SKOOL versus ZOOL: Effects of orthographic and phonological long-term memory on nonword immediate serial recall

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Running Head: Pseudohomophone effects & immediate serial recall

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Abstract

In a now classic study, Besner and Davelaar, (1982) reported an advantage of pseudohomophone (PSH) over nonword recall in a visual immediate serial recall (ISR) task, which remained under articulatory suppression (AS) and interpreted the findings as indicating PSH items obtain support from stored phonological long-term memory (LTM) representations even when phonological rehearsal is disrupted. However, one key question relating to this PSH effect remains: could the results have been contaminated by a potential confound of orthographic familiarity (i.e., PSH items often *look* like the word they sound like)? As a result, the present study examined the impact of orthography on PSH ISR. Our findings indicate that PSH accuracy was consistently higher for items that had an orthographic similarity to the parent word, and this effect did not interact with concurrent task. We therefore argue that PSH items in ISR obtain independent support from both orthographic and phonological LTM representations. The present study demonstrates the critical impact of orthographic LTM representations on visual nonword ISR, and we suggest that this may be a fruitful avenue for further research.

Phonological short-term memory is typically examined via performance on an immediate serial recall task (ISR), in which participants must repeat back a sequence of aurally or visually presented items in the order that they were presented. Success at this task has been linked to a short-term phonological store that is refreshed via a phonological 'loop' (Baddeley & Hitch, 1974). This process of short-term retention has been argued to benefit from lexical-phonological representations held in long-term memory which provide support to decaying short-term memory traces either via a reconstruction processes at the moment of recall, or via direct activation of phonological long-term representations during encoding (e.g., Gupta & MacWhinney, 1997; Martin, Lesch, & Bartha, 1999). Evidence from ISR experiments consistent with this principle include, (a) better recall of high-frequency words relative to low-frequency words (Roodenrys, et al., 1994), (b) semantic processing variables such as concreteness (Walker & Hulme, 1999) and imageability (Bourassa & Besner, 1994; Martin, Lesch, & Bartha, 1999) modulate ISR performance, and (c) span improves for lists of items drawn from the same category relative to different categories (Poirier & St Aubin 1995). These findings indicate an important interaction between stored phonological and semantic long-term memory (LTM) representations and success at the ISR task. It is therefore perhaps not surprising that ISR performance is also reported to be superior with words over nonwords (e.g., Crowder, 1978, Hulme, et al., 1995). This pervasive 'lexicality effect' is entirely consistent with the principle that nonwords (unlike words) have no LTM representations to draw upon and as a result performance is diminished.

The present study aims at providing further evidence for strong and obligatory interactions between long-term language knowledge and short-term memory performance by exploring the effect of phonological and orthographic knowledge on visually presented nonword ISR; manipulation of familiar and unfamiliar phonology can be achieved via the comparison of nonwords that when read either do or do not sound like real words (*pseudohomophones* - SKOOL vs. ZOOL). Besner and Davelaar (1982) reported an advantage of pseudohomophone (PSH) over nonword recall in a visual ISR task, and this advantage remained even when participants performed articulatory suppression (AS) during presentation (i.e., counting from 1-10 repeatedly at a rate of 3 times per second). However, under similar conditions, AS (relative to silence) abolished both syllable length and phonemic similarity effects at recall. The authors argued that this suggested that there are two phonological codes, one that is disrupted by AS and one that is not (see Figure 1).

(Figure 1 about here)

Code 1 is implicated in lexical access, and is linked to long-term memory representations, supporting PSH items via access to familiar phonological representations. Code 2 functions as a durable storage medium for retaining serial order information (Besner & Davelaar, 1982) and is therefore, disrupted by AS. Consistent with this proposal, recent research (Howard & Nickels, 2005) with patients who had an impaired auditory verbal short-term memory (i.e., damage to Code 2 in the Besner & Davelaar model) has also shown that a PSH benefit is still present during a nonword ISR task (preserved Code 1). This work suggests that in an ISR task, if there is an opportunity for LTM representations

(Code 1) to support a phonological trace in STM (Code 2), then this will occur (be it stored phonological form or semantic representations). More recently, it has been demonstrated that such LTM support is most beneficial for item recall, as compared to order recall (Fallon, Groves, & Tehan, 1999; Saint-Aubin & Poirier, 1999), consistent with the principle that AS ‘knocks out’ the order specific information provided by the ‘phonological loop’ (modulated by phonemic similarity/length), but not item information (modulated by lexicality). To reiterate, the influence of LTM representations on a STM task are directly linked to the preservation of items in a sequence, but have no real role to play in the preservation of order based information so critical to success at immediate *serial* recall.

However, although the original Besner and Davelaar (1982) study has been very influential, it is of note that PSHs do not just differ from nonwords on the basis of familiar phonology; PSH items can also bear a strong orthographic familiarity to real words (i.e., SKOOL both sounds like a real word and *looks* similar to the parent word). It is therefore possible, that the PSH effects reported in the Besner and Davelaar (1982) study reflect the support of orthographic rather than phonological LTM representations (or some combination of both). This may be particularly true when AS is undertaken with the consequential impact on phonological codes, in that visually based (orthographic) information may play a bigger role. This has not yet been systematically manipulated, and thus its impact remains unknown. The present study sought to determine the degree to which the PSH advantage under AS reflected the greater use of orthographical

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knowledge rather than phonological knowledge under such conditions[1]. This was achieved by independently manipulating phonological familiarity (i.e., pseudohomophones versus nonwords) and orthographic familiarity (i.e., pseudohomophones/nonwords that were closely visually related to their parent word or otherwise). Studies with patients who have nonword reading impairments (phonological dyslexia) have demonstrated that PSHs with *high visual similarity to the parent word* are read with greater accuracy (e.g., Howard & Best, 1996) and this can even modulate nonword ISR performance in such cases, with poorer recall of visually similar items (Best & Howard, 2005). In light of this evidence, the present study sought to determine whether orthographic effects are also present in the ISR performance of normal participants and the degree to which such effects might be modulated by AS. The results of this work would shed light on the impact (if any) of orthographic long-term memory representations.

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[1] It is also of note that aspects of the methodology of Besner and Davelaar (1982) may have been problematic. Only a small sample of items was used (20 PSHs vs. 20 Nonwords) and items were often re-presented a number of times (in Experiment 1, a total of 32 PSH trials (each comprising of a list of 4 items) were presented across silent/suppression conditions, meaning each of the 20 PSHs were presented at least 6/7 times).

Experiment 1 – ISR with articulatory suppression

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METHOD

Participants:

Thirty-six Exeter University psychology undergraduate students (aged 20-25) with normal reading ability were used, and all obtained course credits for taking part.

Materials:

A total of 96 pairs of critical stimuli (see Appendix 1) were selected from a set of items utilised by Nickels et al., (2008) to originally study orthographic similarity effects in pseudohomophone/nonword reading in cases of phonological dyslexia. This set consisted of stimulus pairs of PSHs matched with a nonword by the substitution of one or two letters (i.e., *virb* with *jirb; wrait* with *knait*). This set also varied in orthographic similarity, with half of the PSHs being highly similar in orthography to the parent word (ORTH+ :- e.g. *kamp,* orthographically similar to the word *camp*) and half of low orthographic similarity (ORTH- :- e.g. *kloo*, orthographically dissimilar to the word *clue*). Letter and phoneme length were matched across each of these four conditions. Another 32 items (16 PSHs/16 NWs) were also used as practice stimuli.

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Design:

The experiment utilised a within-participants design and manipulated pseudohomophony (two levels: PSH vs. NW) x orthographic similarity (two levels: ORTH+ vs. ORTH-) x articulatory suppression (two levels: AS+ vs. AS-). Each trial consisted of four items chosen without repetition from the stimulus set (consistent with Besner & Davelaar, 1982). The experiment consisted of four blocks of fourteen trials; the first two trials were practice items and the subsequent twelve trials were equally distributed across experimental conditions (3 PSH-ORTH+, 3 PSH-ORTH-, 3 NW-ORTH+, 3 NW-ORTH-); trials were presented in a random order within each block. Half the blocks were carried out in either silence or under suppression and this was counterbalanced across participants.

Procedure:

On each trial, four items printed in lower case appeared successively at a rate of one every two seconds. Prior to the initiation of the first practice trial of each block, participants were instructed whether the proceeding block was to be carried out in silence or accompanied by suppression. During suppression, participants were instructed to repeat "the" at a continuous rate. Suppression was prompted before the first item of each trial was initiated and terminated after the last item disappeared and recall began. Recall was made orally after every trial with responses recorded by the experimenter, who prompted participants if suppression slowed or discontinued. All stimuli were used presented twice to participants (once in the silence and once in the AS conditions), and the order of silence/suppression conditions was counter-balanced.

RESULTS

Response accuracy was scored as a function of– (1) *absolute accuracy* (i.e., proportion of items recalled in correct serial position), (2) *item accuracy* (i.e., proportion of items recalled independent of serial position) and (3) *order accuracy* (i.e., absolute accuracy/item accuracy – in this case a higher score indicates that a higher proportion of correctly recalled items were also in the appropriate serial position, with separate analyses conducted in each case.

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Absolute accuracy:

Figure 2 shows absolute accuracy across each of the eight experimental conditions

A three way repeated-measures ANOVA (pseudohomophony (PSH versus NW) x orthographic similarity (ORTH+ versus ORTH-) x suppression (AS- or AS-)) showed significant effects of suppression (F 1, 35 = 143, p=<.001) and pseudohomophony (F 1, 35 = 64.10, p=<.001) but no main effect of orthographic similarity (F 1, 35 = 0.58, n.s.). There were also interactions between suppression and pseudohomophony (F 1, 35 = 16.74, p=<.001) and pseudohomophony and orthographic similarity (F 1, 35 = 15.18, p=<.001), but no interaction between suppression and orthographic similarity (F 1, 35 = 1.36, n.s.) or three-way interaction (F 1, 35 = 0.59, n.s.). Given the presence of a AS x PSH interaction, individual analyses on the PSH effect in both the silence and suppression conditions determined that although this effect was reduced under AS it still remained statistically reliable (Silence – PSH= .66 vs. NW= .47, t(71)= 9.42, p=<.001; AS – PSH= .29 vs. NW= .21, t(71)= 4.83, p=<.001). Given the presence of a PSH x

ORTH interaction, separate analyses on the orthographic similarity effect in both the PSH and NW conditions determined that this effect was only reliable for the PSH items (PSHs – ORTH+ = .50 vs. ORTH- = .45, t(71) = 2.96, p= 0.004; NWs – ORTH+ = .32 vs. ORTH- = .35, t(71) = -1.57, p=< 0.1).

(Figure 2 about here)

Item accuracy:

Figure 3 shows item accuracy across each of the eight experimental conditions.

A three way repeated-measures ANOVA showed significant effects of suppression (F 1, 35 = 165.71, p=<.001) and pseudohomophony (F 1, 35 = 94.54, p=<.001) but no main effect of orthographic similarity (F 1, 35 = 0.02, n.s.). As in the absolute accuracy analyses, there were interactions between suppression and pseudohomophony (F 1, 35 = 8.08, p=<.001) and pseudohomophony and orthographic similarity (F 1, 35 = 111.25, p=<.001), but no interaction between suppression and orthographic similarity (F 1, 35 = 8.34, n.s.) or three-way interaction (F 1, 35 = 2.72, n.s.). Given the presence of a AS x PSH interaction, individual analyses on the PSH effect in the silence and suppression conditions determined that although this effect was reduced under AS it still remained (Silence – PSH= .75 vs. NW= .59. T(71)= 9.61, p=<.001; AS – PSH= .51 vs. NW= .42, T(71)= 6.02, p=<.001). Given the presence of a PSH x ORTH interaction, separate analyses on the orthographic similarity effect in both the PSH and NW conditions determined that orthographic similarity exerted differential effects, having a positive benefit for PSHs and vice versa for nonwords (PSHs – ORTH+ = .66 vs. ORTH- = .61, T(71) = 3.35, p= 0.001; NWs – ORTH+ = .48 vs. ORTH- = .53. T(71) = -3.56, p=<.001).

(Figure 3 about here)

Order accuracy:

Figure 4 shows order accuracy across each of the eight experimental conditions.
A three way repeated-measures ANOVA showed significant effects of suppression (F 1, 35 = 60.67, p=<.001) and pseudohomophony (F 1, 35 = 15.44, p=<.001) but no main effect of orthographic similarity (F 1, 35 = 1.74, n.s.). There was also no interaction between suppression and pseudohomophony (F 1, 35 = 0.66, n.s.), pseudohomophony and orthographic similarity (F 1, 35 = 0.01, n.s.) or suppression and orthographic similarity (F 1, 35 = 1.65, n.s.) and the three-way interaction was also non-significant (F 1, 35 = 0.28, n.s.). Separate analyses on the PSH effect in both silence and suppression conditions demonstrated this effect was reliable in both cases (Silence – PSH= .85 vs. NW= .76, T(71)= 4.09, p=<.001; AS – PSH= .54 vs. NW= .48, T(71)= 2.37, p=<0.02).

(Figure 4 about here)

Discussion:

Experiment 1 yielded the following key findings: (1) main effects of articulatory suppression and pseudohomophony were found on accuracy under all three scoring methods, (2) the visual similarity manipulation had a differential impact on PSH versus NW recall. For PSH items, visual similarity to a parent word yielded higher accuracy, whereas for NW items the reverse was true. Given this pattern was found with item but not order based analyses, this suggests that this effect is linked to the retrieval of *item* based information in the ISR task, (3) under all three scoring methods, analyses determined that AS *reduced* but did not eliminate the PSH recall advantage.

However, although the present experiment indicates that the PSH advantage remains under AS (consistent with the findings of Besner & Davelaar, 1982), it is possible that these findings reflect an insufficiently demanding form of suppression. Other research has indicated that a far more taxing version of this task is to instruct participants to count backwards during the suppression condition (Vallar & Baddeley, 1982). As a result, a second experiment was undertaken utilising exactly the same design and stimuli, but with a concurrent task that was more taxing on the phonological rehearsal system.

Experiment 2 – ISR with counting backwards

METHOD

Participants:

A newly selected sample of thirty-six Exeter University Psychology undergraduate students (aged 20-25) with normal reading ability took part in the experiment, all obtained course credits for taking part.

Materials/Design/Procedure

All materials, design and procedure were identical to the earlier experiment, but a different form of suppression was used. In this case, suppression consisted of participants counting backwards in 3's (from a random 3 digit number provided by the experimenter). As in Experiment 1, recall was made orally after every trial and responses recorded by the experimenter.

RESULTS

As before, response accuracy was scored as a function of absolute, item and order accuracy, with separate analyses conducted on each.

Absolute accuracy:

Figure 5 shows absolute accuracy across each of the eight experimental conditions. A three way repeated-measures ANOVA showed significant effects of suppression (F 1, 35 = 206.47, p=<.001) and pseudohomophony (F 1, 35 = 116.74, p=<.001) but no main effect of orthographic similarity (F 1, 35 = .53, n.s.). There were also interactions between suppression and pseudohomophony (F 1, 35 = 46.60, p=<.001) and pseudohomophony and orthographic similarity (F 1, 35 = 62.09, p=<.001), but no significant interaction between suppression and orthographic similarity (F 1, 35 = .01, n.s.) or three-way interaction (F 1, 35 = 2.42, n.s.). Given the AS x PSH interaction, separate analyses on the PSH effect in both the silence and suppression conditions were conducted and showed that although this effect was reduced under AS it still remained statistically reliable (Silence – PSH= .72 vs. NW= .52, t(71)= 11.18, p= p=<.001; AS – PSH= .24 vs. NW= .19, t(71)= 3.91, p=<.001). Separate analyses on the orthographic similarity effect in both the PSH and NW conditions also determined that orthographic similarity had a beneficial effect for PSH recall and a detrimental effect for nonword recall (PSHs – ORTH+ = .52 vs. ORTH- = .45, t(39) = 4.77, p=<.001; NWs – ORTH+ = .32 vs. ORTH- = .38, t(39) = -4.23, p=<.001).

(Figure 5 about here)

Item accuracy:

Figure 6 shows item accuracy across each of the eight experimental conditions. A three way repeated-measures ANOVA showed significant effects of suppression (F 1, 35 = 366.12, p=<.001) and pseudohomophony (F 1, 35 = 121.67, p=<.001) but no main effect of orthographic similarity (F 1, 35 = 0.83, n.s.). As before, there were interactions between suppression and pseudohomophony (F 1, 35 = 40.58, p=<.001) and pseudohomophony and orthographic similarity (F 1, 35 = 76.74, p=<.001), but no interaction between suppression and orthographic similarity (F 1, 35 = .01, n.s.) or three-way interaction (F 1, 35 = 1.68, n.s.). Given the AS x PSH interaction, individual analyses on the PSH effect across silence and suppression conditions again demonstrated that although this effect was reduced under AS it still remained (Silence – PSH= .76 vs. NW= .56, t(71)= 10.73, p=<.001; AS – PSH= .34 vs. NW= .28, t(71)= 4.19, p=<.001). Further analyses on the orthographic similarity effect across PSH and NW conditions also indicated that the differential directions of this effect across conditions remained reliable (PSHs – ORTH+ = .59 vs. ORTH- = .51, t(71) = 4.77, p=<.001; NWs – ORTH+ = .38 vs. ORTH- = .45. t(71) = -4.90, p=<.001. An overall pattern that is consistent with our earlier absolute scoring analyses.

(Figure 6 about here)

Order accuracy:

Figure 7 shows item accuracy across each of the eight experimental conditions. A three way independent-measures ANOVA showed significant effects of articulatory suppression (F 1, 35 = 15.36, p=<.001) but no main effects of pseudohomophony (F 1, 35 = 1.25, n.s.) or orthographic similarity (F 1, 35 = .54, n.s.). There was also no interaction between articulatory suppression and pseudohomophony (F 1, 35 = .13, n.s.), pseudohomophony and orthographic similarity (F 1, 35 = .01 n.s.) or articulatory suppression and orthographic similarity (F 1, 35 = .07, n.s.) and the three-way interaction was also non-significant (F 1, 35 = .71, n.s.).

(Figure 7 about here)

Discussion:

Experiment 2 yielded an overall pattern of findings that was generally consistent with those found in Experiment 1. Of critical importance however was whether under the more challenging concurrent task conditions of Experiment 2, an effect of pseudohomophony remained in the item and order based analyses. The item based analyses determined that although a pseudohomophony effect remained, no such effects were found for order based analyses and the implications of these findings will be discussed. A key additional finding concerned the influence of orthography on PSH/NW recall in ISR. Across both experiments, the visual similarity manipulation had a differential impact on recall accuracy of each type of nonword. In the case of PSH items, visual similarity to a parent word facilitated accuracy, whereas the reverse was true for NWs. Our analyses suggested that this effect is linked to the retrieval of *item* based information in the ISR task. However, despite these interesting findings, it is possible that the pattern of results reflects some unforeseen confounding variable know to have an impact on the reading and retention of orthographic strings. Given, we have argued that the influence of our orthographic similarity effects reflect the influence of LTM representations, it is important to be certain that other psycholinguistic variables have been suitably controlled. At the same time, a replication of these findings with an additional set of stimuli would provide stronger evidence for the reliability of this pattern of results. As a consequence, we conducted a further experiment in which we repeated all elements of Experiment 2, but with a novel set of stimuli.

Experiment 3 – ISR with counting backwards – replication study

METHOD

Participants:

A newly selected sample of 30 undergraduate students, who in this case were based at Swansea University Psychology department, took part in the experiment, all had normal reading ability and all obtained course credits for taking part.

Materials/Design/Procedure

Given the potential criticisms of the stimulus set that was utilised in the earlier experiments. We endeavoured to create a new stimulus set, with which to replicate our findings. For the construction of the stimulus set used in Experiment 3, the PSH+ and PSH- lists used across conditions were matched on a number of variables: (1) the parent word items used to create the PSH+ and PSH- lists were matched for imageability (PSH + word list = 471.9, PSH- word list 466.7) and orthographic neighbourhood (N – Coltheart, Davelaar, Jonasson, & Besner, 1977) (PSH+ word list 8.2, PSH- word list 9.1) and (2) PSH+ and PSH- items were also matched for N (PSH+ = 4.5, PSH- = 3.7), Bigram frequency (PSH+ = 46, PSH- = 36.5) and Trigram frequency (PSH+ = 2.4, PSH- = 2.3)[2]. All nonword items were created by changing either only a single letter from the parent pseudohomophone item (NW Vis+) or only share a single letter (or none) with the parent pseudohomophone item (NW Vis-), and all but two pairs of items were four letters in length (see Appendix II). Nonword items were matched for N (NW+= 6.91 NW- =5.98), Bigram Frequency (NW+=64.37, NW-=71.66) and Trigram Frequency (NW+=5.66, NW-=6.25). All other aspects of design and procedure were identical to Experiment 2, in that in this case suppression consisted of participants counting backwards in 3's (from a random 3 digit number provided by the experimenter). As in both previous experiments, recall was made orally after every trial and responses recorded by the experimenter.

[2] The authors would like to thank Max Coltheart and Steve Saunders for very kindly assisting in the selection of these items from the ARC nonword database – items were selected using a computer based algorithm.

RESULTS

As before, response accuracy was scored as a function of absolute, item and order accuracy, with separate analyses conducted on each.

Absolute accuracy:

Figure 8shows absolute accuracy across each of the eight experimental conditions.

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A three way repeated-measures ANOVA showed significant effects of suppression (F 1, 27 = 202.70, p=<.001) and pseudohomophony (F 1, 27 = 80.44, p=<.001) but no main effect of orthographic similarity (F 1, 27 = 1.99, n.s.). There were also interactions between suppression and pseudohomophony (F 1, 27 = 5.11, p=<.03) and pseudohomophony and orthographic similarity (F 1, 27 = 10.61, p=<.005), but no significant interaction between suppression and orthographic similarity (F 1, 27 = .63, n.s.) or three-way interaction (F 1, 27 = .205, n.s.). Given the AS x PSH interaction, separate analyses on the PSH effect in both the silence and suppression conditions were conducted and showed that although this effect was reduced under AS it still remained statistically reliable (Silence – PSH= .77 vs. NW= .62, t(59)= 6.25, p= p=<.001; AS – PSH= .31 vs. NW= .23, t(59)= 4.74, p=<.001). Separate analyses on the orthographic similarity effect in both the PSH and NW conditions also determined that orthographic similarity had a beneficial effect for PSH recall but in this case the detrimental effect for nonword recall was not reliable (PSHs – ORTH+ = .58 vs. ORTH- = .51, t(59) = 3.98, p=<.001; NWs – ORTH+ = .42 vs. ORTH- = .44, t(59) = --1.28, p=.206).

(Figure 8 about here)

Item accuracy:

Figure 9 shows item accuracy across each of the eight experimental conditions. A three way repeated-measures ANOVA showed significant effects of suppression (F 1, 27 = 293.15, p=<.001) and pseudohomophony (F 1, 27 = 111.75, p=<.001) but no main effect of orthographic similarity (F 1, 27 = 1.73, n.s.). As before, there were interactions between suppression and pseudohomophony (F 1, 27 = 8.81, p=<.01) and pseudohomophony and orthographic similarity (F 1, 27 = 29.28, p=<.001), but no interaction between suppression and orthographic similarity (F 1, 27 = .43, n.s.) or three-way interaction (F 1, 27 = 0.079, n.s.). Given the AS x PSH interaction, individual analyses on the PSH effect across silence and suppression conditions again demonstrated that although this effect was reduced under AS it still remained (Silence – PSH= .81 vs. NW= .67, t(59)= 7.69, p=<.001; AS – PSH= .34 vs. NW= .28, t(59)= 5.24, p=<.001). Further analyses on the orthographic similarity effect across PSH and NW conditions also indicated that the differential directions of this effect across conditions remained reliable (PSHs – ORTH+ = .64 vs. ORTH- = .56, t(59) = 5.50, p=<.001; NWs – ORTH+ = .47 vs. ORTH- = .51. t(59) = -2.62, p=<.01. An overall pattern that is largely consistent with our earlier absolute scoring analyses.

(Figure 9 about here)

Order accuracy:

Figure 10 shows order accuracy across each of the eight experimental conditions. A three way independent-measures ANOVA showed significant effects of articulatory suppression (F 1, 27 = 26.20, p=<.001) but no main effects of pseudohomophony (F 1, 27 = 3.77, n.s.) or orthographic similarity (F 1, 27 = 1.20, n.s.). There was also no interaction between articulatory suppression and pseudohomophony (F 1, 27 = .04, n.s.), pseudohomophony and orthographic similarity (F 1, 27 = .64 n.s.) or articulatory suppression and orthographic similarity (F 1, 27 = .11, n.s.) and the three-way interaction was also non-significant (F 1, 27 = 1.72, n.s.).

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(Figure 10 about here)

Discussion:

In Experiment 3 we sought to replicate our earlier findings in Experiment 2 using a new set of stimuli that were more strictly controlled for potentially confounded variables often seen as being key in the wider field of psycholinguistics. Overall, the findings of Experiment 3 match those of Experiment 2 and were largely consistent with Experiment 1 (see Table 1). It is therefore apparent that the pattern of findings obtained in Experiment 2 are replicable – in both experiments an effect of pseudohomophony remained in the item but not order based analyses. We would therefore suggest that this indicates that the advantage for pseudohomophone items under AS seen in our work and the earlier Besner and Davelaar (1982) study, reflects the impact of LTM phonological representations providing support for item based representations held in STM – we will return to this issue in the General Discussion. A second critical finding across all these experiments is that the visual similarity manipulation had a differential impact on recall accuracy of each type of nonword. In the case of PSH items, visual similarity to a parent word facilitated accuracy, whereas the reverse was true for NWs. Again, our analyses suggested that this effect is linked to the retrieval of *item* based information in the ISR task. Together, these findings suggest that both phonological and orthographic LTM representations can influence item based information held in STM during a serial recall task.

(Table 1 about here)

GENERAL DISCUSSION

Determining the locus of pseudohomophony effects in ISR

Before considering the findings across all our experiments regarding pseudohomophony effects, it is worth re-iterating the findings of the Besner and Davelaar (1982) study that inspired our work. In their study they found that pseudohomophones had a recall advantage over nonword items in an ISR task, and that this effect remained even when a concurrent task was introduced. They presented a STM model (see Figure 1) in which they argued that the PSH over NW advantage in ISR tasks reflects beneficial effects linked to two codes. On the one hand, PSH items are much easier to rehearse via the phonological loop since they are phonologically familiar (a Code 2 benefit) and on the other hand PSH items have support from LTM phonological representations (a Code 1 benefit). Even when AS is introduced the PSH advantage remains, since it disrupts the

Code 2 benefit, but not the Code 1 benefit – thus the influence of LTM phonological representations in this instance is unfazed by the introduction of a concurrent task.

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In our work we have consistently shown a main effect of pseudohomophony for item scoring in all three experiments even under AS conditions. We therefore argue that this is entirely consistent with the model outlined in Figure 1, since it would indicate that the PSH advantage is gleaned from LTM support for the phonological code (Code 1) generated by reading processes (i.e., the generation of phonology from orthography). In short, PSH reading accuracy is typically superior to NW reading accuracy, such that this will provide an *item* based advantage for PSHs in an ISR task. This is also consistent with the proposals of McCann and Besner (1987) who argued that PSHs and NWs are both read via a non-lexical reading mechanism, but the PSHs get an additional 'boost' from the base word's phonological representation. In other words, the phonological trace generated by the reading process (Code 1) is perhaps more stable for PSH items given the potential influence of LTM phonological representations corresponding to its lexical real word cousin.

Additionally, we also consistently found the presence of an AS x PSH interaction across all experiments – indicative of a reduction but not elimination of the PSH advantage. We would argue (consistent with the model in Figure 1) that this implies that the PSH advantage cannot be *entirely* driven by the reading process (i.e., a Code 1 locus), and there is an additional advantage bestowed to the phonological rehearsal system (a Code 2 locus), which is eliminated during AS (hence the reduction in the PSH effect). This may be because of the articulatory/phonological familiarity of PSH items (they are easier to *say* and therefore easier to rehearse). However, it was apparent that in

Experiment 1 there was evidence that AS did not eliminate the PSH main effect for order (Code 2) analyses. This finding was potentially problematic for the proposals of the model in Figure 1, given it would assume that the PSH advantage generated by Code 1 should remain independent of any presence of AS (as seen by the PSH main effect on *item* analyses), whilst any phonological rehearsal based advantage generated by PSH items (Code 2 – as seen by the PSH main effect on *order* analyses) should be eliminated by AS (assuming the rehearsal system is 'knocked out' under such circumstances). This motivated Experiment 2, in which we used a more demanding suppression task and we found evidence in support of the latter proposal, in that the PSH effect was now eliminated for the order analyses (Code 2), whilst the pattern under item analyses remained the same (Code 1). We would suggest then that the influence of the rehearsal system can still remain under AS conditions, and is only abolished when a sufficiently taxing suppression task is used. In all, we would argue that the overall findings indicate that the PSH recall advantage likely reflects the *combination* of an influence on both types of 'code' as proposed by the model presented in Figure 1.

Orthographic similarity influences in nonword immediate serial recall – an item effect.

A second key issue of the current research was to determine whether the original findings of Besner and Davelaar (1982), may have been contaminated by a potential confound of visual orthographic familiarity. In order to explore this issue we manipulated the degree to which PSH and NW items orthographically overlapped with their parent word. As we have already pointed out, PSHs can also often look more like real words than nonwords. As a consequence it might be possible that participants draw upon LTM orthographic representations when presented with PSH items. Moreover, it may also be possible that the utilisation of orthographic codes to facilitate recall performance may *increase* when the disruptive influence of a concurrent task is present. In an immediate to this, we would point out that none of the experiments yielded a reliable interaction between the orthographic manipulation and AS – suggesting no support for such a possibility. However, regardless of the presence of a concurrent task, we found that in all cases PSH accuracy was higher for items that had an orthographic similarity to the parent word. Additionally, the influence of orthographic similarity was not just limited to the PSH items; for NWs the pattern was reversed such that NWs that bore strong orthographic similarity to a real word were recalled more poorly. Thus it is clear that orthography can impact on PSH and NW ISR accuracy.

Consistent with our earlier account for the influence of LTM phonological representations at the item based level (Code 1) – we would also argue that our manipulations of orthographic similarity to a stored lexical entry (the parent word) suggest that LTM orthographic representations can also play a part in the Code 2 benefit. But interestingly, this influence is not consistent across PSHs and NWs. For the PSH items, there is beneficial support when the PSH is closely related to the parent word, and vice versa for NW items – a pattern that warrants further investigation in future research. It is possible that this pattern across PSHs and NWs reflects the fact that for PSH items both the phonology and the vis+ orthography point to the appropriate target: in such instances both orthography and phonology act as excellent cues for the correct response. In the case of NWs the vis+ orthography cues a competitor (the parent word) that creates a greater degree of interference with a consequential decrease in accuracy. [3]Importantly, we found no evidence that the orthographic similarity effect interacted with AS, and therefore there was no evidence of a *greater* dependence on orthography in instances when the phonological rehearsal code (Code 2) is disrupted (i.e., during AS). Overall, our findings clearly show that the impact of LTM phonological and orthographic representations can be cumulatively beneficial for PSH items and that this is focused on the support of Code 1 representations held in STM.

In conclusion, as regards orthographic effects in ISR the current work provides two key findings, (a) this orthographic effect does not interact with concurrent task and (b) this influence of LTM orthographic representations is focused at the item level; since it was present in item analyses (but not order analyses) across all experiments. Overall, these findings would suggest that orthographic similarity effects are present and independent of any influences of concurrent task. A conclusion that is largely consistent with other studies showing no effects of AS on the process of *reading* (Besner, Julia & Daniels, 1981) and with the fact that our findings attribute any influence of orthography at the *item* level (i.e., in the generation of Code 1). As a result, the present study is the first to identify the locus of the influence of LTM orthographic representations on pseudohomophone ISR accuracy in normal readers and this indicates a new potential avenue for research.

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[3] We would like to thank an anonymous reviewer for this suggestion.

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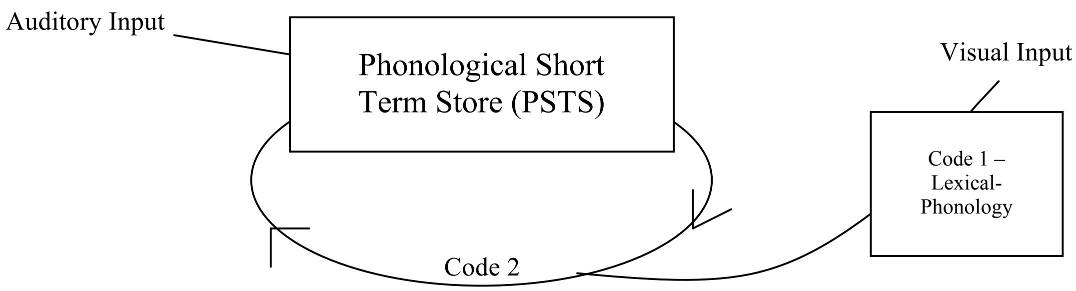

Figure 1 – Besner's (1987) model of STM.

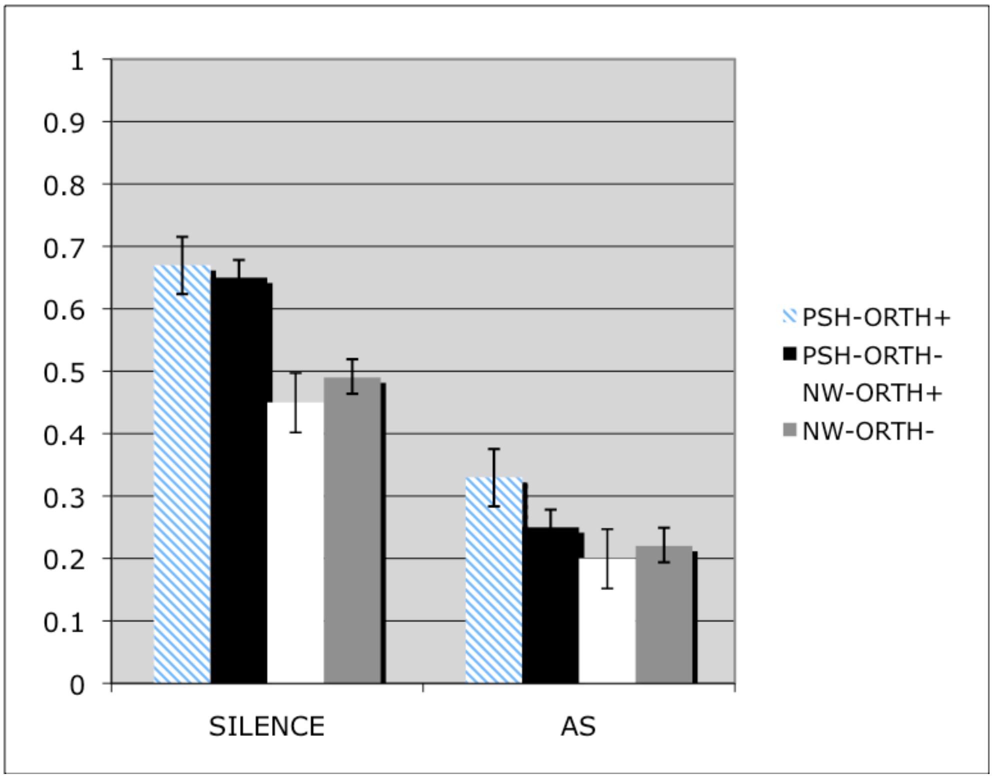

Figure 2 – Expt 1: Absolute accuracy scores across each of the experimental conditions.

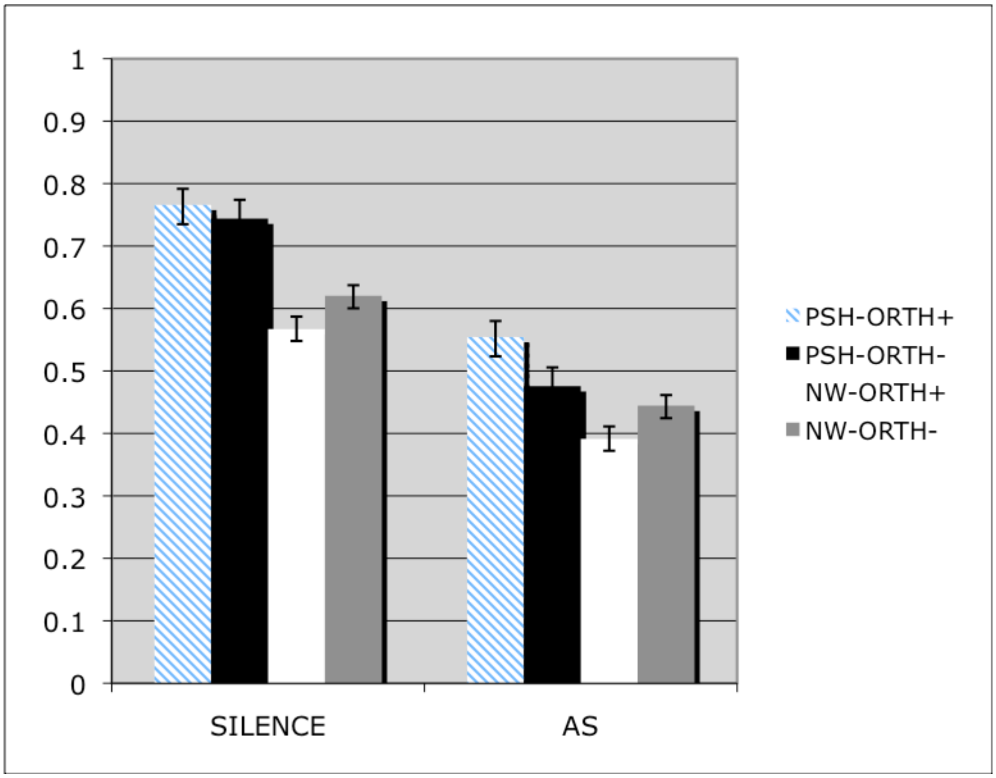

Figure 3 – Expt 1: Item accuracy scores across each of the experimental conditions.

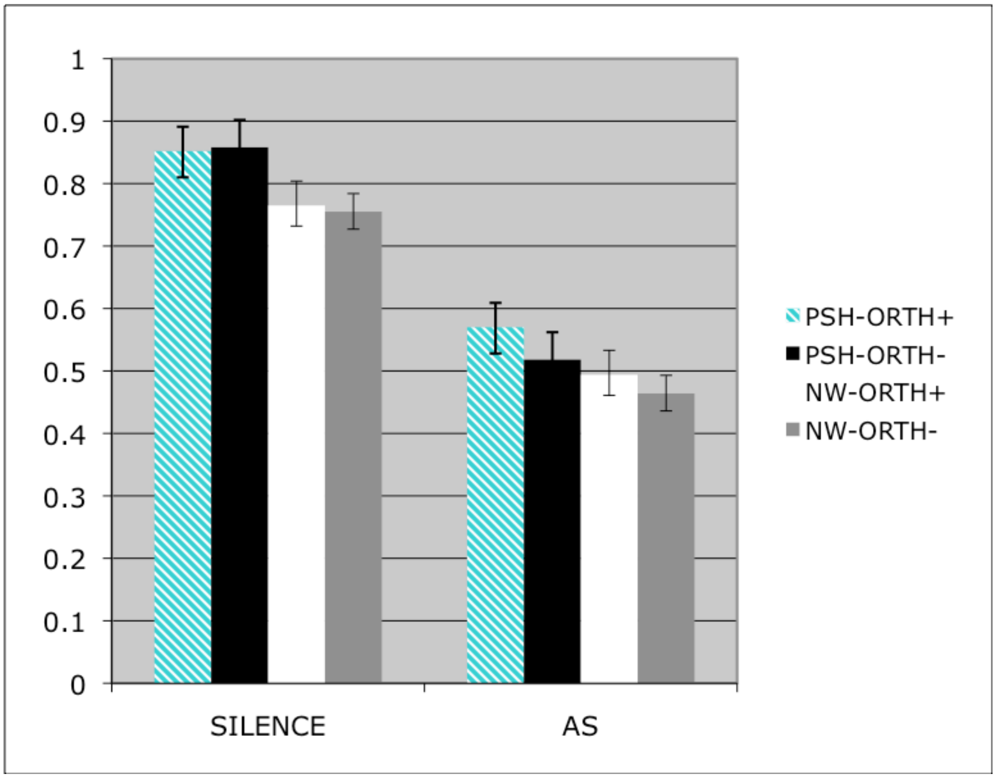

Figure 4 – Expt 1: Order accuracy scores across each of the experimental conditions.

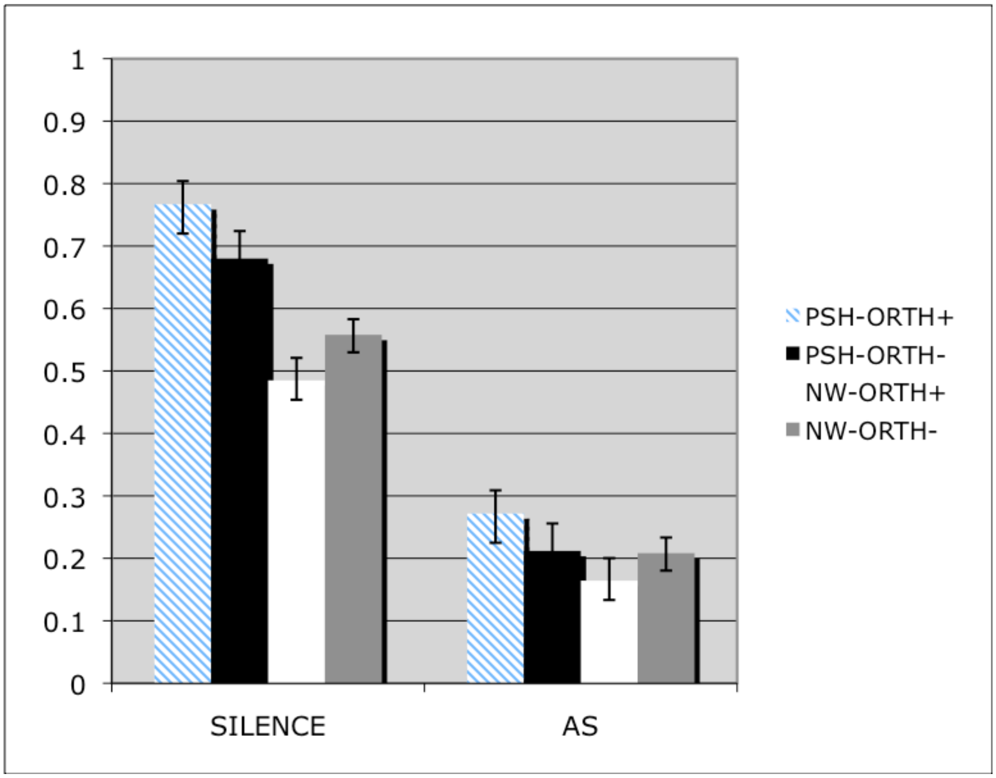

Figure 5 – Expt 2: Absolute accuracy scores across each of the experimental conditions.

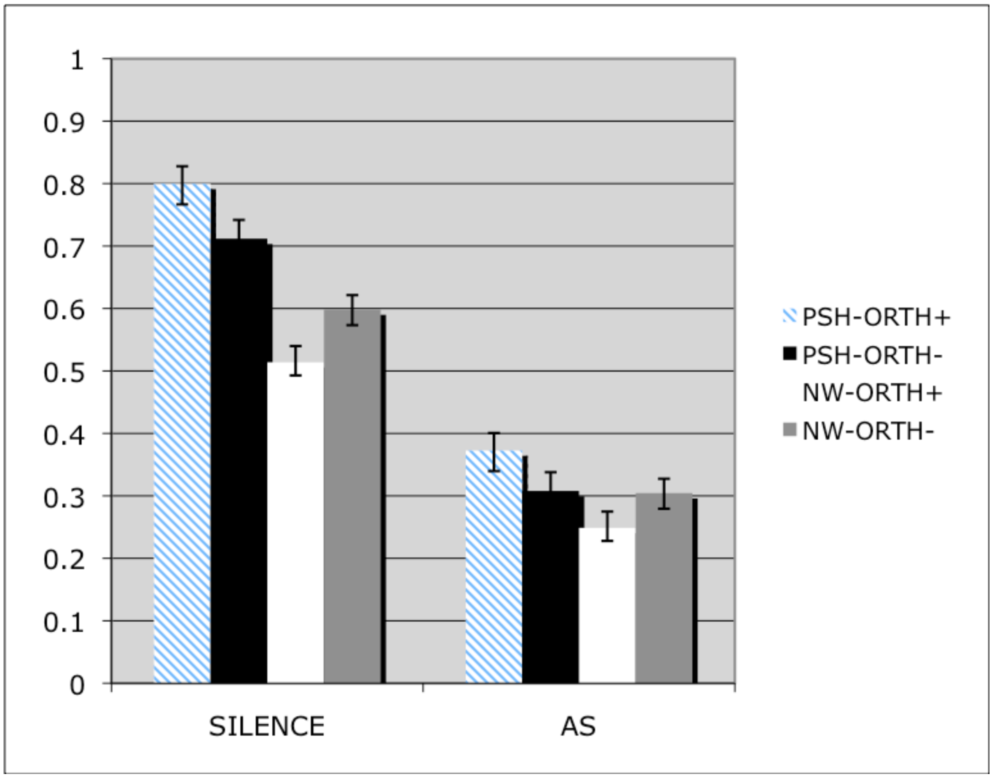

Figure 6 – Expt 2: Item accuracy scores across each of the experimental conditions.

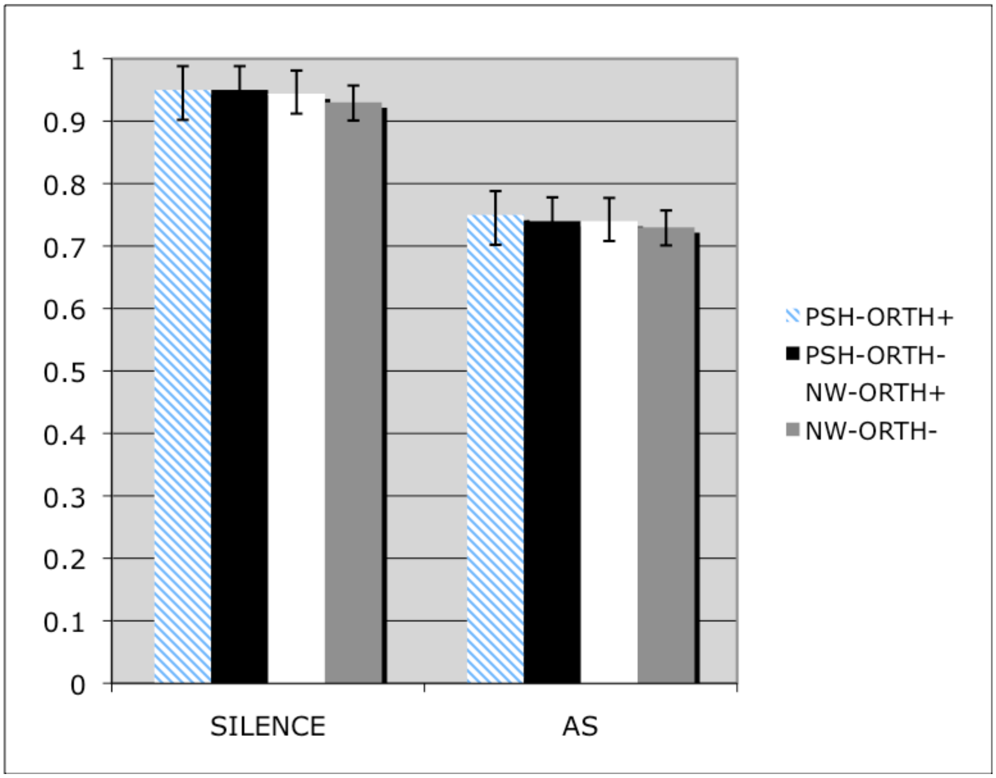

Figure 7 – Expt 2: Order accuracy scores across each of the experimental conditions.

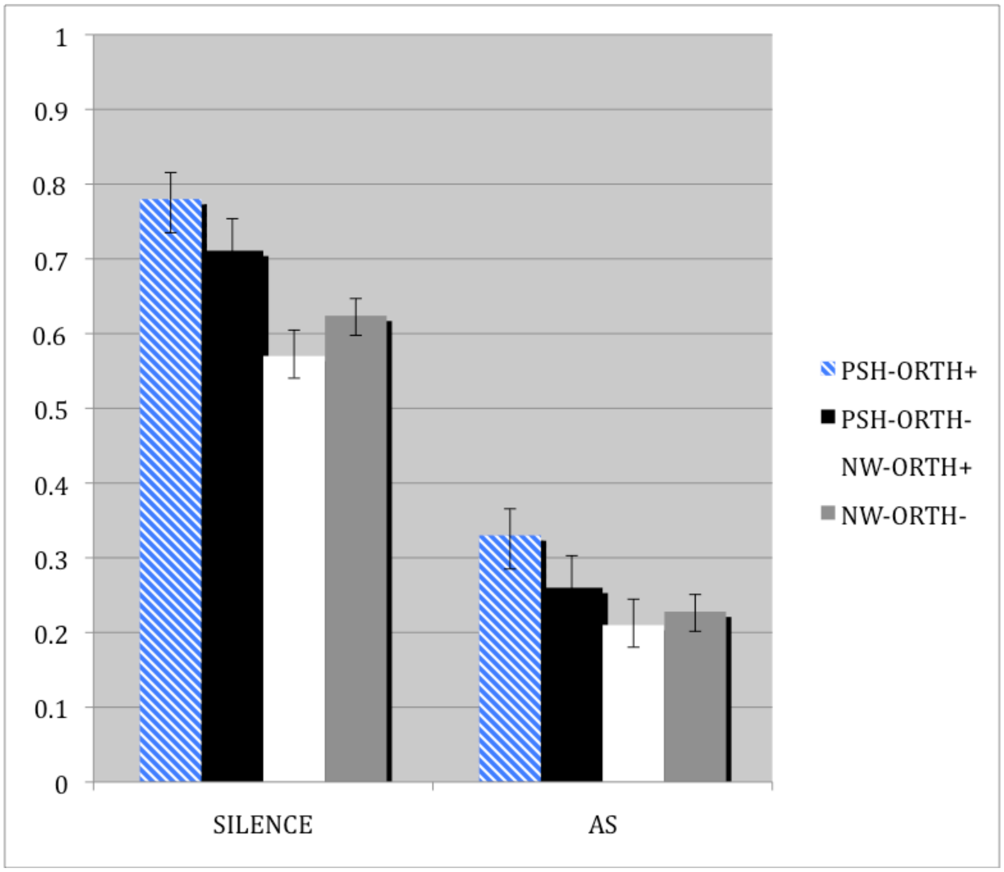

Figure 8 – Expt 3: Absolute accuracy scores across each of the experimental conditions.

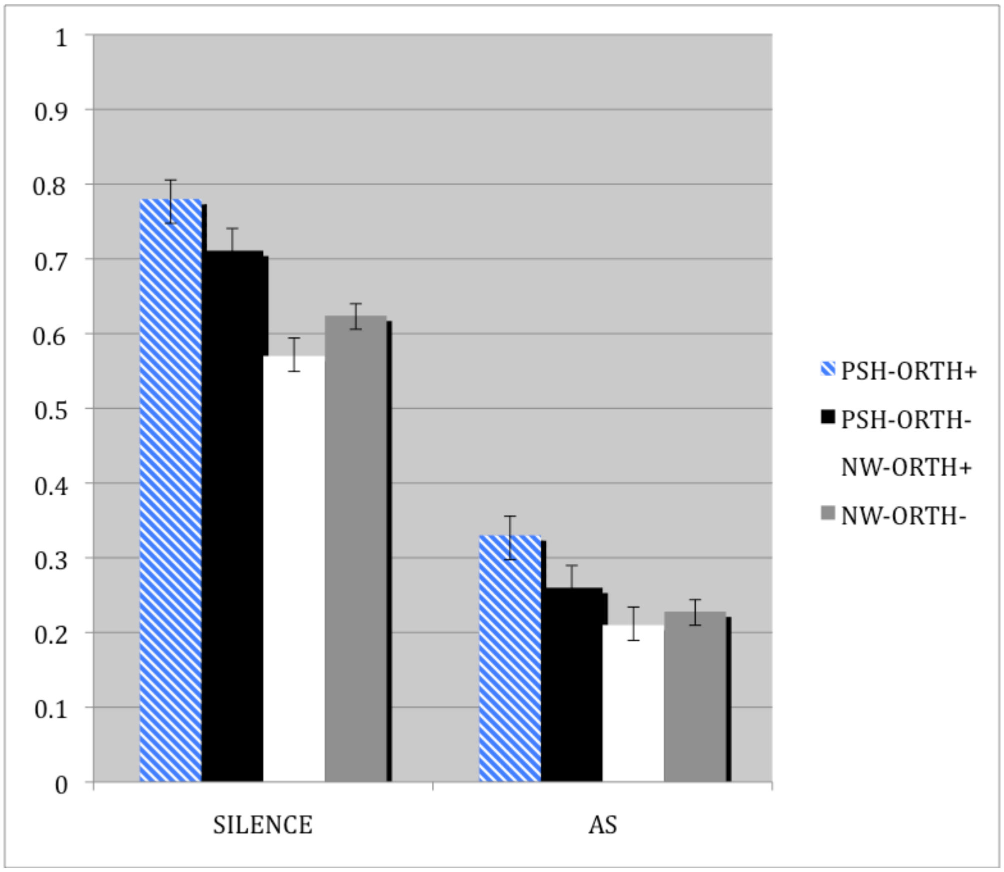

Figure 9 – Expt 3: Item accuracy scores across each of the experimental conditions.

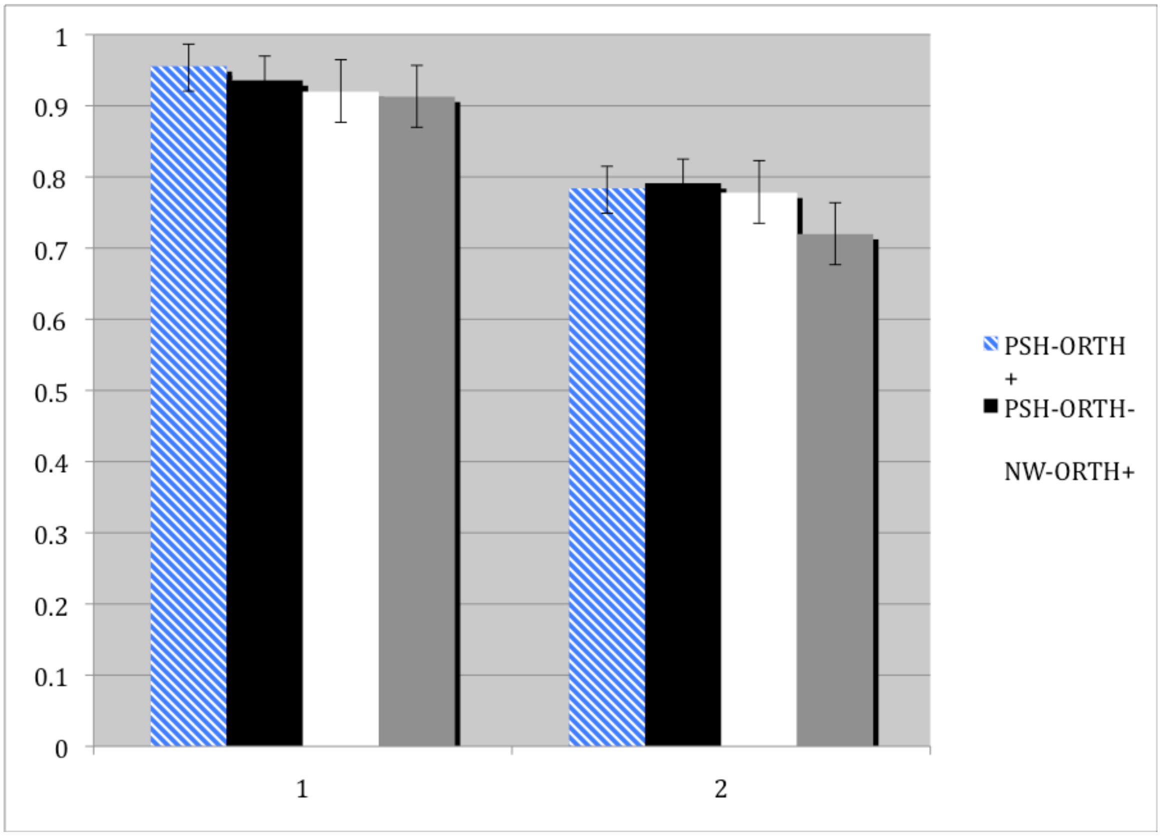

Figure 10 – Expt 3: Order accuracy scores across each of the experimental conditions.

Analysis	AS	PSH	ORTH	AS x PSH	AS x ORTH	PSH x ORTH
Absolute 1	√	√	x	√	x	√
Item 1	√	√	x	√	x	√
Order 1	√	√	x	x	x	x
Absolute 2	√	√	x	√	x	√
Item 2	√	√	x	√	x	√
Order 2	√	x	x	x	x	x
Absolute 3	√	√	x	√	x	√
Item 3	√	√	x	√	x	√
Order 3	√	x	x	x	x	x

1=articulatory suppression 2 – counting backwards
/ = effect x= no effect

Table 1 – Summary of findings across both experiments

				Parent word	Parent word
PSH	**NW**	**PSH**	**NW**	**PSH**	**PSH**
vis+	**vis+**	**vis-**	**vis-**	**vis+**	**vis-**
DEEL	BEEL	KLOO	PLOO	DEAL	CLUE
VIRB	JIRB	KIRCE	FIRCE	VERB	CURSE
KLOWN	PLOWN	TOOM	POOM	CLOWN	TOMB
KULT	TULT	KROOL	TROOL	CULT	CRUEL
HOWND	TOWND	WROWNED	BLOWNED	HOUND	ROUND
FRUNT	PRUNT	KOAN	POAN	FRONT	CONE
GREAN	DREAN	WROK	DROK	GREEN	ROCK
TENCE	KENCE	WREDD	GREDD	TENSE	RED
REECH	NEECH	PHARST	THARST	REACH	FAST
MUNTH	NUNTH	WUNCE	LUNCE	MONTH	ONCE
TEATH	PEATH	PESSED	KESSED	TEETH	PEST
JEM	REM	WRAIT	KNAIT	GEM	RATE
KAMP	PAMP	STRORE	SCRORE	CAMP	STRAW
BLEEK	GLEEK	PHRORD	SHRORD	BLEAK	FRAUD
CHEEZE	SPEEZE	PHREA	STREA	CHEESE	FREER
CHIRCH	SHIRCH	PHAR	THAR	CHURCH	FAR
DETT	RETT	KNEK	GREK	DEBT	NECK
HELLTH	SELLTH	SKAWN	STAWN	HEALTH	SCORN
KAR	SAR	SKOUT	SLOUT	CAR	SCOUT
SWOMP	SLOMP	HED	PED	SWAMP	HEAD
LEACE	WEACE	BLUD	GLUD	LEASE	BLOOD
MEAK	NEAK	FAWCE	PAWCE	MEEK	FORCE
MOWTH	NOWTH	JOOCE	VOOCE	MOUTH	JUICE
STREAT	SKREAT	LOOD	VOOD	STREET	LEWD

Appendix 1 – Critical pairs used as stimuli