Does segmental overlap help or hurt? Evidence from blocked cyclic naming in spoken and written production

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Abstract

Past research has demonstrated interference effects when words are named in the context of multiple items that share meaning. This interference has been explained within various incremental learning accounts of word production, which propose that each attempt of mapping semantic features to lexical items induces slight but persistent changes that result in cumulative interference. We examined if similar interference-generating mechanisms operate during the mapping of lexical items to segments by examining the production of words in the context of others that share segments. Previous research has shown that initial segment overlap amongst a set of target words produces facilitation, not interference. However, this initial-segment facilitation is likely due to strategic preparation, an external factor that may mask underlying interference. In the present study, we applied a novel manipulation in which segmental overlap across target items was distributed unpredictably across word positions in order to reduce strategic response preparation. This manipulation led to interference in both spoken (Experiment 1) and written (Experiment 2) production. We suggest that these findings are consistent with a competitive learning mechanism that applies across stages and modalities of word production.

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Word production involves activation of both a target word and its neighbors that share semantic and/or form-based features. The result is a complex pattern of interference and facilitation arising from the dynamic nature of the processes involved in activation and selection. This study uses a word production paradigm in which robust interference effects have been shown to result from production of semantically related words, investigating whether the same is true for words that share segments. We consider whether mechanisms proposed to account for certain of these effects in lexical selection --the process that identifies a specific word to convey the intended meaning-- may also apply in segmental encoding -- the process that identifies the segments to express the selected word. Furthermore, we examine whether these findings extend across segment types (phonemes and graphemes) in both spoken and written word production

Interference and Facilitation in Lexical Selection and Segmental Encoding

Although word production (e.g., in picture naming or reading) is often facilitated by the prior presentation of a single semantically related word immediately before the target, this benefit is quickly eliminated or masked by the insertion of an intervening item (e.g., Wheeldon & Monsell, 1994). In contrast, the work we report here is concerned with paradigms in which items are named in the context of multiple similar items, a situation in which robust, long-lived interference and facilitation effects have been consistently reported. In the continuous naming paradigm, where semantically related and unrelated pictures are interleaved, participants are slower to name each consecutive item from a semantic category, even when many unrelated items intervene (e.g., Howard, Nickels, Coltheart, & Cole-Virtue, 2006; Schnur, 2014). In the blocked cyclic naming paradigm, where small sets of pictures are named repeatedly, participants are slower to name items from the same semantic category than those same items rearranged into unrelated sets (e.g., Crowther & Martin, 2014; Damian, Vigliocco, & Levelt, 2001; Schnur, Schwartz, Brecher, & Hodgson, 2006).

Two main accounts have been proposed to explain the semantic blocking effect (Howard et al., 2006; Oppenheim, Dell, & Schwartz, 2010), both of which rely on incremental learning as the basis for long-lived changes within the production system and on competive mechanisms to explain interference effects. We briefly describe Oppenheim et al.'s (2010) account, as it does not rely on competitive selection to account for cumulative semantic interference (see Navarrete, Del Prato, Peressotti, & Mahon, 2014 for arguments against competitive selection), but instead assumes that learning is a competitive process that both strengthens and weakens connections between representations, providing an account of faciliation and interference effects in certain contexts. Specifically, upon successful naming of a picture, connections between the correct lexical entry (e.g., *cat*) and its semantic features (e.g., furry, pet) are strengthened. For other lexical items that are active on that trial, connections from the lexical entries to the semantic features that activated them are weakened. Because a semantically-related item (e.g., *dog*) is much more likely to become activated through shared semantic features with the target than is an unrelated item (e.g., *spoon*), *dog* is more likely to undergo weakening of connections to its features than is *spoon*. Thus, when the target on the next trial is *dog*, it is at a disadvantage compared to *spoon*.

While incremental learning accounts have primarily been directed toward semantic-lexical mapping, they may also apply to lexical-segmental mapping. Like semantic-lexical mapping, lexical-segmental mapping is affected by learning: for example, the frequency effect, which is a hallmark of experience-based adjustment to the production system, strongly affects lexical-segmental mapping (e.g. see Kittredge et al. 2008 and references therein). As one example of incremental learning applied to this stage of processing, Mulatti and colleagues (2012) found increased response latencies for production of words that overlapped in rhyme with previously produced words. However, this was demonstrated in reading in an orthographically transparent language (Italian), and the observed interference may arise in non-lexical grapheme-to-phoneme mapping. How might competitive incremental learning work in lexical-segmental mapping? When a word is produced, the connections between the lexical entry and its segments are strengthened, and the connections between other lexical entries and their segments are weakened in proportion to their activation level. Critically, due to feedback, these other active items are likely to be lexical entries that share segments with the target. For example, when *cat* is the target, the segments /æ/ and /t/ are activated. Through feedback, they activate other lexical entries that share these segments (e.g., *mat*). These lexical entries in turn activate their remaining segments, including those that are not shared with the target (e.g., /m/). When the correct target is selected (e.g., *cat*), the connections between these non-target lexical entries and the unshared segments (e.g., *mat*'s connection to /m/) are weakened. Segments of an unrelated word (e.g., *spoon*) are much less likely to be activated and undergo weakening. Therefore, when the next target is *mat*, it is at a disadvantage compared to *spoon*. Thus interference is predicted in the context of segmental overlap. Note that there are important differences between semantic-lexical and lexical-segmental mappings. While semantic-lexical mapping involves connecting many semantic representations to one lexical representation, lexical-semantic mapping requires connecting one lexical representation to many segments. Therefore, while shared features lead to interference in both mappings, the source of this interference differs. In the case of semantic-lexical mapping, interference is caused by the adjustment of connections between shared semantic features and competing lexical items, while in lexical-segmental mapping, the interference results from the adjustment of connections between similar lexical items and their competing features in In both case, however, the adjustments are intended to decrease the strength of competitors vis-à-vis the current target word, reducing the availability of the competitors (interference) on subsequent trials.

Our description is not intended to imply that there is necessarily a single representation at the lexical level. Our proposal is equally compatible with several architectural alternatives with regard to lexical representations including systems with: abstract lemmas only (with lexical syntactic information), only modality- specific phonological and orthographic lexemes (with links to syntactic features) or systems that include both lemmas and lexemes (see Caramazza, 1997 for review of models with and without lemmas). In a system with both lemmas and lexemes, the incremental learning mechanism we discuss above would apply to the connections between lexemes and segments.

Because the effects of segmental overlap are somewhat ambiguous in the current literature, it is not clear that this type of competitive learning mechanism actually applies in segmental encoding. Both facilitation and interference effects have been reported for segmentally overlapping words (e.g., Damian & Dumay, 2009; for a review see Sevald & Dell, 1994 and references therein). Importantly, situations that typically produce interference for semantically related items, including the blocked cyclic naming paradigm, have not shown robust interference for form-related items. When items in a block consistently share onset segments, production is facilitated (e.g., Damian, 2003; Roelofs, 1999; Schnur et al., 2009). Shared onset facilitation is widely attributed to high predictability allowing strategic preparation (e.g., Damian, 2003; Meyer, 1991). This likely arises outside the language production system

(O'Séaghdha & Frazer, 2014), and could mask interference effects generated within the system. Evidence generally consistent with the prediction that removing predictability reveals underlying interference from segmental overlap comes from Belke and Meyer (2007), who reported that facilitation effects on response latencies disappeared when multiple onset-related items were named within a single trial and that gaze durations to onset-related items increased when items were named quickly. However, overt interference effects comparable to those in semantically related naming paradigms have not been reported. This could mean that competitive incremental learning is not operational in segmental encoding, or that the predicted interference is masked by the strategic preparation that is possible in conditions with predictable initial segment overlap.

In the present study, we investigate these possibilities by examining the consequences of segmental overlap when it is distributed unpredictably across positions in words as opposed to being limited to the first position (e.g., *pill* in the context of *pig, peg, pot, log, leg*) in a blocked cyclic naming paradigm. We examined picture naming because it necessarily includes both lexical selection and segmental encoding. While some evidence of segmental overlap interference has been shown in reading (e.g., Mulatti et al., 2012) and repetition (e.g., O'Seaghdha & Marin, 2000; Sevald & Dell, 1994), these results may be due to similarity on input or non-lexical processing in the tasks, making these tasks less appropriate for investigating questions concerning lexical selection and segmental encoding. Removing predictability reduces opportunities for strategic preparation, allowing us to evaluate whether principles such as competitive incremental learning operate during lexical selection and segmental encoding.

We examined both spoken and written word production. Because similar organizational principles have been observed across the two modalities (e.g., Bonin & Fayol, 2000; Rapp & Fischer-Baum, 2014; Shen, Damian, & Stadthagen-Gonzalez, 2013) the extension of the work to written production provides an opportunity to replicate findings with orthographic segmental encoding processes which, presumably, should operate according to similar principles as phonological segmental encoding. Further, given that spoken and written production differ considerably in terms of response execution, with speaking taking place over a shorter time course and in a more parallel fashion than writing, examining both modalities provides an opportunity to evaluate the robustness of findings across these considerable task differences.

Experiment 1: Distributed Segmental Overlap in Spoken Word Production

In Experiment 1, we investigated the effects of unpredictable segmental overlap in a spoken blocked cyclic naming paradigm, investigating whether interference occurs in this situation. Such a finding would suggest that similar principles underlie lexical selection and segmental encoding.

Participants. Twenty-four individuals (mean age 19.8, 11 male, 20 right handed) participated. For both experiments, participants were native English-speaking undergraduate students who gave informed consent and received course credit for participation.

Stimuli. Pictures corresponding to 36 monosyllabic 3-6-letter words were selected to create six homogeneous lists with high position-independent phonological overlap. They were rearranged to form heterogeneous lists (Table 1). Position-independent phonological overlap, defined as the total number of phonemes shared by two strings regardless of position, divided by the total number of phonemes in the two strings (Goldrick, Folk, & Rapp, 2010), was significantly greater in homogeneous (mean=0.44) than heterogeneous lists (mean=0.08), ($t(5.39)=-10.96$, $p<0.001$, 95% CI of difference=0.28-0.45). Stimuli were black and white line drawings of objects freely available online. Using Amazon Mechanical Turk, a separate group of participants (N= 40) rated the visual similarity of all 180 pair-wise picture combinations on a scale ranging from 1 (not at all similar) to 5 (very similar), following Schnur et al. (2006). The ratings for pairs from homogeneous block (mean=1.4) were not significantly different from those from heterogeneous blocks (mean=1.3), $t(478)=-0.83$, $p=0.41$, 95%CI=-0.13-0.05), so visual similarity was not included in the models.

Procedure. The experiment was run using E-Prime 2 Professional (Psychology Software Tools, Pittsburgh, PA). Picture stimuli (7 inches by 5 inches) were displayed at the center of a 19-inch x 12-inch monitor approximately 20 inches in front of participants who responded by speaking into a microphone (E-prime's stimulus-response box voice key captured response times). In the familiarization phase, participants saw each line drawing and silently read its provided label.

Following familiarization, participants completed 36 practice trials in which they named each item aloud once, receiving corrective feedback. On each trial, a fixation cross appeared on the screen for 1000 ms, followed by a stimulus picture that remained on the screen until participants initiated the response (RT) or for 3000 ms if no response was made. Recordings of the responses were used to score accuracy. At the end of each trial, a button was pressed to continue, followed by a fixed 3-second inter-trial interval.

Next, participants completed six homogenous and six heterogeneous blocks, in pseudorandom order, with periodic breaks. Each block consisted of four cycles of the six pictures from one list presented in random order. Trial structure was the same as in the practice session.

Analysis

Error responses in which participants did not correctly produce the intended label and outliers more than 2.5 standard deviations from each participant's overall mean were removed from further analysis. For the analysis of RTs, only cycles 2-4 were considered as past results indicate block type effects typically emerge only after the first cycle (e.g., Belke, Meyer, & Damian, 2005). Repeated measures 2x3 Analysis of Variance (ANOVA) was conducted using IBM SPSS (version 21), including block type (homogeneous or heterogeneous) and cycle (2,3,4) as within-subject factors. The dependent variable was mean RTs, calculated for each participant in the F_1 or item in the F_2 analysis for each of the six block type-by-cycle conditions. A secondary analysis conducted the same by-participant ANOVA, but included only the 21 items that shared their first segment with at least half the items in their homogeneous block.

Results and Discussion

Of the total 6912 trials, 8% were removed due to technical errors, incorrect responses, or outlier status. Participants were slower to initiate production of items in homogeneous than in heterogeneous blocks, $F_1(1,23)=29.90$, $p<0.001$, mean difference=17.0, SE=3.11, 95% CI=10.6-23.4, $\eta_p^2=0.57$; $F_2(1,35)=25.21$, $p<0.001$, mean difference=18.4, SE=3.67, 95% CI=11.0-25.9, $\eta_p^2=0.42$. There was no significant main effect of cycle, $F_1(2,46)=0.16$, $p=0.80$, $\eta_p^2=0.01$; $F_2(2,70)=0.66$, $p=0.52$, $\eta_p^2=0.02$, or interaction of cycle and block type, $F_1(2,46)=1.12$, $p=0.33$, $\eta_p^2=0.05$; $F_2(2,70)=2.40$, $p=0.10$, $\eta_p^2=0.06$ (Figure 1A). Thus, distributed segmental overlap resulted in interference in spoken production.

In the secondary analysis, including only items that shared the initial segment with at least half of the other items in the homogeneous block, interference was again observed. Participants were slower to initiate production in homogeneous blocks, $F(1,23)= 21.55$, $p<0.001$, mean difference=17.1, SE=3.68, 95% CI=9.5-24.7, $\eta_p^2=0.48$, even when items shared onsets, the condition past research has suggested is most likely to yield facilitation in predictable situations (Figure 1B).

Experiment 2: Distributed Segmental Overlap in Written Word Production

Experiment 2 tested whether the results of Experiment 1 can be replicated in written production. A similar interference effect would indicate that reliable segmental overlap interference occurs regardless of whether the segments are phonemes or graphemes.

Methods

Participants. Thirty-four individuals (mean age 19.2, 13 male, 28 right handed) participated. The sample was increased in this experiment due to borderline results with the initially planned 24 participants.

Stimuli. Identical to Experiment 1. The relevant overlap type was orthographic rather than phonological, with significantly greater position-independent letter overlap in the homogeneous (mean=0.57) than the heterogeneous (mean=0.16) lists ($t(5.474)=-7.52$, $p<0.001$, 95% CI=0.27-0.53).

Procedures. The procedure was identical to Experiment 1 except that participants responded by writing their response on a graphics tablet (Wacom Bamboo), which they were trained to use before the experiment. Participant responses were constrained to a 2.5-inch x 1-inch rectangle centered at the bottom of the responsive surface. On each trial, participants began with the pen on a marked starting point centered one inch below the writing surface. They were instructed to begin writing their response in either cursive or print when they knew the name of the picture. As soon as the writing surface was touched, the picture was replaced by the participant's pen strokes on the monitor and response time recorded. Screen shots of completed responses were used to score accuracy. After writing their response, participants returned the pen to the marked starting point and pressed a button with their non-dominant hand to advance to the next trial.

Analysis

Data were analyzed as in Experiment 1. To further compare the interference effect between the written and spoken experiments data from Experiments 1 and 2 were entered into the same model, with experiment as a between-subjects factor.

Results and Discussion

Of the 9792 total trials, 4% were removed due to technical errors, incorrect responses, or outlier status. The analysis revealed a significant effect of block type (Figure 2A), whereby participants were slower to initiate production of items in homogeneous than in heterogeneous blocks, $F_1(1,33)=4.96$, $p=0.033$, mean difference=12.0, SE=5.37, 95% CI=1.0-22.9, $\eta_p^2=0.13$; $F_2(1,35)=5.98$, $p=0.020$, mean difference=11.6, SE=4.76, 95% CI=2.0-21.3, $\eta_p^2=0.15$. There was no significant main effect of cycle, $F_1(2,66)=1.25$, $p=0.29$, $\eta_p^2=0.04$; $F_2(2,70)=1.99$, $p=0.15$, $\eta_p^2=0.05$, or interaction of cycle and block type, $F_1(2,66)=0.46$, $p=0.63$, $\eta_p^2=0.01$; $F_2(2,70)=0.58$, $p=0.56$, $\eta_p^2=0.02$. As in Experiment 1, these results point to interference induced by distributed segmental overlap. In the model with datasets from both experiments included, the main effect of block type remained significant, $F_1(1,56)=17.51$, $p<0.001$, mean difference=14.5, SE=3.46, 95% CI=7.5-21.4, $\eta_p^2=0.24$; $F_2(1,70)=25.02$, $p<0.001$, mean difference=15.0, SE=3.01, 95% CI=9.0-21.0, $\eta_p^2=0.26$. However, there the interaction between experiment type (written vs. spoken) and block type (heterogeneous vs. homogeneous) was not significant, $F_1(1,56)=0.53$, $p=0.47$, $\eta_p^2=0.01$; $F_2(1,70)=1.27$, $p=0.26$, $\eta_p^2=0.02$, indicating no reliable differences in interference found in spoken and written modalities.

As in Experiment 1, there was a numerical interference effect when only items sharing initial segments with at least half of the items in their homogeneous block were analyzed (Figure 2B). Although this effect did not reach statistical significance, $F(1,33)= 1.65$, $p=0.21$, $\eta_p^2=0.05$, the effect was not reliably different from that of Experiment 1, as indicated by the significant effect of block type, $F(1,56)=8.43$, $p=0.01$, mean difference=13.1, SE=4.52, 95% CI=4.1-22.2, $\eta_p^2=0.13$ but non-significant interaction of experiment and block type in the analysis of combined data, $F(1,56)=0.77$, $p=0.38$, $\eta_p^2=0.01$. In summary, we found comparable robust interference in both modalities for segmentally overlapping words.

General Discussion

Using a novel manipulation in which segmental overlap was distributed unpredictably across word positions, we observed interference in spoken and written word production, even when considering only items that shared their initial segment with half the items in their homogeneous block. Critically, this interference that was observed for items with distributed segmental overlap mirrors the interference previously observed in lexical selection for items with semantic overlap, but not the facilitation found when picture names predictably shared onset segments. The effect was replicated across modalities and was not reliably different between the two, increasing confidence in the stability of the effects across considerable variability in task conditions.

Implications for Theories of Word Production

The results of these experiments have several implications for theories of word production. First, we find evidence that similarity-based interference occurs at both stages of word production. In general, distributed feature overlap creates interference during repeated retrieval, regardless of the nature of the overlap (semantic or segmental), modality of production (spoken or written), or locus of selection (lexical items or segments). While our predictions were framed using Oppenheim et al.'s (2010) model, our data are equally consistent with an incremental learning account that relies on lateral inhibition rather than competitive learning

(Howard et al., 2006). While we believe the interference reflects a similar computation principle, we do not expect the resulting effect to have identical properties at the two stages. For instance, the interference generated during lexical-segmental mapping might be more susceptible to the presence of intervening items than the interference generated during semantic-lexical mapping which typically survives lags of 10+ items (Schnur, 2014). In future work, it will be important to investigate potential differences to more fully characterize the mechanisms at the two stages.

Second, these results also support the claim that the facilitation effects reported for initial segment overlap arise at least in part outside the word production system since they disappear when predictability is eliminated. Note that we do not rule out that there may also be facilitatory effects of similarity that arise within the production system itself and are masked by the stronger interference effects. This point underscores that it is important to consider that facilitatory and inhibitory effects coexist in the word production system, and performance reflects the sum of these opposing forces. This interplay is affected by the task such that semantic similarity typically creates interference when related pictures are named repeatedly (e.g., Damian et al., 2001), but facilitation with presentation of a single semantically related word (e.g., Wheeldon & Monsell, 1994). Phonological overlap can, similarly, have both facilitatory and inhibitory effects, and phonological neighbors can also induce facilitation or inhibition depending on how strongly activated they are, which can be task-dependent (Sadat et al., 2014; see also Chen & Mirman, 2012). Furthermore, facilitation and interference maybe observed even within the same task: in the blocked cyclic naming paradigm, often there is initially a large facilitation due to repetition (e.g., see response time drop between cycles 1 and 2 in Experiments 1 and 2) before the interference becomes visible in later cycles. The critical claim of the current work is that the competitive incremental learning guiding facilitation and interference is similar between semantic-lexical and lexical-segmental mapping

Third, within the frameworks we have considered, there must be feedback between segments and lexical representations for shared activation to affect lexical-segmental mapping (see Dell, Nozari, & Oppenheim 2014; Rapp & Goldrick, 2000). Without feedback, there is no reason to expect shared activation for targets and form-related competitors and therefore no reason to expect interference for high segmental overlap. This creates a challenge for strictly feed-forward models (e.g., Levelt, Roelofs, & Meyer, 1999), where segmental overlap effects could not arise within the production system itself but would instead need to be explained in terms of the operation of the monitoring system.

In sum, these findings provide evidence for the generality of the incremental learning mechanisms that apply across semantic and form-based levels of representation, giving rise to the complex patterns of facilitation and interference we observe in spoken and written word production.

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Tables

heterogeneous blocks (columns); **homogeneous blocks** (rows)

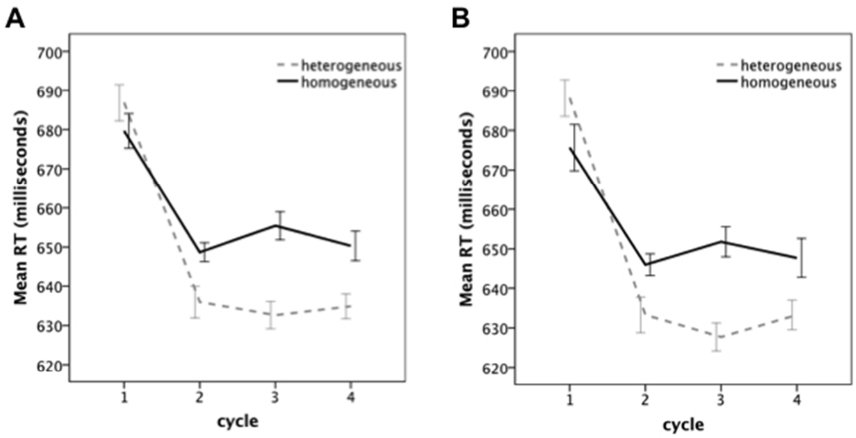
cat	mat	cot	cap	map	mop
pill	peg	pig	pot	log	leg
house	horse	rose	nose	robe	hose
rain	stairs	hair	stain	chain	chair
slide	bride	bread	bridge	sled	bird
belt	well	wall	bell	bull	ball

Table 1. Items used in Experiments 1 and 2A. The six items in each row form a homogeneous block, with high position-independent segmental overlap. The six items in each column form a heterogeneous block, with low position-independent segmental overlap.

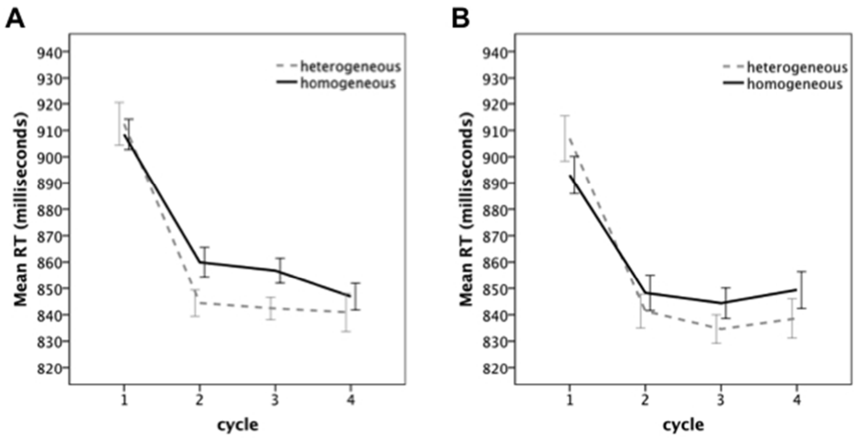
Figures

Figure 1. Results of Experiment 1: The effect of distributed segmental overlap on response times for spoken picture naming of words in blocks with high segmental overlap (homogeneous) versus low segmental overlap (heterogeneous). Error bars represent the between-subjects standard errors of the means, corrected for repeated measures using the Cousineau (2005) method. Panel A includes data from all items. Panel B depicts the secondary analysis that includes only items that share the initial segment with at least half of the other items in the homogeneous block.

Figure 2. Results of Experiment 2: The effect of distributed segmental overlap on response times for written picture naming of words in blocks with high segmental overlap (homogeneous) versus low segmental overlap (heterogeneous). Error bars represent the between-subjects standard errors of the means, corrected for repeated measures using the Cousineau (2005) method. Panel A includes data from all items. Panel B depicts the secondary analysis that includes only items that share the initial segment with at least half of the other items in the homogeneous block.



254x119mm (72 x 72 DPI)



254x119mm (72 x 72 DPI)