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Identity and Similarity in Repetition Deafness

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The repetition blindness (RB) and repetition deafness (RD) effects demonstrate that repeated objects are more difficult to notice than unrepeated ones when presented within rapid streams of stimuli. Previous research has shown that RB can occur even if two visual targets are similar but not completely identical. In the present study we investigated RD for similar non-identical auditory targets. In Experiment 1 we compared recall performance for similar target pairs to that for identical target pairs and found that the difference (the RD) was significantly smaller than when comparing recall performance for unrelated target pairs to that for identical target pairs. In Experiment 2 we presented similar, identical and unrelated target pairs in a within-participants design and confirmed that RD occurs for similar targets but to a lesser extent than it does for identical targets. In both experiments, the influence of response biases and lexical competition effects were minimized so as to render the explanation of the results clear in terms of pure perceptual processes. The data reported here support models that predict perceptual RB and RD between similar items, as opposed to other accounts that predict RB and RD only for items sharing the same identity.

Psychological research has often described the beneficial effects of redundancy in perception. Identifying or detecting an object is usually easier (i.e., the observer is faster and more accurate) if an instance of that same object has been perceived in the recent past, as if its representation was more prevalent after being activated by a recently processed stimulus. The *repetition blindness* (RB) and *repetition deafness* (RD) effects illustrate a phenomenon that is apparently paradoxical, for they render the perception of a stimulus *less* accurate if an instance of the same object has been presented a short time ago (within a temporal window of about 200 ms). This decrement in sensitivity for redundant stimuli has been regarded as an adaptive mechanism of the perceptual system that helps to parse information more effectively. For instance, visual RB would help to maintain object constancy despite brief interruptions in the flow of visual information, such as eye blinks (Kanwisher,

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1987), whereas auditory RD might act as a useful mechanism that filters out redundant information in natural speech (Fox-Tree, 1995), where repetitions are very frequent (e.g., after hesitations or reformulations; 'it is like a … like a jar or something').

In her original studies on visual RB, Kanwisher (1986, 1987) reported a series of experiments in which participants frequently failed to notice word repetitions in sentences presented word by word in rapid succession (rapid serial visual presentation- RSVP). For instance, observers would recall the sentence "It was work time so *work* had to get done" as "It was work time so had to get done", even at the cost of loosing grammaticality. RB studies usually include a control condition in which performance for the repeated item in the experimental condition is measured under non-repetition conditions. For example, in the cited Kanwisher experiments, participants were presented with sentences like "It was day time so *work* had to get done", in which the first instance of the word 'work' had been replaced by another unrepeated word (i.e., 'day'). In this case, participants were often aware of the word 'work' in the sentence, and consequently their recall accuracy for that word was better than in the repeated trials. The RB effect has been studied under several presentation conditions (e.g., rapid serial presentation, simultaneous displays) and with many different types of materials (e.g., words in sentences, words in lists, letters, colors, homophonic words, homographic words, pictures). The basic empirical characterization of RB has been established and several explanatory accounts have been proposed. The most popular theories attribute the RB to a failure at a perceptual stage (token individuation failure, as in Bavelier, 1994; Kanwisher, 1987; Park & Kanwisher, 1994, or recognition failure, as in Hochhaus & Johnston, 1996; Luo & Caramazza, 1995, 1996; Soto-Faraco & Spence, 2001) as opposed to a failure in memory storage or retrieval processes (see Arsmtrong & Mewhort, 1995; Fagot & Pashler, 1995; Whittlesea, Dorken & Podrouzek, 1995; Whittlesea & Podrouzek, 1995).

The auditory analogue of RB, called repetition deafness (RD), has been established more recently (Miller & MacKay, 1994; 1996; Soto-Faraco, 2000; Soto-Faraco & Sebastián-Gallés, 2001; Soto-Faraco & Spence, in press a), and while some of its properties have been identified, its characterization is still incomplete. For instance, it is known that the magnitude of RD is inversely proportional to the temporal interval between the two repeated targets (Miller & MacKay, 1994; Soto-Faraco, 2000), that RD can be modulated by attention (Soto-Faraco & Sebastián-Gallés, 2001), and that RD is sensitive to spatial displacement between the repeated targets (Soto-Faraco & Spence, 2001). In all of these respects RD is comparable to its visual counterpart (RB) although they may differ in other dimensions (see, Soto-Faraco & Spence, 2001, 2002).

In the present study we address whether similar but non-identical auditory targets are subject to repetition deafness, an aspect of RD that has not been previously explored. The use of the label *repetition* blindness and/or deafness to describe the effects to arise between similar non-identical targets is inaccurate, for there is no actual repetition in the strict sense. However, it will be used here as a label for the same effect as would be found were the two targets identical, as it is common usage in the literature.

In the visual domain, the possibility of repetition deficits between similar items has been investigated but still remains controversial, as two opposing views have received empirical support in the RB literature. For instance, some authors have reported RB between similarly written words such as ‘cap’ and ‘cape’ (e.g., Kanwisher & Potter, 1990; Bavelier, Prasada & Seguí, 1994). In their explanation, Bavelier et al. argue that the representations of similar objects share some codes, and therefore the presentation of one stimulus not only activates its own representation, but also contributes to partial activation of the representations of similar stimuli. Following Bavelier’s claims (Bavelier et al., 1994; Bavelier, 1994; see also Park & Kanwisher, 1994), the same mechanisms underlying RB for identical stimuli would also apply to similar items, although to a lesser extent (because they only share a subset of their representational codes). Chialant and Caramazza (1997) recently proposed an alternative to Bavelier’s account, claiming that true RB was to be observed only if the very same representation is activated twice in a short period of time. They argued that Bavelier’s results, which suggest the existence of RB between similar words, could be explained by lexical competition rather than RB (see also Miller & MacKay, 1994; MacKay & Miller, 1994, for a similar argument). To support their argument, Chialant and Caramazza conducted an experiment in which, in addition to the two typical RB conditions (i.e., identity, as in ‘cap’ – ‘cap’, and unrelated, as in ‘set’ – ‘cap’), they included pairs of similar words (as in ‘cape’ – ‘cap’). They presented sentences containing the critical targets, word by word, at different presentation rates (ranging from 100 ms/word to 260 ms/word). In the identity condition, the difference in recall performance between identical and unrelated pairs (typical measure of RB) was maximal at the shortest interstimulus intervals, and decreased at longer time intervals. In contrast, the similarity condition showed a performance decrement (in comparison to the unrelated baseline condition) that was maximal at longer interstimulus intervals, thus dissociating the effects of similarity from the effects of identity in RB. Note that inhibitory effects between formally similar words have been widely established in the visual (e.g., Colombo, 1986; Grainger, 1990; Grainger, O'Reagan, Jacobs, & Seguí, 1989) as well as in the auditory word recognition literature (e.g., Goldinger, Luce, & Pisoni, 1989; McQueen, Norris, & Cutler, 1994; Soto-Faraco, Sebastián-Gallés, & Cutler, 2001). However, one possible criticism to Chialant and Caramazza’s account is that the temporal scale at which RB between similar items has been observed in previous experiments is much smaller than the timing at which lexical competition usually occurs (Bavelier, 1997, personal communication). The fact that no studies of similarity in RB have been conducted using non-word stimuli leaves this question unresolved. The resolution of this issue has important implications for the theories of RB and RD. In particular, some proposals account for the RB as a failure in a processing stage involving a single unitary representation such as a lexical node (e.g., Chialant & Caramazza, 1997; Luo & Caramazza, 1995, 1996; MacKay & Miller, 1994; Miller & MacKay, 1994). These theories should be revised if similar items produce RB and RD independently of lexical competition, and a more flexible mechanism should be proposed.

The present study addresses two related questions. First, whether RD can be observed for similar non-identical auditory items; second, in the case of finding RD for such stimuli, whether it can be obtained in the absence of lexical competition. To this end, we used a methodology that has reliably produced RD for identical targets in past studies (Soto-Faraco, 1999, 2000; Soto-Faraco & Sebastián-Gallés, 2001; Soto-Faraco & Spence, 2001). In the RD studies cited above, 2 or 3 items (spoken syllables, words, or digit names, digitally compressed to 100 ms duration) were presented in dichotic lists. Each list contained 2 critical elements in succession (C1 and C2, respectively) that could be presented to the same ear (within channel) or to different ears (across channels). In half of the lists C1 and C2 were identical, and in the other half C1 and C2 were distinct. In some of the lists, an additional unrelated item was presented concurrently with C1 or to C2, to the opposite ear (this item is called simultaneous element or S). Participants were required to recall all of the items that they heard after each list was presented. The reason for including an additional simultaneous item (S) was to increase the rate of elements presented per unit of time (presentation rate) and the uncertainty in stimulus presentation, thereby ensuring that performance remains within a measurable range. As shown in Soto-Faraco (2000), the inclusion of the simultaneous element significantly increases the amount of RD (although its presentation is not critical to observe the effect). Using the described methodology, we compared recall performance for pairs of identical spoken letter names with that for control pairs consisting of similar letter names (Experiment 1) and pitted the results against data from a comparable manipulation in which the control pairs were totally unrelated items. Two factors ensured that lexical competition could not account for any effects observed in the present experiments. First, the presentation rates used here were well above the range in which lexical competition effects were observed in Chialant and Caramazza’s (1997) study, thus making it unlikely that any potential decrement in performance was due to lexical effects. Second, a reduced vocabulary of stimuli (letters) was used rather than unpredictable words. That is, although letter names may have a representation in lexical memory, we used a list presentation with a reduced stimulus set (three possible items) rather than unpredictable words forming sentences (as in Chialant & Caramazza, 1997 and in Bavelier, 1994). These conditions should minimize potential lexical effects, as every item is highly predictable throughout the experiment.

The working hypothesis in Experiment 1 was as follows. If RD between similar non-identical targets does *not* exist, then a difference in performance should be observable between similar and identical targets that is comparable to the difference observed when comparing unrelated and identical pairs. In other words, similar pairs should be processed as accurately as unrelated pairs. In contrast, if RD between similar items exists, then a reduced or null difference between the similar and the identical condition is expected (i.e., similar targets should behave as identical targets), and the magnitude of the difference should be comparatively smaller than the difference observed when using unrelated and identical pairs.

EXPERIMENT 1

In this experiment we presented time-compressed versions of spoken letter names (selected from the set *B*, *D*, and *P*) in rapid dichotic lists. As noted above, these conditions are unlikely to produce lexical competition for various reasons. First, the presentation rate (2 or 3 items each 200 ms) was faster than the fastest rate used by Chialant and Caramazza (1997; in which no lexical competition was observed). Second, the stimulus set was reduced and the targets were repeatedly presented throughout the experiment, rather than being unpredictable words presented in a sentence context.

If no RD for similar targets exists, then the difference in recall between the identical and the similar conditions will be significant and comparable to that obtained when using unrelated controls (i.e., a repetition decrement for identical targets but not for similar non-identical pairs). If, on the contrary, RD between similar targets does exist, then the difference in recall accuracy between identical and similar targets will be null or at least reduced with respect to that found when using unrelated pairs as controls (as in Soto-Faraco, 2000).

METHOD

Participants. Twenty undergraduate students from the University of Barcelona took part in the present study. One participant performed below 10% in the identical condition and was excluded from the analyses.

Materials. The letter names B, D, and P were digitally recorded (16 kHz sampling rate) from a female speaker who pronounced them in various random orders and speeds. Letter names were pronounced in Spanish, and their phonological transcriptions are /be/ for B, /de/ for D, and /pe/ for P. These letter names were recorded in the same session as other letter names used in a related experiment with different participants. All the recorded letter names were compressed to 100 ms (applying a compression algorithm that left pitch intact, from Cool Edit sound editor, Syntrillium Software Corporation). One exemplar of each letter name was finally selected on the basis of its clarity once compressed (the recordings of the chosen letter names had a duration before compression of 240 ms, 200 ms, and 220 ms, respectively for B, D, and P). All possible pairings made with the three selected letter names were phonologically close, differing only in one or two phonological features. The pairings B – D and B – P differ in one phonological feature only (place of articulation and voicing, respectively), whereas the pairing P – D differs in two phonological features (voicing and place of articulation). Note, that all of these possible pairs are phonologically closer than the target pairs originally used in Soto-Faraco (2000; PA, PI, and PO) in which the distinction involved a vocalic category (this distinction is phonetically large, since Spanish vowels are very distinctive in terms of their formant frequencies; see, Navarro- Tomás, 1968; Skelton, 1969; Stockwell & Bowen, 1965).

Each list was composed of two time-steps of 100 ms (first and second list position), and in each time-step a stimulus could be presented at one of two possible locations (left or right ear). The two critical elements, named C1 and C2, were always presented in successive time steps (never at the same time). The factors manipulated included ear of presentation of C1 (left or right) and ear of presentation of C2 (left or right), identity of C2 (B, D, or P) and repetition (C1 equal or different than C2). Each factor was equally balanced in the 192 experimental lists. Half of these lists contained an additional non-repeated item (called S henceforth) that was presented simultaneously with C1 or with C2 in the opposite ear (the position of S was balanced across the other conditions). An additional set of 96 filler lists was included. Among these filler lists, 48 contained three elements without repetitions, and 48 contained one element. Four different random orders of the lists were used to form four versions of the experimental materials. The distribution of materials was exactly the same used in Soto-Faraco (2000, Experiment 3), with the sole change of the actual identity of the list items.

Apparatus and procedure. Participants sat in front of a computer screen in a dimly illuminated room. The spoken letter names were presented to the participants at a comfortable sound pressure level via headphones (Sennheiser HMD224X) connected to the computer's soundcard (MediaVision Proaudio Spectrum 16). The experimental protocol was programmed using the Expe 6 software (Pallier, Dupoux & Jeannin, 1997) on a PC-compatible computer (HP Vectra VL2 4/66). Each trial started with a blank screen and a tone presented binaurally (500 ms duration and 100 Hz frequency). After a silent period of 500 ms, the 200 ms experimental list was presented, followed immediately by another 500 ms 100 Hz binaural tone. After the presentation of the list, participants were prompted to report the letters heard using the computer keyboard. The 'Enter' key was used to terminate the response sequence and this led automatically to the next trial. Participants were explicitly instructed to recall each letter as many times as it had been heard, and they were informed that the order or ear of presentation of the stimuli were irrelevant. At the end of every block of 72 trials, the experiment was stopped and participants were allowed to take a brief resting break. Prior to the start of the experiment participants received a training session containing 8 trials that were representative of the experimental materials.

During the training, participants were reminded about all possible target letter names at the response stage of each trial. After the training phase, each participant was presented with one of the four equivalent versions of the materials.

Table 1. C1 and C2 uncorrected recall proportion (+SE) as a function of repetition and ear-switch in Experiment 1.

	Within	**Across**
Similar	0.54 (.03)	0.65 (.03)
Identical	0.56 (.05)	0.39 (.03)

RESULTS

Accuracy was assessed as the proportion of trials in which both critical targets (C1 and C2) were correctly recalled (independently of other intrusions or omissions). Identical pairs were correctly recalled 48 % (SD = 28) of the time, whereas similar pairs were correctly recalled on 60 % (SD = 19) of the trials. Data were submitted to an ANOVA including the within-participant factors Repetition (identical vs. similar) and Ear-switch (whether the two critical elements were presented to the same ear or to opposite ears; within- vs. across-channels, respectively). Table 1 shows the average performance in each condition. The main effect of Repetition was significant ($F[1, 18] = 17.4$, $p < .005$) whereas there was no main effect of Ear-switch ($F[1, 18] = 1.7$, *ns*). The interaction between Ear-switch and Repetition was significant ($F[1, 18] = 107.5$, $p < .001$), indicating that there was a repetition effect when the critical elements were presented to opposite ears (26% difference; $t[18] = 8.9$, $p < .001$) but not in the within-channel lists ($|t| < 1$).

The amount of RD obtained in this manipulation (using similar vs. identical conditions) was compared to that obtained in the typical RD setup (using unrelated vs. identical conditions). A new analysis was computed using the present data pooled with data from Soto-Faraco (2000, Experiment 3) including Experiment as a between-participant factor (Experiment 1 using similar controls, vs. Soto-Faraco's, 2000, Experiment 3 using unrelated controls). Repetition (identical vs. unrepeated) and Ear-switch were included as within-participant factors. The interaction between repetition and experiment was highly significant ($F[1, 49] = 14.3$, $p < .001$), indicating that the manipulation with unrelated controls (Soto-Faraco, 2000, Experiment 3) produced significantly more RD (31%) than the experiment using similar controls (12%). The interaction between ear-switch and experiment was also significant in this analysis ($F[1, 49] = 5.7$, $p < .05$), because within-channel lists were reported more accurately than across-channel lists when using unrelated controls but they were overall equivalent when using similar controls. The triple interaction between Experiment, Repetition and Ear-switch did not approach significance ($F < 1$).

Intrusion errors. We assessed the influence of response biases in the present experiment by analysing the frequency with which two kinds of errors occurred. First, the intrusion of a repeated element in the response to an unrepeated list (perseverative intrusion), and second the intrusion of a non-repeated element in the response to a repeated list (non-perseverative intrusion). The comparison between perseverative and non-perseverative intrusion rates in each condition gives an indication of the impact of response biases on the effects observed. In particular when perseverative intrusions are more frequent than non-perseverative ones performance tends to be overestimated in the identical condition (thus, reducing possible RD effects and eventually producing facilitation). When non-perseverative intrusions are more frequent than perseverations, performance in the non-identical condition tends to be inflated (and therefore, chances to observe RD are artificially augmented). Table 2 shows the proportion of intrusions and the comparisons between perseverative and non-perseverative intrusions for each type of list used. An examination of the pattern of intrusion errors (see the results of statistical comparisons in Table 2) indicates that some of the RD observed in Experiment 1 may have been caused by response biases (and therefore, not necessarily associated to perceptual processes).

Table 2. Proportion of perseverative (P) and non-perseverative (NP) intrusions as a function of list length and ear-switch in Experiment 1.

	List length			
	2		3	
Ear switch	Within	Across	Within	Across
P	.32	.08	.23	.24
NP	.14	.26	.33	.33
NP-P	-.18 **	.18 ***	.10 +	.09 n/s

Note. The last row contains the difference between perseverative and non-perseverative intrusion rates together with the significance level of the comparison. Stars represent the significance level (two stars, $p < .01$; three stars, $p < .001$). The + symbol indicates a marginal difference ($.1 > p > .05$). The label 'n/s' indicates a non-significant difference.

Analyses of corrected data. We performed a new analysis with accuracy data corrected for guessing biases (see Figure 1). Data correction was based on the conservative assumption (i.e., against finding RD) that the proportion of intrusions is a direct indicator of the impact of guessing biases. We subtracted the proportion of perseverative intrusions from the proportion of correct responses to repeated lists, and the proportion of non-perseverative intrusions from the proportion of correct responses to unrepeated (similar) lists. This correction was applied separately to data from every participant and condition.

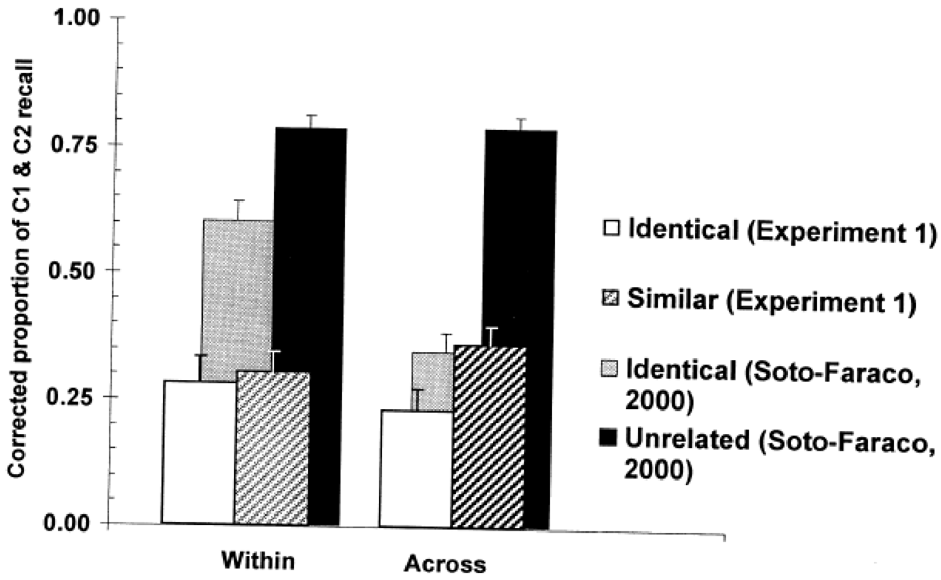

Figure 1. Mean C1 and C2 recall accuracy (+SE) corrected for guessing in Experiment 1 (stripped bars represent accuracy for similar trials, and white bars represent accuracy for identical trials), and in Soto-Faraco (2000; Experiment 3; gray bars represent performance for identical trials, black bars represent performance for unrelated trials).

A new ANOVA performed on the corrected accuracy proportions of Experiment 1 showed that the repetition effect was significant again ($F[1,18] = 7.1$, $p < .05$), indicating that identical pairs were recalled less accurately than similar pairs (25% vs. 33%, respectively). Ear-switch was not significant ($F < 1$) but the interaction between Repetition and Ear-switch reached significance ($F[1, 18] = 6.7$, $p < .05$) indicating that the amount of RD was significant only in the across-channel trials (13%; $t[18] = 3.3.$, $p < .001$) but not in the within-channel condition ($|t| < 1$). We conducted a further analysis including the corrected proportions from Experiment 1 together with the corrected version of the data from Soto-Faraco (2000, Experiment 3) in a three way ANOVA with Experiment as a between participants factor and Repetition and Ear-switch as within participants factors. The significant interaction between Experiment and Ear-switch ($F[1, 49] = 9.3$, $p < .005$) indicated that whereas Soto-Faraco's (2000) experiment produced a generalized ear-switch effect (i.e., within-ear lists recalled better than across-ear), the present manipulation did not. Critically, the interaction between Experiment and Repetition was significant (F[1, 49] = 29.3, p < .001) indicating that, as in the uncorrected data analysis, RD was smaller in Experiment 1 (when using similar controls, 8%) than in Soto-Faraco (2000) Experiment 3 (when using unrelated controls, 32%).

DISCUSSION

The main result to emerge from Experiment 1 was that RD was significantly attenuated when highly similar targets were used as controls for comparison with the identical condition. This significant reduction in RD when using similar rather than unrelated items as controls suggests that the repetition deficit that affected the identical condition was also (partially) present in the similar condition. Thus, this supports the notion that RD between similar items exists in the same way as between identical pairs. In addition, data from Experiment 1 replicates previous findings that RD and RB are larger when the two critical items are presented from different locations rather than from the same location (Soto-Faraco, 2000; Soto-Faraco & Spence, 2001), as indicated by the interaction between ear-switch and repetition.

The reduced accuracy observed in the similar condition of the present experiment is unlikely to be caused by lexical competition. First, the items used were extracted from a restricted set of only three letter names that were repeated throughout the experiment, thus likely leading to a reduction of any lexical effects. Second, and more importantly, the presentation rate used in this experiment was faster than the presentation rate at which lexical competition effects are normally observed. Chialant and Caramazza (1997) did not find lexical competition effects when they presented similar words at rates even slower than the ones used here. Lexical competition was observed in Chialant and Caramazza's study only at the slowest rate (about 246 ms / word, with 2 to 3 words intervening between the critical targets). The context in which the auditory events in our study were presented (lists rather than sentences) as well as the fact that letter names might not have the same lexical status as other content words, makes it still less likely that lexical effects caused the observed pattern of data for similar items.

However, RD is not the only possible explanation to account for similar target pairs being recalled almost as poorly as the repeated targets in the present experiment. For instance, one could argue that the decrement effect observed in the similar condition reflects mainly confusions (i.e., it is easy to misperceive B as P when presented fast) rather than omissions (the typical outcome in RB and RD). This potential explanation can be evaluated directly with a new data analysis using a more liberal scoring. In particular, we re-scored participants' responses in Experiment 1 counting as correct any response that simply contained the correct number of items presented or more (irrespective of their identity). Using this scoring, responses to any three-element list containing at least three letters, or responses to two-element lists containing at least two letters, would thus be counted as correct. Erroneous responses to similar pairs caused by confusions but not omissions would contain the right number of items, and therefore would not be counted as errors and would not contribute to the effects observed. A comparison between accuracy in identical and similar lists of Experiment 1 indicated that the effect of repetition was still small (but significant) even when using this liberal scoring (68% vs. 61%; $F[1, 18] = 16.2$, $p = .001$), indicating that the reduction observed in the similar lists was due to omissions rather than to confusions. This same scoring was applied to data from Soto-Faraco (2000, Experiment 3) and pooled with data from Experiment 1 in a new ANOVA using Experiment as a between participants factor. Using this liberal scoring procedure to the data from Soto-Faraco (2000, Experiment 3) yielded again a larger overall RD (24%) than Experiment 1 (7%), as revealed by the significant interaction between Experiment and Repetition $F[1, 49] = 14.7$, $p < .001$). This result indicates that the differences between identical and similar items in Experiment 1 were clearly reduced with respect to the differences between identical and unrelated targets, and that this effect was not due to participants reporting one item instead of another (i.e., confusion errors). Rather, it appears that they omitted more items in the response to similar lists than in the responses to unrepeated lists. Therefore, the data favors again the existence of RD between similar items.

The contrast between the present data and data from the equivalent manipulation in Soto-Faraco’s (2000,) experiment 3 provides clear evidence supporting the existence of RD between similar items. The outcome of this comparison appears to be robust, since it provided exactly the same result regardless of the three different data scoring procedures used (direct proportions, corrected proportions to avoid biases due to guessing strategies, and liberal scoring to avoid biases due to confusions rather than true omissions). However, the present argument rests on a comparison between the effects obtained in two different experiments (nonetheless equivalent in every respect except the materials). Therefore, the true size of the difference can only be inferred by comparison of the difference between control condition and the identical condition across experiments. A direct comparison between the RD obtained with similar items and the RD obtained with identical items, will allow us to verify whether the hypothesis about RB between similar objects (the more similar, the stronger the effect) previously proposed by Bavelier (1994) can be extended to the case of RD. In order to do so, in the next experiment we addressed a direct comparison between similar and identical pairs against an unrelated control condition. In addition, nonsense syllables (rather than letter names) were used to minimize even further the potential role of lexical competition.

EXPERIMENT 2

In the present manipulation we tested the effect of similarity in RD using an experimental logic slightly different from that used in Experiment 1. In particular, recall accuracy for similar targets was compared to that for identical targets and for unrelated targets. The identical condition contained two instances of the same syllable (i.e., KI – KI), the similar condition contained two syllables differing in one phonological feature in the onset consonant (i.e., PI – KI), and the unrelated condition contained two syllables differing at least in the vowel and potentially also in the onset consonant (i.e., KO – KI; PO - KI). To render the interpretation of the results as straightforward as possible, only the two element lists were used in the analyses (this is because three element lists always contained one similar pair and one unrelated pair regardless of the condition). Another feature of this experiment is that nonsense syllables were used as stimuli instead of letter names, thus making a lexical competition account even less likely than it may have been in Experiment 1 (where letter names were used).

If RD between similar targets exists and it is *not* produced by lexical competition, then a reduction in performance for similar items should be observed relative to performance for unrelated pairs. Furthermore, if the effect of RD is modulated by similarity (as the small RD effect observed in Experiment 1 suggests), then its magnitude should be maximal for identical pairs (where similarity is complete) and smaller in the similar pairs (where some of the representational codes for the two stimuli mismatch). On the contrary, if RD was to occur only for identical but not for similar pairs, then the interpretation of the results of Experiment 1 should be revised, and the hypothesis that RD occurs for similar pairs would be challenged.

METHOD

Participants. Eighteen participants from the same population as in the previous experiment took part in the present study. Data from two of them were excluded because their performance level was lower than 10% overall. None of the participants had taken part in the previous experiment.

Materials. Eight new stimuli (the syllables PA, PE, PI, PO, KA, KE, KI, and KO) were recorded and time-compressed to 100 ms using the same procedure as in Experiment 1 (the phonological transcription of the stimuli for KA, KE, KI, KO, PA, PE, PI and PO, is respectively; /ka/, /ke/, /ki/, /ko/, /pa/, /pe/, /pi/, and /po/). Their original duration was 177 ms, 170 ms, 180 ms, 189 ms, 180 ms, 170 ms, 180 ms, and 195 ms, respectively. The voiceless occlusive consonants /p/ and /k/ were chosen because they are close in phonological space (only differing in place of articulation, see Miller & Nicely, 1955). Thirty-two lists of two identical elements were constructed combining ear of C1 and ear of C2 (four possible combinations), and identity (8 possible combinations). The 32 lists of two similar items were constructed replacing C1 in the identical lists by another element with the same vowel but a different initial consonant (i.e., PA was combined with KA, PE with KE, and so on). Similarly, the 32 two-element unrelated lists were constructed by changing C1 by an element in which at least the vowel was different from C2 (i.e., KA was replaced by either PE, KE, PO, KO, PI, or KI at random). An additional set of 128 lists containing three elements was constructed based on the identical and similar two-element sets combining systematically the position of the S element (simultaneous with C1 or with C2). Note that, in the three element lists, any possible combination (of unrepeated items) contains both similar, as well as unrelated elements, and therefore these lists were solely included to equate the proportions used in the previous experiment, but were not analysed. Finally, 32 additional one-element lists were added as fillers (combining in equal proportion, ear of presentation, position in the list, and identity). A total of 256 lists were included in the materials, which were grouped in 4 blocks of 64 trials with every experimental factor balanced within each block.

Apparatus and procedure. Presentation conditions and instructions were the same as in Experiment 1 except that now participants were asked to recall meaningless syllables instead of letter names. All participants received an eight trial training phase containing lists representative of the experimental materials. Participants were allowed a brief resting break after each block.

RESULTS AND DISCUSSION

Data on the proportion recall of C1 and C2 (only from the two-element lists) were submitted to an ANOVA including the within-participants factors Repetition (identical, similar and unrelated) and Ear-switch (Table 3 shows the average performance in each condition).

Table 3. C1 and C2 uncorrected recall proportion (+SE) of two-element lists as a function of repetition, and ear-switch in Experiment 2.

	Within	Across
Unrelated	0.70 (.04)	0.83 (.02)
Similar	0.54 (.04)	0.76 (.04)
Identical	0.59 (.09)	0.61 (.08)

Note. Data are presented as a function of ear-switch and repetition (identical, similar and unrelated conditions are shown separately).

The main effect of repetition (F[2, 30] = 6.3, p < .005) and the interaction between Ear switch and Repetition (F[2, 30] = 11.5, p < .001) were significant. This interaction indicated that repetition was significant only in across-channel lists (F[2, 30] = 14.1, p < .001) but not in within-channel lists (F[2, 30] = 2.5, p = .095). Pair-wise comparisons restricted to across-channel lists revealed the existence of significant differences between identical and unrelated lists (t[15] = 4.3, p < .001) and between similar and unrelated lists (t[15] = 2.9, p < .05), thus indicating the existence of RD for identical as well as for similar pairs. Crucially, the comparison between the amount of RD for identical pairs (36%) and for similar ones (11%) was also significant (t[15] = 3.2, p < .01), showing that the magnitude of RD was smaller in the similar condition than in the identical condition.

We assessed the frequency of intrusions in participants' responses (i.e., the influence of guessing tendencies, see Table 4). The proportion of non-perseverative intrusions in the identical lists was compared to the perseverative intrusion rate in the unrelated and similar lists separately.

Table 4. Proportion of perseverative (P) and non-perseverative (NP) intrusions as a function of ear-switch in Experiment 2.

	Within	Across
P (Unrelated)	0.01	0.00
P (Similar)	0.28	0.06
NP (Identical)	0.11	0.13

We assumed that every non-perseverative intrusion (in repeated lists) is potentially a correct guess for a similar item as well as for an unrelated item. In this way, we can only overestimate the true amount of guessing in the two types of unrepeated lists (therefore, leading to a conservative data correction). The rate of non-perseverative intrusions was higher than the rate of perseverative intrusions in unrelated lists (both in the within- and across-channel conditions, t[15] = 4.0, p<.001 and t[15] = 4.1, p<.001, respectively). The rate of non-perseverative intrusions was also higher than the rate of perseveration in similar lists in the across-channel condition, although marginally (t[15] = 1.9, p = .06). For the within channel condition, the perseveration rate was significantly higher than the non-perseverative intrusion rate (t[15] = 2.5, p < .05). Given that the intrusion analyses indicated that guessing tendencies had significantly influenced the data, a correction was performed and a new ANOVA was run including Repetition and Ear-switch as factors. Perseverative intrusion data from the similar condition was used to estimate the probability to correctly guess a target in identical lists. The proportion of the non-perseverative intrusions in the identical condition was used to estimate the chances of making a correct guess on a target in the similar and in the unrelated conditions. The chances of correctly guessing elements in unrelated lists were underestimated because this procedure assumes that every non-perseverative intrusion always led to a correct response (both in a similar list and in an unrelated list). This ensures that, if RD was detected, it could not be caused by the correction procedure.

The ANOVA using the corrected data (see Figure 2) revealed a significant effect of Repetition ($F[2, 30] = 13.9$, $p < .001$), caused by the difference between unrelated and similar lists (63% vs. 49%; $t[15] = 3.6$, $p < .005$) and also between similar and identical lists (49% vs. 36%; $t[15] = 2.5$, $p<.05$). Of course, the difference between unrelated and identical lists was also significant ($t[15] = 4.3$, $p<.005$). The effect of Ear-switch was marginal ($F[1, 15] = 4.5$, $p = .050$). There was no significant interaction between Ear-switch and Repetition in this analysis.

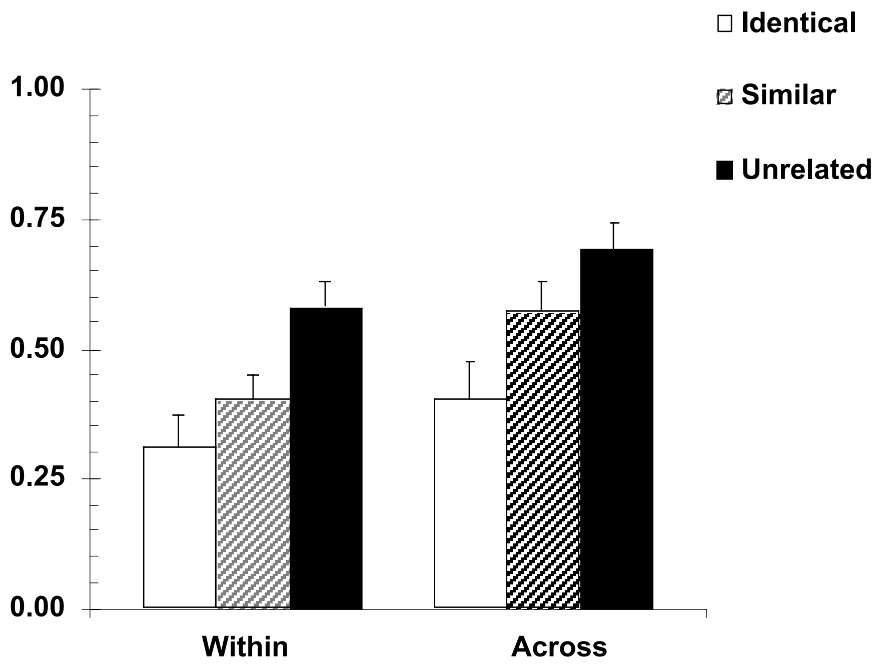

Figure 2. Mean accuracy (+SE) average corrected for guessing in Experiment 2. White bars represent accuracy for identical trials, shaded bars represent performance for similar trials, and black bars represent performance for unrelated trials.

Overall, the results of Experiment 2 replicate the RD between identical and unrelated pairs (27%) and demonstrate RD between similar and unrelated pairs (14%). The RD obtained in two-element lists of Soto-Faraco (2000, Experiment 3) using corrected data was 29%. Crucially, the results of this experiment revealed that the RD for similar pairs was significantly smaller than the RD for identical pairs. The present outcome does not only support the idea that similar events are subject to RD, but it also suggests that, as in RB, the magnitude of the effect is related to the degree of similarity between the critical targets. In addition, because the items used in this experiment were totally meaningless syllables, the chances of lexical competition occurring in the present manipulation were even more remote than in Experiment 1.

GENERAL DISCUSSION

The goal of the present study was to determine whether RD could occur between similar non-identical auditory events and furthermore, if it could be obtained in the absence of lexical competition. The data obtained allow us to answer both questions. There is RD between similar targets and it is not caused by lexical competition. In addition, the present results suggest that the magnitude of RD is a function of the degree of similarity between the two critical items. Further, there are several arguments that may be used to dismiss an explanation of the present results based on lexical competition. First, the materials used were elements with little (Experiment 1) or no lexical status (Experiment 2). Second, the presentation rates used were faster than those reported to lead to lexical competition effects (see the results of Chialant & Caramazza, 1997). Third, the items used in the present experiments were extracted from a small vocabulary and presented in lists, rather than unpredictable words from the lexicon presented in sentences. Yet, another indirect argument against lexical competition is found in examining the ear-switch effects on RD observed in the present experiments; The increase in RD when critical items are presented to different positions is a typical signature of the present phenomenon (Soto-Faraco, 2000; Soto-Faraco & Sebastián-Gallés, 2001) that is likely accounted for by the costs of shifting attention from one spatial location to another (see Soto-Faraco & Spence, 2001, on this point), but there is no obvious reason for why one should expect to find this type of spatial effect in lexical competition.

RD between similar targets

The fact that RD occurred for similar non-identical targets extends the characterization of this auditory temporal deficit over previous studies showing that RD occurs between pairs of events with the same identity but mismatching in some task-irrelevant feature (Miller & MacKay, 1996; Soto-Faraco & Sebastián-Gallés, 2001). Both Miller and MacKay's (1996) and Soto-Faraco and Sebastián-Gallés's (2001) studies used identical auditory targets (i.e., same word or syllable) pronounced by different speakers to show RD between targets sharing identity, but acoustically mismatching. However, note that their result is different from the one here reported in one important respect. In the cited studies, the critical targets always shared complete identity at least at one level (i.e., same lexical representation or same phonological representation), whereas in the present study similar targets were never identical in any respect, but were phonologically close. The clarification of this issue is important for current models of RB and RD. If one proposes that RD is caused by a failure in a processing stage associated with one unitary representation of the stimulus (Luo & Caramazza, 1996; MacKay & Miller, 1994; Miller & MacKay, 1994, 1996), then repetition effects will only occur when the very same representation is accessed twice in a short period of time. These types of models can explain RD when the two target stimuli are identical in at least one of their possible representational codes (e.g., two words spoken by different persons are identical in their lexical representation and their phonology, and differ only in their acoustical make up). However, if the relationship between the targets is one of mere similarity (but not identity in any respect) as in the present experiments, then RD effects are more difficult to accommodate by the "single node" models. In the mentioned theories, only lexical competition or confusion among similar items could explain the reduction in performance for similar targets, and thus they cannot accommodate the results reported here where RD for similar items was demonstrated in the absence of lexical competition or simple confusion effects.

There are, however, alternative models that can account for the present data (as well as similar RB results reported by Bavelier, 1994 and Kanwisher & Potter, 1990). In particular, Bavelier (1994) proposed that multiple representational codes are involved in RB (see also Park & Kanwisher, 1994, for a similar account). For instance, in the presence of the printed word 'CAT', not only the orthographic representation of the word form is activated, but also the phonological representation and the concept of 'cat' are activated and consequently subject (to some extent) to the repetition deficit. In a similar fashion, some of the codes sub-serving the representations of two stimuli that are similar would be shared between the two. For instance, the words 'FEAR' and 'REAR' share part of their representational codes (orthographic and phonologic). According to Bavelier (1994) the larger the number and the higher the saliency of the codes that are shared between two stimuli, the bigger the chance to observe RB between them. From the results obtained here, this idea can be readily extended to the case of RD.

The magnitude of RD is a function of similarity

The hypothesis sketched above makes one straightforward prediction; that the magnitude of RB (and by extension of RD) will increase as the similarity between the two critical targets increases. Results of previous studies in RB have shown that this may be the case in the visual modality (e.g., Bavelier, 1994) and the present results enable this hypothesis for the case of the auditory repetition deficit. If we consider that identical events have maximal degree of similarity (therefore, RD should be highest), and unrelated targets have a degree of similarity close to zero (therefore, RD should be null), similar targets should produce an amount of RD in between the two extremes.

This is precisely what happened in our study. In Experiment 1 we observed a reduction in RD when similar rather than unrelated targets were used as a baseline for performance in the repeated condition. When performance for similar and identical targets was directly compared to performance for totally dissimilar target pairs, the similarity condition produced a smaller (but significant) RD than the identical condition (Experiment 2). Moreover, these results were robust to different types of scoring and data correction, and they were replicated across different types of materials (letter names and meaningless syllables).

SUMMARY AND CONCLUSIONS

The results of the present study provide evidence favoring the existence of RD between auditory events that are phonologically similar but do not share identity at any level. Response biases and/or simple confusion were dismissed as the possible cause of RD in this study by applying conservative data correction procedures. However, the use of distinct data correction procedures did not affect the evaluation of the hypothesis under consideration and statistical analyses always supported the same explanation. Lexical effects were also discarded as a possible account of the RD observed here on several grounds; (a) the materials used (letter names and meaningless syllables), (b) the rate of presentation (too fast to produce lexical effects, as assessed in previous literature), and (c) the use of the same materials repeatedly and predictably throughout the experiment. This result challenges previous hypotheses arguing that RD and RB between similar targets were produced by lexical competition (e.g., Chialant and Caramazza, 1997; Miller & MacKay, 1994). Indeed, the hypothesis supported by the present data argues that the representations involved at the level of processing where RD and RB occur are subserved by multiple codes (Bavelier, 1994, 1999) not by a single unitary representational node.

REFERENCES

Armstrong, I. T., & Mewhort, D. J. K. (1995). Repetition deficit in rapid-serial-visual-presentation displays: Encoding failure or retrieval failure? *Journal of Experimental Psychology: Human Perception and Performance,* ***21***, 1044-1052.

Bavelier, D. (1994). Repetition blindness between visually different items: The case of pictures and words. *Cognition,* ***51***, 199-236.

Bavelier, D. (1999). Role and Nature of Object Representations in Perceiving and Acting. In V. Coltheart (Ed.), *Fleeting Memories: Cognition of brief visual stimuli*. (pp. 151- 179). Cambridge, MA: MIT Press.

Bavelier, D., & Potter, M. (1992). Visual and phonological codes in repetition blindness. *Journal of Experimental Psychology: Human Perception and Performance,* ***18***, 134-147.

Bavelier, D., Prasada, S., & Seguí, J. (1994). Repetition blindness between words: Nature of the orthographic and phonological representations involved. *Journal of Experimental Psychology: Learning, Memory, and Cognition,* ***20***, 1437-1455.

Chialant, D., & Caramazza, A. (1997). Identity and similarity factors in repetition blindness: Implications for lexical processing. *Cognition*, ***63***, 79-119.

Fox-Tree, J. E. (1995). The effects of false starts and repetitions on the processing of subsequent words in spontaneous speech. *Journal of Memory and Language,* ***34***, 709-738.

Grainger, J. (1990). Word frequency and neighborhood frequency effects in lexical decision and naming. *Journal of Memory and Language,* ***28***, 228-244.

Grainger, J., O'Reagan, J. K., Jacobs, A. M., & Seguí, J. (1989). On the role of competing word units in visual word recognition: The neighborhood effect. *Perception & Psychophysics,* ***45***, 189-195.

Hochhaus, L., & Johnston, J. C. (1996). Perceptual repetition blindness effects. *Journal of Experimental Psychology: Human Perception and Performance,* ***22***, 355-366.

Kanwisher, N. G. (1986). *Repetition blindness: Type recognition without token individuation.* Unpublished doctoral dissertation, Massachusetts Institute of Technology, Cambridge.

Kanwisher, N. G. (1987). Repetition blindness: Type recognition without token individuation. *Cognition,* ***27***, 117-143.

Luo, C., & Caramazza, A. (1995). Repetition blindness under minimum memory load: Effects of spatial and temporal proximity and the encoding effectiveness of the first item. *Perception & Psychophysics,* ***57***, 1053-1064.

Luo, C., & Caramazza, A. (1996). Temporal and spatial repetition blindness: Effects of presentation mode and repetition lag on the perception of repeated items. *Journal of Experimental Psychology: Human Perception and Performance,* ***22***, 95-113.

MacKay, D. G., & Miller, M. D. (1994). Semantic blindness: Repeated concepts are difficult to encode and recall under time pressure. *Psychological Science,* ***5***, 52-55.

Miller, G. A., & Nicely, P. E. (1955). An analysis of perceptual confusions among some English consonants. *Journal of the Acoustical Society of America,* ***27***, 338-352.

Miller, M. D., & MacKay, D. G. (1994). Repetition deafness: Repeated words in computer-compressed speech are difficult to encode and recall. *Psychological Science,* ***5***, 47-51.

Miller, M. D., & MacKay, D. G. (1996). Relations between language and memory: The case of repetition deafness. *Psychological Science,* ***7***, 347-351.

Navarro-Tomás, T. (1968). *Manual de Pronunciación Española (14th ed.)*. Madrid: Consejo Superior de Investigaciones Científicas.

Pallier, C., Dupoux, E., & Jeannin, X. (1997). EXPE: An expandable programming language for on-line psychological experiments. *Behavior Research Methods, Instruments, & Computers,* ***29***, 322-327.

Park, J., & Kanwisher, N. G. (1994). Determinants of repetition blindness. *Journal of Experimental Psychology: Human Perception and Performance,* ***20***, 500-519.

Skelton, R.B. (1969). The pattern of Spanish vowel sounds. *International Review of Applied Linguistics in Language Teaching*, **7**, 231-237.

Stockwell, R.P. & Bowen, J.D. (1965). *The Sounds of English and Spanish.* Chicago: University of Chicago Press.

Shillcock, R. C. (1990). Lexical hypotheses in continuous speech. In G. T. M. Altmann (Ed.), *Cognitive Models of Speech Processing: Psycholinguistic and Computational Perspectives* (pp. 24-49). Cambridge, MA: MIT Press.

Soto-Faraco, S. (1999). *Efectos de repetición en la codificación de estímulos auditivos*. Unpublished doctoral dissertation, Universitat de Barcelona, Barcelona, Spain.

Soto-Faraco, S. (2000). An auditory repetition deficit under low memory load. *Journal of Experimental Psychology: Human Perception and Performance,* ***26***, 264-278

Soto-Faraco, S. & Sebastián-Gallés, N. (2001). The role of acoustic mismatch and selective listening on repetition deafness. *Journal of Experimental Psychology: Human Perception and Performance*, ***27,*** 356-369

Soto-Faraco, S., Sebastián-Gallés, N., & Cutler, A. (2001). Segmental and supra-segmental mismatch in lexical access. *Journal of Memory and Language, 45,* 412-432.

Soto-Faraco, S. & Spence, C. (2001). Spatial displacement modulates repetition blindness and repetition deafness. *Quarterly Journal of Experimental Psychology (A),54*, 1181-1202.

Soto-Faraco, S. & Spence, C. (2002). Intramodal and crossmodal temporal processing deficits. *Quarterly Journal of Experimental Psychology (A),55,* 23-40.

Whittlesea, B. W. A., Dorken, M. D., & Podrouzek, K. W. (1995). Repeated events in rapid lists: Part 1. Encoding and representation. *Journal of Experimental Psychology: Learning, Memory, and Cognition,* ***21***, 1670-1688.

Whittlesea, B. W. A., & Podrouzek, K. W. (1995). Repeated events in rapid lists: Part 2. Remembering repetitions. *Journal of Experimental Psychology: Learning, Memory, and Cognition,* ***21***, 1689-1697.

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