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3aEDb4. Auditory change detection with common and uncommon sounds

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Change deafness, the inability to detect a change in an auditory scene, is similar to change blindness, the inability to detect a change in a visual scene. In this experiment, participants were asked to detect changes in auditory scenes (one, three, or five sounds). The sounds were either common sounds (e.g. alarm clock) or uncommon sounds (e.g. science fiction laser). Only one sound was modified in pitch or loudness for half of the trials. Participants were not always able to detect changes in a sound sequence (M = 67.1%) even though they could almost perfectly discriminate between the ten sounds (M = 99.2%). Participants performed best with a scene size of one (M = 82.6%) and worse with a scene size of five (M = 63.8%). Participants performed significantly better with common sounds (M = 74.7%) vs. uncommon sounds (M = 69.1%). Participants were significantly better at detecting a pitch change (M = 80.8%) than a loudness change (M = 53.5%). These results are consistent with the idea of change deafness. We remember the gist of an auditory scene but we don't detect changes in every sound.

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I. INTRODUCTION

Change deafness, the inability to detect one or more changes in an auditory scene, is similar to change blindness. Change blindness is the inability to detect a change in a pair of visual scenes (Simons & Levin, 1997). The implication of change blindness studies is that we remember the gist of the scene but fail to remember the details of the scene, which suggests that we do not perceive all details of our environment. Change deafness appears to have analogous features to change blindness; both concepts suggest the failure to encode, retain, and represent some of the visual or auditory objects (Eramudugolla, Irvine, McAnally, Martin & Mattingley, 2005).

In change deafness studies, participants can listen to one sound or many sounds and be asked to determine whether a sound changed in any way. Vitevitch (2003) tested listener's ability to detect a change in a voice while completing a shadowing task of repeating the words they heard. When hearing the same voice, all listeners were able to accurately say they did not detect a change in the voice, but when the voice changed, 42% of listeners were not able to accurately say they detected a change. McFadden and Callaway (1999) tested participants to see if they could notice a change when listening to common sounds vs. commons sounds, such as in chords vs. nonchords, tunes vs. nontunes, and forward vs. backward played speech. Participants were significantly better at detecting changes with common vs. uncommon stimuli.

Eramudugolla et al. (2005) had participants listen to four, six, or eight sounds while also viewing an object that they needed to pay attention to or viewing no visual stimulus. With almost perfect accuracy, participants were able to tell if a sound was missing if they were visually directed to pay attention to that one sound, but when not given any visual direction and scene size increased, change detection became considerably poorer. This showed that visual attention might play a role in change deafness. If we are told to pay visual attention to a particular item in an auditory scene with multiple items, we will be able to note an auditory change. Gregg and Samuel (2008) tested change deafness with natural sounds in scene sizes of four, five, or six sounds. Both familiar sounds (sounds that were heard on the previous day) and unfamiliar sounds were tested. Participants had to determine whether there was a change or no change. As the scene size got larger, change detection became worse. Sound familiarity did not change performance. This may be because participants may have not learned the sounds on the first day of testing, or that the change detection task may have been too difficult.

The present study examined change deafness with common sounds (e.g., bird chirp, alarm clock beep) and uncommon sounds (e.g., alligator hiss, ice skate). Scene sizes of one, three and five sounds were tested. We hypothesized that when scene size increases the rate of change detection will decrease, similar to the results of Gregg and Samuel (2008). We also hypothesized that participants will have more difficulty detecting a change with uncommon sounds vs. common sounds, like McFadden and Callaway's (1999) study.

II. METHOD

A. Participants

Twenty-four participants (8 men and 16 women) from Rochester Institute of Technology in Rochester, NY completed this experiment. The ages of the participants

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ranged from 18 years to 25 years (*M* = 20.5 years, *SD* = 1.5 years). A hearing test (Digital Recordings, 2010) was used to determine that all participants had normal hearing. Participants either received extra credit for Psychology courses or were entered into a lottery to win one of two $25 gift cards.

B. Materials

The sounds used in this experiment were chosen from a databank of sounds (Starter FX Sound Effects Download Pack by Blastwave FX, 2009). The five common sounds used were: a cow mooing, keyboard typing, birds chirping, an alarm clock beeping, and a bicycle bell ringing. The five uncommon sounds were: an alligator hissing, ice skater passing by, science fiction laser, a magical burst, and a coffin lid sliding. Sounds were pilot tested on ten individuals to make sure sounds were correctly identified as common and uncommon. All pilot participants correctly identified the common sounds and none could correctly identify the uncommon sounds.

Sounds were normalized using WavePad Sound Editor (NCH Software, 2008). Sounds were modified in pitch or volume using GarageBand (Apple, 2007). GarageBand uses a 24-point scale in which pitch can be changed, with 0 indicating the center and -12 and 12 indicating the lowest pitch and highest pitch attainable using the program. To create a higher pitch, the pitch would be raised 4 points and to create a lower pitch, the pitch would be lowered 4 points. In order to create a higher volume, the original sound was increased 4 decibels and to create a lower volume, the original sound was decreased 4 decibels. Therefore, for each original sound there were four modified sounds. When multiple sounds were played at the same time in an auditory scene, the sounds were layered in GarageBand. Each trial consisted of two sequence sets which were also created using GarageBand (see Figure 1). Sequence set 1 and sequence set 2 were separated by 500 milliseconds of silence. For a no change trial, the sequence sets contained identical sounds. For a change trial, the sequence sets were identical except one original sound in sequence set 1 was replaced by a modified version of the original sound in sequence set 2. All sounds were played through headphones (BOSE OE Audio Headphones, 2006) using iTunes (Apple, 2010) on an iMac (Apple, 2007).

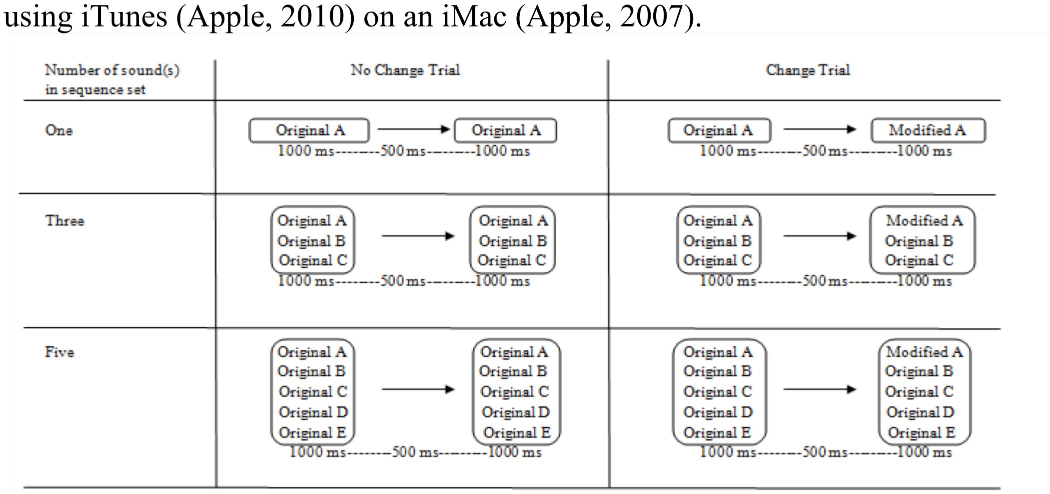

Figure 1. The stimuli for no change and change trials shown for each scene size. For both trial types, sequence set 1 and sequence set 2 were separated by 500 milliseconds of silence. Each letter (A, B, C, D & E) indicates one of the ten sounds used, which was either the original sound or a modified version of the original sound (modified in pitch or loudness).

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C. Procedure

Participants were tested individually in a quiet room by one experimenter. First, participants completed a hearing test, which took approximately five minutes. Next, participants were told that they would be listening to changes in pitch or loudness, were read definitions of pitch and loudness, and were played examples of each through their headphones. Participants were allowed to listen to these examples as many times as they wanted, but most chose to listen to the examples one or two times.

Subjects then completed three tasks: a change detection task, an object-encoding task, and a sound identification task. The change detection task had three within-subject independent variables; auditory scene size (one, three, five sounds), sound familiarity (common, uncommon), and trial type (change, no change). Half of all of the trials consisted of common sounds and half consisted of uncommon sounds. The common and uncommon sounds were never mixed in trials. The change detection task contained an equal number of each of the scene sizes, common and uncommon sounds, and change and no change trials. Within the change trials, there were an equal number of pitch change trials and loudness change trials. The change detection task consisted of four sessions with 60 trials per session.

There was one between-subjects independent variable: trial order. The order in which the scene size of three trials were presented was different for each participant. There were ten combinations of common sounds with a scene size of three, only five (e.g. common group 1) of them were chosen for two of the orders (e.g. Order A and Order B). The second group of five common sounds with a scene size of three (e.g. common group 2) were used in two different orders (e.g. Order C and Order D). The same was true for the uncommon sounds. This created four different orders (Order A, Order B, Order C, and Order D). Six participants were randomly assigned to each of the four orders.

Before the change detection task began, participants were instructed to listen to sequence set 1 and sequence set 2 and note if they heard any change in loudness or pitch. If they heard a change they were told to say “change” out loud and if they did not hear a change they were told to say “no change” out loud. Each sequence set was only played once. After the participant made their decision, they would be given feedback on whether they were correct or incorrect. Then the next trial would immediately begin. Participants were allowed to take a one to two minute break between sessions. The 240 trials took approximately 40 minutes.

Next, participants completed an object-encoding task. In this task, participants listened to only unmodified sounds, each lasting one second. Common and uncommon sounds were never mixed. The participants were told that they would hear two sounds labeled “Sound A” and “Sound B.” Then they would hear another sound that was one of the first two sounds that they heard. They were instructed to reply with whether the third sound was the first sound they heard (“Sound A”) or the second sound they heard (“Sound B”). Feedback was given after each trial. In half of the trials, the correct answer was Sound A and in the other half the correct answer was Sound B. The twenty trials took approximately 10 minutes.

Participants then completed the sound identification task. Participants heard a one-second sound and identified the source of the sound. The experimenter would give feedback on whether they were correct or incorrect and would give the correct answer if incorrect. This task took approximately three minutes.

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Finally, participants completed a one-page survey, which took approximately five minutes. The first portion of the survey included questions on whether it was easier to detect a change in pitch or loudness, whether it was easier to detect changes in uncommon vs. common sounds, and whether it became harder to detect a difference as the scene size increased. The last part of the survey focused on the test sounds and how familiar a participant may be with each sound (e.g. "Do you set an alarm clock everyday?"). The entire experiment took approximately one hour for each participant to complete.

III. RESULTS

A. Change Detection

1. Change vs. No Change Trials

Figure 2 shows performance accuracy on no change vs. change trials with common and uncommon sounds with scene sizes of one, three, and five. To determine whether participants performed significantly above chance in each condition, t-tests were performed comparing the condition mean against a value of 0.50. All scene size (1, 3, 5) by familiarity (common, uncommon) by trial type (change, no change) combinations were significantly above chance except a scene size of 5 with uncommon sounds on change trials (M = 55.8, SD = 15.0), $t(23) = 1.9$, p >.05.

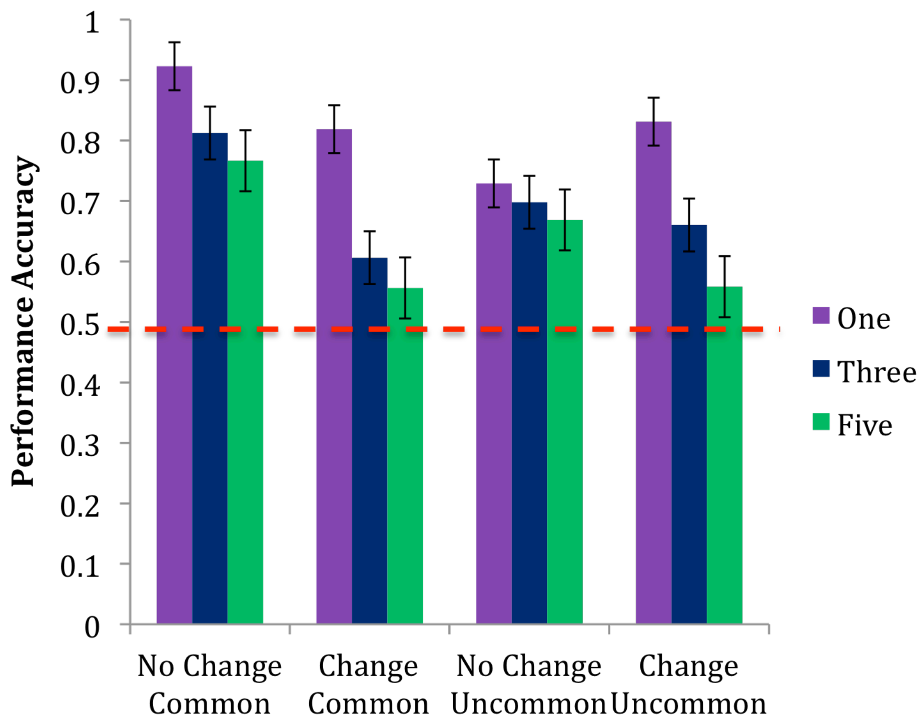

Figure 2. Participants' performance accuracy in change and no change trials with common and uncommon sounds shown for scene sizes of one, three, and five. Chance choice accuracy (50%) is shown by the dotted line.

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A 4 (order: A, B, C, D) x 3 (scene size: 1, 3, 5) x 2 (familiarity: common, uncommon) x 2 (trial type: change, no change) analysis of variance (ANOVA) was conducted on the proportion of correct answers made by participants with the last three variables as repeated measures. There was a significant main effect of scene size, $F(2, 40) = 121.1$, $p < .001$. Post hoc analyses revealed that as scene size increased, choice accuracy decreased (Newman-Keuls, $p < .05$). Choice accuracy for a scene size of one ($M = 82.6\%$) was significantly higher than accuracy for scene sizes of three ($M = 69.4\%$) or five ($M = 63.8\%$). Performance for a scene size of five was significantly lower than performance for a scene size of three. There was also a significant main effect of familiarity, $F(1,20) = 22.7$, $p < .001$. Choice accuracy with common sounds ($M = 74.7\%$) was significantly higher than with uncommon sounds ($M = 69.1\%$).

There was a significant main effect of trial type, $F(1, 20) = 13.9$, $p < .01$, with two significant interaction effects of scene size by trial type, $F(2, 40) = 15.4$, $p < .001$, and familiarity by trial type, $F(1,20) = 10.6$, $p < .01$. With a scene size of one, there was no significant difference in performance on change trials ($M = 82.5\%$) vs. no change trials ($M = 82.6\%$). With a scene size of three, there was a significant difference in performance between no change ($M = 75.5\%$) and change trials ($M = 63.3\%$). For a scene size of five, there was also a significant difference in performance between no change trials ($M = 71.7\%$) and change trials ($M = 55.7\%$). For common sounds, choice accuracy with no change ($M = 83.4\%$) trials was significantly higher than change trials ($M = 66.0\%$). For uncommon sounds, there was no significant difference in choice accuracy between no change trials ($M = 69.9\%$) and change trials ($M = 68.3\%$).

2. Pitch vs. Loudness Changes

Figure 3 shows performance accuracy for only change trials (pitch and loudness changes) with common and uncommon sounds with scene sizes one, three and five. To determine whether participants performed significantly above chance in each condition, t-tests were performed comparing the condition mean against a value of 0.50. All scene size (1, 3, 5) by familiarity (common, uncommon) by auditory feature (pitch, loudness) combinations were significantly above chance except in four cases. The performance mean of a scene size of three with uncommon sounds with changes in loudness were not significantly different from chance ($M = 56.7$, $SD = 23.5$), $t(23) = 1.4$, $p > .05$. The performance mean of a scene size of five with uncommon sounds with changes in loudness was not significantly different from chance ($M = 47.1$, $SD = 22.4$), $t(23) = -0.6$, $p > .05$. The performance mean of a scene size of three with common sounds with changes in loudness was not significantly different from chance ($M = 43.3$, $SD = 14.0$), $t(23) = -2.32$, $p > .05$. The performance mean of a scene size of five with common sounds with changes in loudness was not significantly different from chance ($M = 38.8$, $SD = 18.5$), $t(23) = -2.98$, $p > .05$.

A 4 (order: A, B, C, D) x 3 (scene size: 1, 3, 5) x 2 (familiarity: common, uncommon) x 2 (auditory feature: pitch, loudness) analysis of variance (ANOVA) was conducted on the proportion of correct answers made by participants with the last three variables as repeated measures. There was a significant main effect of auditory feature, $F(1, 20) = 112.2$, $p < .001$, and a significant interaction effect of familiarity by auditory feature, $F(1, 20) = 8.9$, $p < .01$. Overall, it was significantly easier to detect a pitch change ($M = 80.8\%$; Newman-Keuls tests, $p < .05$) than a loudness change ($M = 53.5\%$). For

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pitch change trials, there was no significant difference in performance between detecting a change in common sounds (*M* = 82.5%) and detecting a change in uncommon sounds (*M* = 79.2%). For loudness change trials, there was a significant difference in performance between detecting a change in common sounds (*M* = 49.6%) than detecting a change with uncommon sounds (*M* = 57.5%; Newman-Keuls, $p < .05$).

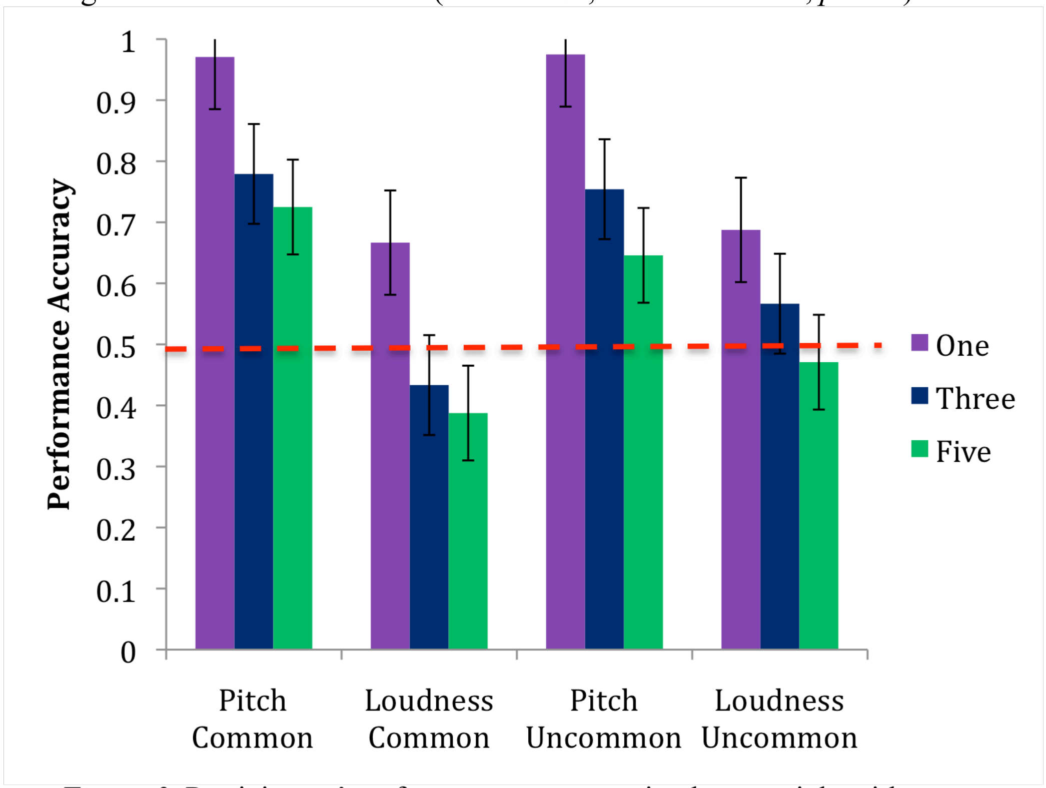

Figure 3. Participants' performance accuracy in change trials with common and uncommon sounds shown for scene sizes of one, three, and five. In change trials, one sound changed in either pitch or loudness. Chance choice accuracy (50%) is shown by the dotted line.

B. Object Encoding

Participants correctly encoded auditory objects during this task (*M* = 99.2%). Twenty participants correctly matched sounds on all trials. Four participants each made only one error in the twenty trials.

C. Sound Identification

Participants were able to correctly identify the common sounds (*M* = 98.3%), but few were able to correctly identify the uncommon sounds (*M* = 7.5%). Of the common sounds, all participants were able to identify the alarm clock, birds chirping, cow mooing, and keyboard typing. Two of the participants incorrectly identified the bicycle bell as a telephone or a cash register. Of the uncommon sounds, no participants were able to correctly identify the alligator hissing, coffin lid being slid shut, and the ice skater passing by. One participant was able to correctly identify the science fiction laser and several participants (33.0%) were able to correctly identify the magical burst.

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D. Post-Experimental Survey

Eighteen participants (75.0%) reported pitch changes to be easier to detect than a loudness change, two participants reported loudness changes (8.3%) to be easier to detect than pitch changes, and four participants (16.7%) thought that detecting a change in pitch and loudness were equally easy. Ten participants (41.7%) thought that it was easier to detect a change with common sounds, three participants (12.5%) thought that it was easier to detect a change with uncommon sounds and 11 participants (45.8%) thought that their ability to detect a change with uncommon sounds and common sounds was equal. All participants reported that it became increasingly difficult to detect a change when the scene size increased from one to three to five sounds. Of the common sounds, participants were most familiar with an alarm clock, birds chirping, and typing on a keyboard. Of the uncommon sounds, participants were most familiar with an ice skater passing by and a sci-fi laser ray.

IV. DISCUSSION

The participants were often unable to detect changes in a sound sequence in the change detection task even though they were nearly perfect at differentiating between the ten sounds in the object-encoding task. The participants were better at detecting a change in a sound sequence of common sounds vs. uncommon sounds. As scene size increased from one sound to three sounds to five sounds, participants found it increasingly difficult to detect a change. Participants were better at detecting a pitch change than a loudness change.

Participants in the current study were better at detecting changes in common sounds rather than uncommon sounds, like participants in McFadden and Callaway's (1999) study. Similar to other studies, as scene size increased, it became increasingly difficult for participants in this study to detect a change (Eramudugolla et al., 2005; McAnally et al., 2010). The results of this experiment were different than Gregg and Samuel's (2008) results. Gregg and Samuel (2008) found that familiarizing participants with the sounds used in their study did not have an effect on the participants' ability to detect a change. The participants were familiarized with the sounds on the first day of the experiment and tested on another day. In the current experiment, participants were significantly better at detecting changes in common and familiar sounds. Instead of pre-exposing participants to certain sounds, in this experiment the participant's past experiences determined the familiarity of the sounds. For example, typing on a keyboard was a common sound because the participants complete this task every day.

Our ability to perceive how sounds change depends on the number of sounds we hear at once, the properties of sounds that change (e.g. loudness, pitch), and the familiarity of the sounds. Change deafness and change blindness show that across multiple sensory systems, we only remember the gist of the scene, not necessarily all the details. Participants were able to detect a pitch change in this study because they perceived that a pitch change altered the gist of the auditory scene whereas a loudness change did not. In conclusion, this study demonstrates that we are not always able to detect a change in a single sound between two auditory sequences.

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