roelofs, 2006; Alario et al., 2007). Alario et al., argued that associative cuing does involve memory processes, and so advocated for the picture naming format. One way in which the cuing procedure might lead to the loss of preparation in variable but not in constant conditions is as follows. Speakers may seek to combine the cue with the constant phoneme in homogeneous conditions, in a formulation such as *'target is indicated by cue and begins with /b/'*. The form preparation benefit could then reflect phonological preparation, a mnemonic benefit, or both. If the target set is variable, however, this formulation becomes incoherent. Speakers need to check if the target begins with the desired phoneme rather than using it to promote retrieval, and so participants in variable conditions of cued associate form preparation experiments prefer to rely on the cues, ignoring the phonological information. Whether through this process or another one, it is clear that preparation failure in associative cuing experiments with variable sets reflects specific task demands rather than a general property of phonological encoding.

General Discussion

In two commonly used production tasks, picture naming and word naming, we observed form preparation in odd-one-out conditions that included an exception item. This disconfirms an established consensus that preparation is impossible in these conditions. We also observed distinctive responding to exception items in the picture naming task, such that responses to exception items were initially disrupted relative to consistent items but were later incorporated into a sophisticated plan that addressed both the consistent majority and the exception, to the benefit of both. In contrast, and in agreement with the previous literature, in the original and most widely employed form preparation task, associative cuing, there was no benefit of form preparation and there was no evidence of distinctive reactions to exception items. Our findings show both why form preparation has been viewed as impossible in variable sets (Experiment 3), and that it is not (Experiments 1 and 2).

The clarity of these conclusions partly results from our design choice to assess preparation over two testing blocks. Although the difference in preparation effects was not large enough in either Experiment 1 or Experiment 2 to create a significant increase in preparation over blocks, the effects were descriptively smaller in both experiments in the first blocks, so much so that if we had only the first block data we would not be reporting these experiments. In fact, previous single block picture naming form preparation experiments such as that of Roelofs (1999) did not find form preparation in variable sets. In our Experiment 1, if exception items were not segregated, the preparation effect would have been nil. Thus, it is easy to understand how the task difference could have been missed in previous work. On the other hand, the tendency for preparation to increase over blocks makes sense. In an attentional account, it is natural for preparation to vary with experience.

Form Preparation as Resource-Limited Sustained Attention

To account for the form preparation observed in picture and word naming, and for its absence in associative cuing, we propose that form preparation is better understood as sustained attention operating from outside the production pathway than as a suspended, partial production within the pathway (Levelt et al., 1999; Roelofs, 1997; see O'Séaghdha et al., 2010 for related discussion). More specifically, attention is directed to phonological fragments, perhaps preactivating them, but not inserting them in incipient productions. The account adopts the idea of sustained attention from the attention literature (e.g., Posner & Petersen, 1990; Braver, 2012), and asserts that planning for word production, like any other action, is subject to strict capacity limits. In addition, it incorporates a division of labor between preparation and execution that is well established in motor action (Rosenbaum, 2010), and is similarly configured in speech (Eickoff et al., 2009; Hickok & Poeppel, 2007). This is crucial in that it allows for preparation to be maintained with some degree of autonomy with respect to actual production, removing the need to assume continuous reinsertion of prepared components in the production pathway. Though the context is different, our idea is closely related to McElree's (2001) analysis of limited capacity working memory in an n-back procedure. McElree showed that the focus of attention in working memory may be narrowed to as little as a single item. Although the single item limit has been challenged (e.g., Verhaeghen, Cerella & Basak, 2004; Gilchrist & Cowan, 2011), for the present purpose the important point is that the capacity is very small. In the context of form preparation, the focus of attention may be more abstract than particular items in an n-back procedure. It may be a shared phonological component such as a word-initial consonant, or that component incorporated in a goal or construal. Attention to a phonological component or goal may contend with other task-specific demands.

Thus the essentials of the sustained attention account are as follows. 1) Form preparation is a resource-limited attentional process that is distinct from actual production. 2) Accessible units such as word onsets may receive sustained attention, and therefore activation, when capacity is available. In agreement with the suspend-resume account, activation of non-initial components does not significantly benefit encoding. 3) More abstract formulations or construals may also be placed in working memory. These enable dual attention to a majority component and an exception such as we observed in Experiment 1. 4) Unlike the suspend-resume account (Roelofs, 1997, 2008; Levelt et al., 1999), there is no necessity to store the preparation in the production pathway. Rather, entire words are encoded whether they are prepared or not.

Next we summarize how this account applies to form preparation in picture naming and word naming, and how associative cuing may require a different explanation. Picture naming is of greatest interest because it captures essential processes of word retrieval and encoding in a straightforward way. Because retrieval of picture names is not very demanding in the context of the form preparation task, it is possible to maintain attention to a phonological component or to a component in combination with an exception item contingency. As we have seen in Experiment 1, the nature of preparation may change with task experience. In the first block, attending to a majority characteristic (first phoneme) left the exception item out of account, but in the second block the benefit of first phoneme preparation was numerically larger, and the exception item showed a benefit not a cost. We propose that a natural explanation of this transition is that speakers, given sufficient opportunity, develop more sophisticated branching expectations such as 'expect a particular phoneme OR a specific exception word'. Because the exception word is signaled by a picture, it soon becomes easy to implement this directive. Assuming that this kind of conditional preparation is not implemented in phonological encoding until after one of the conditions has been met, it requires an attentional mechanism. Also supporting the attentional view, exception items did not disrupt consistent items that followed even in the first block of the experiment. This indicates that participants maintained attention to the salient word-initial component despite the need to deviate from it to accommodate the exception items. Nonetheless, especially in the second block when participants knew that exception items never occurred consecutively, enhancement of the post-exception item (Figure 2) suggests that sustained preparation can be rapidly modulated from one response to the next.

For printed word naming, retrieval may bypass or at least attenuate conceptual engagement (see Nozari, Kittredge, Dell, & Schwartz, 2010 for a detailed analysis of the distinct processes of picture and word naming), and unambiguous and singular cues (the visual presentations of the words) are available for each naming episode. There was little cost or benefit for the exception items. We suggest that this is because even if participants in Experiment 2 generated contingent expectations, they could fall back on simple reading of the exception words whenever they appeared. However, there was a benefit to the homogeneous majority in the word naming task just as there was in picture naming. We attribute this to sustained attention to the probable first phoneme. That the effect size is similar in word and picture naming despite the much slower latencies in the latter suggests that form preparation influences phonological encoding processes that are common to these tasks.

There is a long-standing concern that associative cuing taps into memory processes instead of or in addition to the targeted production ones (Meyer, 1990; Alario et al., 2007). We propose that the specific demands of the associative cuing task make it difficult to maintain attention to any but the simplest form preparation conditions (i.e., constant sets). It seems plausible that cued retrieval draws on the same attentional resources as preparation, and so even for constant sets retrievals may temporarily displace preparation. Preparation in constant sets may be accounted for either by a freeing of attentional capacity in time to activate the relevant phonology or by a task-specific retrieval procedure whereby associative cues are combined with phonological information in working memory. Cues combined with reliable word beginnings (e.g., cue word + constant first phoneme) lead to expedited target retrieval and also allow attention to function. But if the word beginnings are variable (e.g., cue word plus uncertain phoneme), the retrieval strategy is problematic and is discarded (see discussion of Experiment 3). Disregarding a majority phonological property also means that it does not receive attention, and so there is no preparation effect.

To further clarify the nature of the difficulty created by variable sets in the associative cuing task, it may be useful to return to our opening game show metaphor. Recall that contestants competed for how quickly they produced the target words. If the primary clue is a picture, probabilistic phonological information about the target word beginning can be combined with the clue to yield an advantage when the sound clue is valid. But if the clue is an associated word, trying to combine this with probabilistic sound information for the target would be a losing strategy, likely costing valuable time. The sound clue becomes relevant only when the answer is already identified, and so it should be ignored.

This limitation of associative cuing may also help explain the puzzle of preparation failure in the variable orthography conditions of Damian and Bowers (2003), but not in an equivalent Dutch experiment (Roelofs, 2006). As suggested by Roelofs, Damian and Bowers's English participants may have focused on the orthographic variability of the items, whereas his Dutch participants ignored the different spellings and recognized the phonological constancy. Thinking of the letters 'K or C' in combination with the associative cues for the set *kennel, coffee, cushion* would not help fluent retrieval of the targets, whereas thinking of a phonic '/k/' would.

To summarize, for constant sets, a) associative cuing may enable sustained attention to phonological word beginnings as in picture and word naming, b) a distinct memory process involving the combination of cues with metacognitively accessible form properties, or both. The same properties that make phonological beginnings useful to preparation make them effective memory cues. In variable sets, the memory process is not viable and, perhaps as a result, attention is not allocated to majority phonological components. Thus, failure of preparation in variable sets tells us about task-specific processes rather than about the nature of phonological preparation.

Recommendations and Conclusion

The goal of this article was to clarify the nature of form preparation in word production. We found that all-or-none preparation is specific to the associative cuing task and does not apply to form preparation in general. Theoretically, we advocate for a reconception of lexical form preparation as employing general attentional resources, including sustained attention to symbolically addressable phonological components. Our findings and attentional perspective have a number of specific implications.

First, picture or word naming are preferable methods for assessing form preparation than the more extensively used associative cuing task. Preparation failure for variable sets of words in the associative cuing task is due to task-specific requirements rather than to general properties of word preparation. Therefore, previous conclusions based on comparisons of variable and heterogeneous contexts should be revisited. Nonetheless, many useful discoveries have been made with associative cuing (e.g., Meyer, 1990, 1991; Roelofs & Meyer, 1998; Chen et al., 2002; Damian & Bowers, 2003; O'Séaghdha et al., 2010). In general, for preparation effects with constant sets, because the memory cuing and sustained attention processes respond to the same manipulations, the findings remain valid.

Second, variable sets are not equivalent to heterogeneous ones. Most obviously, the claim that preparation is impossible in the presence of an exception, and the corollary that a variable set may be viewed as equivalent to a fully heterogeneous one, are invalidated for the picture and word naming tasks. Therefore, future form preparation experiments with these tasks should return to the safer practice of using a fully heterogeneous baseline. Ironically, our results also suggest that the use of variable sets as a baseline with the associative cuing task may be justified.

A third conclusion from our study is that form preparation cannot tell us whether phonological encoding itself taps central attention (Roelofs, 2008; Roelofs & Piai, 2011). As discussed above, Roelofs (2008) proposed that costs of form preparation in a secondary perceptual task show that phonological encoding absorbs central attentional capacity. Our findings suggest that preparatory processes involve attentional mechanisms that are positioned outside the production pathway. Accordingly, costs of form preparation in a dual tasking procedure show only that preparation demands attentional resources. No conclusion can be drawn about the attentional demands of actual phonological encoding based on this evidence. The question of whether actual phonological encoding requires central attentional capacity should be addressed by tasks that directly engage phonological encoding (see Ferreira and Pashler, 2002; Cook & Meyer, 2008; Ayora et al., 2011, for relevant discussion).

Although the rationale for our attentional view of form preparation is clear in hindsight, we confess that these conclusions were not entirely foreseen in this research project. We began with the same assumption as other researchers that form preparation is all-or-none. The experiments reported here were originally conceived as baseline demonstrations of limited or failed preparation against which to explore the conditions necessary to promote successful preparation (Frazer & O'Séaghdha, 2010). We hypothesized that such conditions existed, and conducted various tests that encouraged strategic preparation. For example, in one picture naming study participants were advised that focusing on the initial sound shared by three of four words in homogeneous sets could be beneficial. This and other similar experiments were quite unsuccessful in promoting preparation. Instead, participants seemed to become preoccupied with the exception items. These failures of preparation, even in ecologically valid tasks, can be reconciled with the attentional account. Preparation failure can occur in any task where capacity is exceeded or put to ineffective use. If form preparation is constrained by a very limited attentional capacity, our 'helpful' instructions may have occupied working memory or led to detrimental strategies, thus preventing deployment of sustained attention to initial phonemes. In general, elaboration of preparation instructions may be inimical to effective preparation.

In conclusion, we strongly agree with Roelofs and Piai (2011) and others (e.g., Ferreira & Pashler, 2002; Nozari & Dell, 2012; Nozari & Thompson-Schill, 2013; Wundt, 1900, cited by Roelofs and Piai, 2011) that integration of modern attentional theories into accounts of language production is long overdue. Our perspective is consistent with Roelofs and Piai's (2011) distinction between declarative procedures of goal setting and the actual steps of phonological encoding:

> When a goal is placed in working memory, processing in the system is focused on those rules that include the goals among their conditions. The rules mediate attentional influences by selectively enhancing the activation of target nodes in the network in order to achieve speeded and accurate picture naming and word reading.

(Roelofs & Piai, 2011, p 2).

To apply this approach to form preparation as well as to actual production, we suggest that it is necessary to incorporate mechanisms such as sustained attention into theories of word production. From this perspective, form preparation is not a window on the intricacies of phonological production but rather a reflection of the flexibility and limitations of preparation itself.

Acknowledgments

This research was supported by NIDCD grant R01DC006948. Gwendolyn (Johnson) Rehrig and Laura Kelly contributed to implementation of the experiments. We thank Marilyn Andersen, Alexandra Huttle, Siri Amster-Olszewski, Alexa Procaccino, and Kimberly Preusse for research assistance.

References

Alario FX, Perre L, Castel C, Ziegler JC. The role of orthography in speech production revisited. Cognition. 2007; 102:464–475. [PubMed: 16545792]

Aslin, RN.; Saffran, JR.; Newport, EL. Statistical learning in linguistic and nonlinguistic domains. In: McWhinney, B., editor. The emergence of language. Taylor and Francis; 1999. p. 359-380.

Ayora P, Peressotti F, Alario FX, Mulatti C, Pluchino P, Job R, Dell'Acqua R. What phonological facilitation tells about semantic interference: A dual-task study. Frontiers in Psychology. 2011; 2:1–10. [PubMed: 21713130]

Balota DA, Yap MJ, Cortese MJ, Hutchinson KA, Kessler B, Loftus B, Neely JH, Nelson DL, Simpson GB, Treiman R. The English lexicon project. Behavior Research Methods. 2007; 39:445–459. [PubMed: 17958156]

Bi Y, Wei T, Janssen N, Han Z. The contribution of orthography to spoken word production: Evidence from Mandarin Chinese. Psychonomic Bulletin & Review. 2009; 16:555–560. [PubMed: 19451384]

Braver TS. The variable nature of cognitive control: A dual-mechanisms framework. Trends in Cognitive Sciences. 2012; 16:106–113. [PubMed: 22245618]

Chen TM, Chen JY. Morphological encoding in the production of compound words in Mandarin Chinese. Journal of Memory and Language. 2006; 54:491–514.

Cook AE, Meyer AS. Capacity demands of phoneme selection in word production: New evidence from dual-task experiments. Journal of Experimental Psychology: Learning Memory and Cognition. 2008; 34:886–899.

Cholin J, Schiller NO, Levelt WJM. The preparation of syllables in speech production. Journal of Memory and Language. 2004; 50:47–61.

Damian MF, Bowers JS. Effects of orthography on speech production in a form-preparation paradigm. Journal of Memory and Language. 2003; 49:119–132.

Eickhoff SB, Heim S, Zilles K, Amunts K. A systems perspective on the effective connectivity of overt speech production. Philosophical Transactions of the Royal Society A. 2009; 367:2399–2421.

Ferreira VS, Pashler H. Central bottleneck influences on the processing stages of word production. Journal of Experimental Psychology: Learning, Memory, and Cognition. 2002; 28:1187–1199.

Fournier LR, Gallimore JM, Feiszli KR, Logan GD. On the importance of being first: Serial order effects in the interaction between action plans and ongoing actions. Psychonomic Bulletin & Review. 2013

Frazer, AK.; O'Séaghdha, PG. Flexible planning in word production. Poster presented at the annual meeting of the Psychonomic Society; St. Louis, MO. Nov. 2010

Gilchrist AL, Cowan N. Can the focus of attention accommodate multiple, separate items? Journal of Experimental Psychology: Learning, Memory, and Cognition. 2011; 37:1484–1502.

Hickok G, Poeppel D. The cortical organization of speech processing. Nature Reviews Neuroscience. 2007; 8:393–402.

Janssen DP, Roelofs A, Levelt WJ. Inflectional frames in language production. Language and Cognitive Processes. 2002; 17:209–236.

Levelt WJM, Roelofs A, Meyer AS. A theory of lexical access in speech production. Behavioral & Brain Sciences. 1999; 22:1–75. [PubMed: 11301520]

McElree B. Working memory and focal attention. Journal of Experimental Psychology: Learning, Memory, and Cognition. 2001; 27:817–835.

Meyer AS. The time course of phonological encoding in language production: The encoding of successive syllables of a word. Journal of Memory & Language. 1990; 29:524–545.

Meyer AS. The time course of phonological encoding in language production: Phonological encoding inside a syllable. Journal of Memory and Language. 1991; 30:69–89.

Nozari N, Kittredge AK, Dell GS, Schwartz MF. Naming and repetition in aphasia: Steps, routes, and frequency effects. Journal of Memory and Language. 2010; 63:541–559. [PubMed: 21076661]

Nozari N, Dell GS. Feature migration in time: Reflection of selective attention on speech errors. Journal of Experimental Psychology: Learning Memory and Cognition. 2012; 38:1084–1090.

Nozari, N.; Thompson-Schill, SL. More cognitive control when speaking: does it help or does it hurt? Evidence from tDCS. Neuropsychologia. 2013. http://dx.doi.org/10.1016/j.neuropsychologia.2013.08.019i

O'Seaghdha PG, Chen JY, Chen TM. Proximate units in word production: Phonological encoding begins with syllables in Mandarin Chinese but with segments in English. Cognition. 2010; 115:282–302. [PubMed: 20149354]

O'Seaghdha, PG.; Frazer, AK. Consequential form preparation in word production. 2013. Manuscript under revision

O'Seaghdha PG, Marin JW. Phonological competition and cooperation in form-related priming: Sequential and nonsequential processes in word production. Journal of Experimental Psychology: Human Perception & Performance. 2000; 26:57–73. [PubMed: 10696605]

Posner MI, Petersen SE. The attention system of the human brain. Annual Review of Neuroscience. 1990; 13:25–42.

Roelofs A. The WEAVER model of word form encoding in speech production. Cognition. 1997; 64:249–284. [PubMed: 9426503]

Roelofs A. Phonological segments and features as planning units in speech production. Language and Cognitive Processes. 1999; 14:173–200.

Roelofs A. The influence of spelling on phonological encoding in word reading, object naming, and word generation. Psychonomic Bulletin & Review. 2006; 12:33–37. [PubMed: 16724765]

Roelofs A. Attention, gaze shifting, and dual-task interference from phonological encoding in spoken word planning. Journal of Experimental Psychology: Human Perception and Performance. 2008; 34:1580–1598. [PubMed: 19045994]

Roelofs A, Baayen H. Morphology by itself in planning the production of spoken words. Psychonomic Bulletin & Review. 2002; 9:132–138. [PubMed: 12026945]

Roelofs A, Meyer AS. Metrical structure in planning the production of spoken words. Journal of Experimental Psychology: Learning, Memory, and Cognition. 1998; 24:922–939.

Roelofs A, Piai V. Attention demands of spoken word planning: A review. Frontiers in Psychology. 2011; 2:1–14. [PubMed: 21713130]

Rosenbaum, DA. Human motor control. 2. San Diego: Academic Press/Elsevier; 2010.

Sevald CA, Dell GS. The sequential cuing effect in speech production. Cognition. 1994; 53:91–127. [PubMed: 7805353]

Verhaeghen P, Cerella J, Basak C. A working memory workout: how to expand the focus of serial attention from one to four items in 10 hours or less. Journal of Experimental Psychology: Learning, Memory, and Cognition. 2004; 30:1322–1337.

Wundt, W. Die Sprache. Leipzig: 1900.

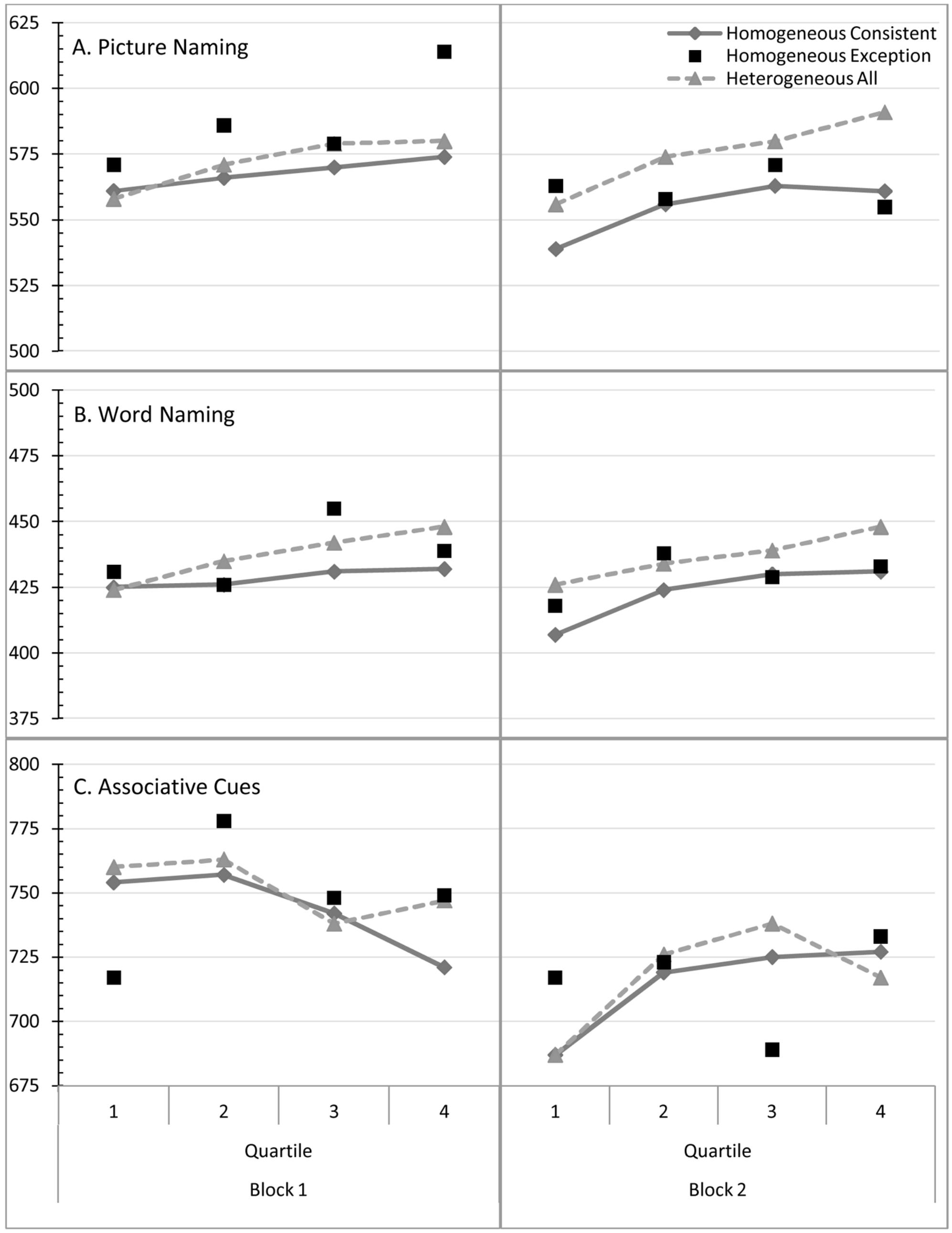


Figure 1.

Mean Reaction Times for the four exception items and for consistent homogeneous and heterogeneous condition targets in corresponding quartiles of the data over two blocks in Experiment 1 (Picture Naming), Experiment 2 (Word Naming), and Experiment 3 (Associative Cuing). To reduce noise, the first items in the first quartiles were discarded.

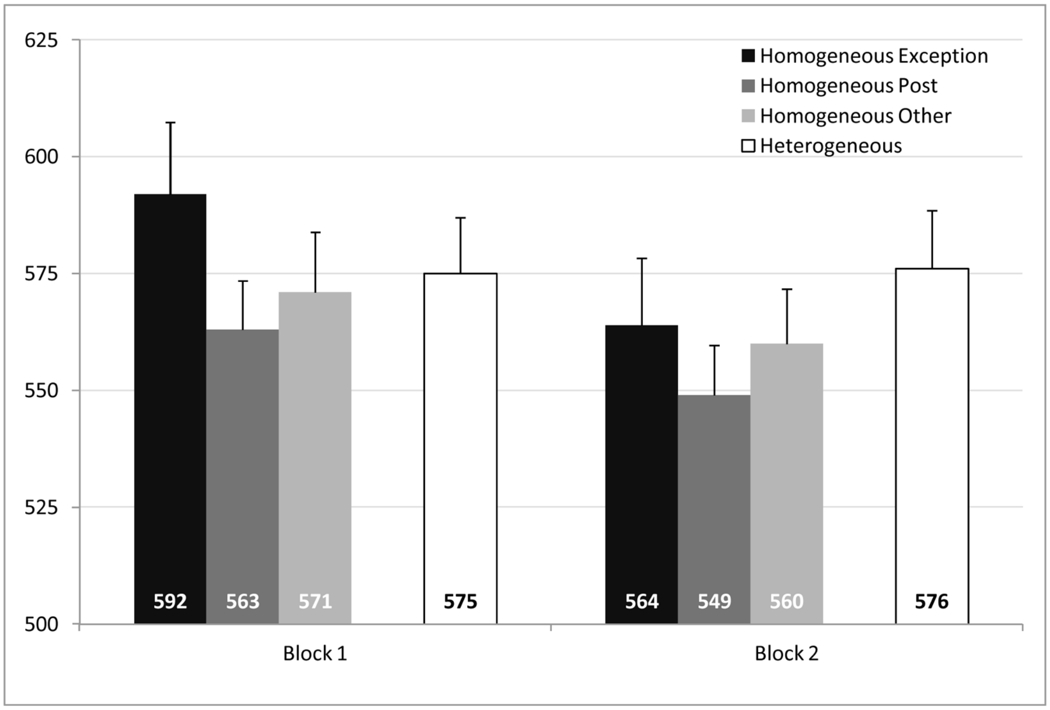


Figure 2.
Experiment 1 Picture Naming: Initiation times for exception, post-exception, and all other homogeneous responses in each block. The overall heterogeneous context latencies are shown for comparison.

NIH-PA Author Manuscript

NIH-PA Author Manuscript

Table 1

Base materials for all experiments showing the four constant homogeneous sets, their mean naming latencies (SDs) (Balota et al., 2007), and the corresponding heterogeneous sets. The associative cues were used only in Experiment 3. To create the variable homogeneous sets one item was systematically swapped out with an item from a different set (see Table 2 for examples and text for full details).

		Constant Homogeneous Sets			
Heterogeneous Sets	**1**	tan-beach	robe-gown	pair-mate	frog-toad
	2	chef-bake	score-goal	feel-mood	brake-tire
	3	dull-bore	lock-gate	snack-meal	pipe-tube
	4	hike-boot	tool-gear	rock-mine	mouse-tail
		623 ms (8.7)	637 ms (16.5)	608 ms (40.1)	615 ms (13.4)

Table 2

One of the four configurations of variable homogeneous sets. The exception items (bolded) are placed on the top-left to bottom-right diagonal. The pictures were named in Experiment 1 and the words were named (Experiment 2) or cued by associates (Experiment 3).

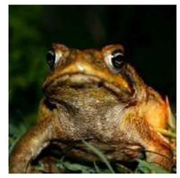
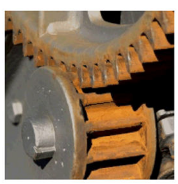
Homogeneous Sets: Version A			
B	**G**	**M**	**T**
 ***tail***	 Gown	 mate	 toad
 bake	 ***beach***	 mood	 tire
 bore	 Gate	 ***goal***	 tube
 boot	 Gear	 mine	 ***meal***

Table 3

Mean Word Initiation Times with Standard Errors and Percentage Word Production Errors as a Function of Block and Context for the three Experiments. The Context Effects (Heterogeneous – Homogeneous) are shown separately for Consistent and Exception Words.

Experiment		Variable Homogeneous		Heterogeneous	Context Effect	
		Consistent	Exception		Consistent	Exception
1. Picture Naming	Block 1					
	M	569	592	575	6	−17
	SE	12.07	15.39	11.99		
	%E	.07	.07	.08		
	Block 2					
	M	557	564	576	19	12
	SE	11.42	14.40	12.61		
	%E	.10	.07	.09		
	Total					
	M	563	578	576	13	−2
	SE	11.18	14.32	11.56		
	%E	.08	.07	.09		
2. Word Naming	Block 1					
	M	431	439	438	7	−1
	SE	16.93	18.61	15.11		
	%E	.01	.02	.01		
	Block 2					
	M	425	432	439	14	7
	SE	13.84	15.42	16.04		
	%E	.01	.02	.01		
	Total					
	M	428	436	438	10	2
	SE	14.86	16.54	15.41		
	%E	.01	.02	.01		

Experiment		Variable Homogeneous		Heterogeneous	Context Effect	
		Consistent	Exception		Consistent	Exception
3. Associative Cues	Block 1					
	M	745	753	751	6	−2
	SE	12.02	12.09	12.91		
	%E	.10	.15	.10		
	Block 2					
	M	716	719	717	1	−2
	SE	12.93	13.48	12.74		
	%E	.07	.09	.05		
	Total					
	M	730	736	734	4	−2
	SE	12.18	11.82	12.54		
	%E	.08	.12	.08		