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Auditory Memory Distortion for Spoken Prose

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Abstract

Observers often remember a scene as containing information that was not presented but that would have likely been located just beyond the observed boundaries of the scene. This effect is called *boundary extension* (BE; e.g., Intraub & Richardson, 1989). Previous studies have observed BE in memory for visual and haptic stimuli, and the present experiments examined whether BE occurred in memory for auditory stimuli (prose, music). Experiments 1 and 2 varied the amount of auditory content to be remembered. BE was not observed, but when auditory targets contained more content, boundary restriction (BR) occurred. Experiment 3 presented auditory stimuli with less content and BR also occurred. In Experiment 4, white noise was added to stimuli with less content to equalize the durations of auditory stimuli, and BR still occurred. Experiments 5 and 6 presented trained stories and popular music, and BR still occurred. This latter finding ruled out the hypothesis that the lack of BE in Experiments 1–4 reflected a lack of familiarity with the stimuli. Overall, memory for auditory content exhibited BR rather than BE, and this pattern was stronger if auditory stimuli contained more content. Implications for the understanding of general perceptual processing and directions for future research are discussed.

Keywords

boundary extension; central tendency; boundary restriction; attention; audition

Memory for visual or haptic scenes often exhibits extended boundaries, that is, observers remember those scenes as including information that might have been present just beyond the boundaries of the scene but that was not actually perceived. This has been referred to as *boundary extension* (BE; e.g., Intraub, 2004; Intraub, Bender, & Mangels, 1992; Intraub & Richardson, 1989; for review, see Hubbard, Hutchison, & Courtney, 2010). Hypotheses of

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BE typically stress the role of spatial continuity in BE (e.g., DeLucia & Maldia, 2006; Gottesman & Intraub, 2002, 2003; Intraub et al., 1992; Intraub, Gottesman, & Bills, 1998; Munger, Owens, & Conway, 2005), but whether a similar type of distortion might exist in memory for a stimulus dimension, such as audition, that is often considered more temporal than spatial has not been considered. If BE is specifically a property of spatial perception, then one would not necessarily expect it to occur in the auditory domain. However, if BE is a more generalized property of object/ scene perception (cf. O'Callaghan, 2008, regarding auditory objects), one would expect to find auditory BE as a function of memory distortion across time, much as visual BE is a function of memory distortion across space.

Intraub and Richardson (1989) provided the initial demonstration of BE. In one experiment, participants were presented with a set of target pictures followed by a recall task in which participants were asked to draw the target pictures as they recalled them. Boundaries were extended outward on 95% of the drawings. In a second experiment, participants were initially presented with a set of target pictures including both close-up (i.e., focused on a central object with little periphery in view) and wide-angle scenes (i.e., focused on a central object but with a wide expanse of periphery in view). Subsequently, participants were shown test pictures that included a close-up or wide-angle test scene corresponding to each target, and they were required to indicate on a 5-point scale whether probe pictures of target scenes were much closer-up (−2), a little closer-up (−1), the same (0), a little farther away (+ 1), or a lot farther away (+ 2) than they were in the target pictures. Participants more frequently rated the probe pictures as "closer-up" rather than "farther away" for both kinds of scenes. An effect of BE was observed in this recognition task, as well as in a recall task in which participants were asked to draw the scenes that had been presented to them. For both tasks, there was a larger effect of BE for the close-up scenes (see also Bertamini, Jones, Spooner, & Hecht, 2005). Indeed, probe pictures with extended boundaries were often mistaken for the target pictures.

One of the most common findings in the visual BE literature is that memory for close-up views exhibits larger BE than does memory for wide-angle views. For example, when participants' memories for close-up, prototypic (or mid-range), and wide-angle pictures were tested, Intraub et al. (1992) found that close-up views resulted in the largest BE in recognition tasks (cf. Intraub & Richardson, 1989, Experiment 2), followed by prototypical views; wide-angle views either showed only slight directional distortion or no distortion. Intraub and Berkowits (1996) found BE both with a recognition task using a rating scale and with a recall task in which participants were asked to recreate the picture they had seen by sketching it on paper. In the recognition task, BE was largest for close-up stimuli but still occurred for prototypic and wide-angle stimuli. In the recall task, BE similarly occurred for close-up and prototypic stimuli; however, there was no evidence of BE for wide-angle views (for similar results, see also Intraub, Gottesman, Willey, & Zuk, 1996). If BE occurs in memory for auditory stimuli, then an auditory stimulus more analogous to a close-up view (i.e., containing relatively little content/information, thus requiring more extrapolation to obtain information regarding the broader landscape) would be expected to exhibit more BE than would an auditory stimulus analogous to a wide-angle view (i.e., containing relatively large amounts of content/information, thus requiring less extrapolation to obtain information regarding the broader landscape).

The notion of auditory BE makes the clear prediction that memory for an auditory stimulus should include more information (i.e., information that might have been presented just before or just after the actual stimulus) than was actually presented. However, other theoretical frameworks make different predictions (see Table 1). One such alternative framework involves a shift toward central tendency, and there are at least two possible types of such a shift. The first type of central tendency shift involves memory averaging, in which details of memory representations are distorted toward the mean of some aspect of stimulus presentation (e.g., see Chase, 1986; Posner & Keele, 1968, 1970). The second type of central tendency shift involves *time order error* effects (TOE; Fechner, 1860, 1882), in which a probe stimulus is judged as more extreme in duration than the target stimulus (e.g., if both stimuli are short, the probe stimulus is judged as shorter; if both stimuli are long, the probe stimulus is judged as longer; see Tse, Intriligator, Rivest, & Cavanagh, 2004). The mechanism behind TOE is not completely understood, but it occurs across such a variety of stimulus dimensions (see Hellström, 1985) that it is probably a function of how perceptual judgments are made (cf. Tse et al., 2004). A second alternative framework involves boundary restriction (BR) similar to that typically observed after a time-delay with wide-angle visual stimuli (e.g., see Intraub et al., 1992). In BR, boundaries are thus restricted in memory such that less content is remembered than was actually presented.

We examined whether memory for auditory prose and music exhibits BE, and we evaluated the alternative frameworks of central tendency and BR. Given that BE in the visual and haptic domains is thought to depend upon the existence of a scene (Bertamini et al., 2005; Gottesman & Intraub, 2002, 2003; Intraub et al., 1998; Legault & Standing, 1992; but see Hubbard, 1996), BE in the auditory domain might similarly depend upon the existence of a scene. Bregman (1990) suggested that music and speech offer appropriate contextual material for the analysis of auditory scenes. Auditory scenes can take many forms such as a complex landscape of violins, oboes, and trumpets, the cacophony of an opera, or a heated conversation. Auditory scenes can also be simple, such as a sine wave or a spoken soliloquy.

We sought to minimize the complexity of the stimuli in Experiments 1–4 by utilizing auditory spoken text excerpted from a wide range of sources in English language literature (originals or translations). As all participants would presumably have experience with speech and spoken text, this guaranteed some level of generalizability. Because one's explicit familiarity with a particular scene could potentially affect one's experience and recall of a scene and its boundaries (cf. Glanzer & Razel, 1974; but see Intraub, Daniels, Horowitz, & Wolfe, 2008), participants in Experiment 5 were familiarized with passages of spoken stories that had been written specifically for the experiment; these stories were subsequently used as stimuli to assess boundary distortion under conditions of high levels of stimulus familiarity. Finally, because music is a continuous, flowing landscape and might be more likely than language to elicit extension at its artificially curtailed boundaries (cf. Gottesman & Intraub, 2002, regarding the nature of scenes eliciting BE), we utilized popular music excerpts in the assessment of boundary distortion in Experiment 6. For purposes of discussion, the term "stimulus content" henceforth refers to a grouping of words or notes presented as a single stimulus unit. More content thus means that more words or notes were presented and less content means that fewer words or notes were presented (see Method section for further details).

Given that BE involves an incorporation of additional material, it is necessary to distinguish between BE and estimates of greater length or duration. Duration of auditory stimuli has been extensively studied (e.g., Jones, Boltz, & Klein, 1993; Wearden, Todd, & Jones, 2006), but BE for auditory stimuli has not been studied. In both BE and duration tasks, a target excerpt is presented, followed by a brief delay interval, and then a probe excerpt is presented. In both tasks, participants are asked to determine whether the second auditory excerpt is different from the first auditory excerpt. However, in a duration-estimation study, the goal is to assess memory for the duration of the excerpt (i.e., were the excerpts of the same duration?), whereas in a BE study, the goal is to assess memory for the content of the excerpt (i.e., did the excerpts have the same content?). Thus, the participant's task in the present experiments was to compare the stimulus content of the target and probe excerpts.

In the present experiments, we adapted methodology involving the use of wide-angle, prototypical, and close-up pictures as targets and probes (Intraub et al., 1992). In the auditory domain, these may be considered analogous to target passages containing more-content, mid-content, or less-content, respectively. On each trial subjects listened to a target passage. After a delay, a probe passage was presented, and participants compared the amount of probe stimulus content with that of target stimulus content. Participants were also asked to make tempo judgments so that we could assess the extent to which perceived temporal variation played a role in stimulus content judgments.

In Experiment 1 we focused on comparisons using mid-content and more-content auditory prose stimuli, and in Experiment 2 we focused on comparisons using less-content and mid-content auditory prose stimuli. By constraining the stimulus sets in this manner, the possibility of a convergence about mid-content stimuli due to a normalization or regression was minimized. Experiment 3 was similar to Experiment 2 except that it incorporated different less-content stimulus lengths, and Experiment 4 included white noise to standardize stimulus durations from Experiment 3. Experiment 5 used a training paradigm to assess whether stimulus familiarity impacted distortions in memory for target content using spoken prose stimuli, and Experiment 6 made a similar assessment using previously learned, popular music stimuli.

BE occurs when probes that are identical to the initial target are rated as closer (for pictures; e.g., Intraub et al., 1992; Intraub & Richardson, 1989) and as having less content (for auditory stimuli). Accordingly, a preference for judging probes as containing less content than their associated target excerpts across all stimulus types would support BE in the auditory domain (as greater extension of boundaries would be expected for less-content stimuli due to a greater need for extrapolation; cf. Intraub et al., 1992, Experiments 1 and 2). Alternatively, a preference for judging probes as containing more content than their associated target excerpts for more-content stimuli, and judging probes as containing less content than their associated target excerpts for less-content stimuli would be consistent with a central tendency process. A preference for judging probes as having more content than their associated target excerpts across all stimulus types would suggest BR in the auditory domain.

Experiment 1

In Experiment 1 we examined auditory memory distortions for mid-content and more-content auditory stimulus scenes using a recognition task. An auditory target was presented, and then after a brief delay, a probe was presented, and participants compared the probe to their memory of the target. If auditory BE occurs in memory for spoken prose, then participants should rate probes that are identical to the targets as containing less stimulus content (i.e., fewer words). If a distortion based on central tendency (such as memory averaging or TOE) occurs, then participants should rate probes for more-content targets as containing less stimulus content and rate probes for less-content targets as containing more stimulus content. If auditory BR occurs in memory for spoken prose, then participants should rate probes that are identical to the targets as containing more stimulus content (i.e., more words) than their associated targets.

Method

Participants—The participants were 35 undergraduates at Texas Christian University (TCU) who received partial course credit in a psychology course in return for their participation in the experiment, which was approved by TCU's Institutional Review Board (IRB). Data from four other participants were excluded from the analyses, two because of

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difficulty concentrating on the task and two because of confusion regarding the experimental procedure. All participants reported normal hearing.

Apparatus—Stimuli were recorded with a Samson C01U-USB studio condenser microphone connected to a Dell Inspiron 5150 notebook computer with a Windows XP platform. The microphone was attached to a Samson SP01 spider mount and then attached to a small tabletop microphone stand. Recordings were acquired using the Cakewalk Sonar Studio 3.0 software package using the right portion of the microphone only (to eliminate sound distortions), and then the tracks were exported as stereo MP3s with identical information in the left and the right auditory channels. MP3s were imported into the Audacity editing program, edited to the desired length, and then exported back out of Audacity in MP3 format as finished stimuli.

Stimuli were presented using two identical Compaq Pentium IV personal computers with the Microsoft Windows XP computing environment, using Microsoft PowerPoint as the stimulus presentation package. The sound level of the stimuli was approximately 57 dB (a comfortable sound level that was neither too soft nor too loud for the participants), as determined by a Radio Shack Digital Sound Level Meter (Cat. No. 33-2055). Koss UR-15C headphones were used as the vehicle of stimulus presentation; a built-in pad encircled the speakers such that outside noises were dampened and comfort was maximized.

Stimuli and response materials

Stimuli: Stimuli were taken from English-language literature, either original English or translations, one stimulus per author, written over a range of dates. Most of the stimuli were gathered from *The Online Literature Library* (http://www.literature.org/authors/; for a full listing of the authors, dates, literature works, and the sources from which the works were obtained, see Appendix A). The spoken stimuli were recorded separately by a male voice and by a female voice. Presentation of male and female versions of each stimulus was counterbalanced across participants, with each participant receiving half of the stimuli in a male voice and the other half of the stimuli in a female voice. Musical stimuli were also presented but their presentation did not affect literature stimulus ratings; these data are reported separately.

Recordings of the female voice were originally made in 1-min excerpts but were later edited to between 9 s and 22 s in duration for more-content stimuli ($M = 13.8$ s, $SD = 3.1$ s), between 7 s and 14 s in duration for mid-content stimuli ($M = 10.1$ s, $SD = 2.3$ s), and between 4 s and 10 s in duration for less-content stimuli ($M = 6.2$ s, $SD = 1.6$ s) using the Audacity editing program; all stimuli were generated in more-, mid-, and less-content versions. Pilot testing had indicated that these stimulus durations contained enough content for the participants to hear meaningful information yet were succinct enough to keep the experiment within a reasonable duration. The more-content stimuli became the basis from which the mid-content stimuli were created, and the mid-content stimuli became the basis from which the less-content stimuli were created. In editing down the more-content stimuli to obtain the mid-content stimuli (and in editing the mid-content stimuli to obtain the less-content stimuli), content in the form of whole words was removed from both the beginning and end of the excerpt. Meaningfulness of stimulus content was considered more important than exact stimulus duration; pilot studies had indicated that stimulus content and relative stimulus duration were of greater importance than exact stimulus duration. Edited stimuli, although they did contain natural boundaries to some extent, did sound somewhat “cut off,” as they maintained inflections and coarticulations from the original recordings. Because object completion does not affect BE for visual scenes (e.g., Intraub et al., 1992), this quality of truncation should not be problematic for determining whether auditory BE exists. In fact, it is possible that the naturalistic nature of such quotes could have enhanced the auditory scenic nature of the stimuli, making BE a theoretically more likely possibility (cf. Intraub et al., 1998).

After the female-voice tracks were complete, the male-voice tracks were recorded using the excerpts retained from the female-voice recordings. In an effort to maintain the same continuity and flow as that of the female speaker, the male speaker started reading slightly before and ended reading slightly after the excerpt intended for retention, and then the male excerpts were edited to match the female excerpts based on content. Although the durations of the male-voice and female-voice excerpts were similar, they were not identical; for the male reader, more-content stimuli were 11 s to 24 s in duration ($M = 16.5$ s, $SD = 3.7$ s), mid-content stimuli were 8 s to 19 s in duration ($M = 12.1$ s, $SD = 2.9$ s), and less-content stimuli were 4 s to 12 s in duration ($M = 7.5$ s, $SD = 2.0$ s). Because pilot studies indicated no significant differences between responses to the male-voice excerpts and female-voice excerpts, generating stimuli that were exactly the same duration was not attempted.

One target/probe pairing was presented on each trial. The same content was used for the target and probe, and each excerpt was used on only one trial for each participant. Only more- and mid-content stimuli were used in Experiment 1. There were four possible configurations of the target and the probe in Experiment 1: mid-content/mid-content (mid/mid), more-content/mid-content (more/mid), mid-content/more-content (mid/more), or more-content/more-content (more/more). The mid/mid condition and more/more condition are referred to as *matching* conditions, and the mid/more condition and more/mid condition are referred to as *nonmatching* conditions. Thus, on each trial the participant heard either (a) identical content between the target and the probe in the matching conditions or (b) highly similar content in the nonmatching conditions (i.e., content was either added to both the beginning and end of the excerpt or removed from both the beginning and end of the excerpt when comparing probe to target content). Each participant received 36 trials (nine examples of each of the four configurations), and order of stimulus presentation was randomized.

Response materials: Participants used a 5-point scale (−2, −1, 0, +1, +2) to make two judgments per target/probe pair (cf. Intraub et al., 1992; Intraub & Richardson, 1989); they were to indicate both the perceived content of the probe compared with the target (labeled with −2 representing much less content, 0 representing the same amount of content, and +2 representing much more content) and the perceived tempo/speed of the probe compared with the target (labeled with −2 representing much slower tempo, 0 representing same tempo, and +2 representing much faster tempo), although tempo was not manipulated. Use of the 5-point scale in judgment of stimulus content provided simplicity and the benefit of a methodological replication of studies on visual BE (cf. Intraub et al., 1992). Response sheets were provided such that participants could indicate the values that best reflected their memory of the target/stimulus relationship.

Procedure—Each participant received instructions via the computer, with a recorded voice reading aloud instructions that were printed on the screen, and was presented with one example and three practice trials. Participants pressed a designated key to begin each trial. The target was presented, followed by a 7-s delay, and then the probe was presented. Participants used the provided scale to record their judgments regarding both stimulus content and tempo for each target/probe pair. Participants were explicitly instructed that stimulus content judgments were to reflect the stimulus content that they heard, regardless of tempo— specifically, were the same words presented, or were more or fewer words presented? Participants were also instructed that tempo judgments were to reflect the tempo of the probe excerpt compared with the tempo of the target excerpt, independent of stimulus content. The intertrial interval was 9 s, and the current trial number always appeared on the screen. Participants were debriefed at the conclusion of the experimental trials.

Results

Interpreting judgment results—For identically presented target/probe pairs, judgments of stimulus content less than the expected value of 0 were interpreted as consistent with BE, as the extension of boundaries of a target in memory would make an identical-length probe seem to contain fewer words (i.e., less stimulus content). Judgments of stimulus content larger than the expected value of 0 were interpreted as consistent with BR, as the restriction of boundaries of a target in memory would make an identical-length probe seem to contain more words (i.e., greater stimulus content). For nonmatching stimuli, a comparison was made between the absolute values of judgments made for most/ mid presentations and the absolute values of judgments made for mid/most presentations. A tendency toward a more exaggerated response with one comparison type compared with the other was interpreted in terms of whether the extension or restriction of boundaries was more prominent (cf. Intraub et al., 1992). Specifically, if more/mid comparisons were more negative than the mid/more comparisons were positive, this would indicate a tendency toward BE, whereas the opposite configuration of responses would indicate a stronger tendency toward BR. Analyses suggested female-voice excerpts and male-voice excerpts did not differ significantly in the responses they elicited (*p*s > .05), and so the data were collapsed across voice type.

Data analyses—We were most interested in the pattern of errors in the data. However, response patterns that were generally correct and that differed from chance in their distributions were more likely to be related to successful task performance and not simply related to a response bias induced by the task (e.g., de Blois, Novak, & Bond, 1999; Suddendorf, Nielsen, & van Gehlen, 2011). Thus, stimulus content data were initially analyzed in terms of whether response patterns differed from chance. Chi-square analyses (cf. McDonald, 2009) indicated that responding occurred at levels different from chance (*p*s < .001; see Table 2). The majority of responses were correct (overall mean accuracy = 72.54%), with values ranging from 66.67% (more/mid comparisons) to 80.00% (mid/more comparisons).

Stimulus content data were then analyzed using *t* tests to determine whether responses were directionally distorted compared with the expected value of 0 for the mid/mid and more/more comparisons. Mid/mid judgments (*M* = 0.01, *SD* = 0.24) were not significantly different from 0, *t*(34) = 0.22, *p* = .829, *d* = 0.08. More/more judgments (*M* = 0.09, *SD* = 0.25), however, were in the direction of BR, *t*(34) = 2.14, *p* = .040, *d* = 0.73; using a Bonferroni correction, the *p* value needed to reject the null hypothesis is .025, rendering this observation marginally significant. A one-way dependent-measures analysis of variance (ANOVA) was used to contrast the extent of distortion in the mid/mid and more/more conditions, and there was no significant difference, *F*(1, 34) = 2.07, *p* = .159, $\eta_p^2 = .057$.

A paired *t* test comparing mid/more (*M* = 1.08, *SD* = 0.57) and more/mid (*M* = −0.79, *SD* = 0.74) judgments showed that responding was significantly stronger in the direction of BR than in the direction of BE (*M* difference = 0.29, *SD* = 0.52), *t*(34) = 3.29, *p* = .002, *d* = 0.44; absolute values of long/mid judgments were used in this analysis to compare estimated magnitude differences (cf. Intraub et al., 2008). This result indicates that no significant directional memory distortion occurred with matching mid- or more-content stimuli, but distortion in the direction of BR was introduced with nonmatching stimuli.

Tempo data were similarly analyzed. Response patterns in the tempo data differed from chance levels of responding (all *p*s < .001). Tempo data were then analyzed using *t* tests to determine whether responses were directionally distorted compared with the expected value of 0; the expected value was 0 in all cases because tempo was not manipulated. More/more judgments ($M = 0.09$, $SD = 0.40$), $t(34) = 1.36$, $p = .183$, $d = 0.47$, mid/mid judgments ($M = 0.06$, $SD = 0.34$), $t(34) = 1.10$, $p = .281$, $d = 0.38$, and mid/more judgments ($M = 0.07$, $SD = 0.31$), $t(34) = 1.25$, $p = .219$, $d = 0.43$, indicated no directional distortion. More/mid judgments ($M = 0.20$, $SD = 0.45$) were greater than 0, $t(34) = 2.64$, $p = .013$, $d = 0.91$, indicating that probes were judged as faster than targets; using a Bonferroni correction, the p value needed to reject the null hypothesis is .003, rendering this observation marginally significant. This result was supported by a one-way repeated-measures ANOVA, indicating no significant effect of comparison type on tempo judgments, $F(3, 32) = 1.11$, $p = .360$, $\eta_p^2 = .033$.

Discussion

There was a trend in the direction of BR when stimuli involved excerpts containing greater amounts of stimulus content (mid/ more, more/mid, more/more); this trend was significant for non-matching stimulus comparisons. Taking the overall pattern of results into account, the results suggest that BR occurred, with a tendency for boundaries to be more restricted in memory for more-content, nonmatching stimuli. There was no evidence of auditory BE. Tempo judgments were not consistently related to judgments of probe stimulus content; only in the more/mid condition were probes judged as faster than their associated targets.

Stimuli with relatively more content in Experiment 1 seem more analogous to wide-angle visual stimuli than to close-up visual stimuli because they included more informational (and purportedly peripheral) content regarding the auditory scene; this idea is consistent with the trend toward restriction in memory with more/ more comparisons in Experiment 1. As noted earlier, Intraub et al. (1992) found that BE was larger for close-up views than for wide-angle views, and she suggested that this was because more extrapolation occurred with close-up views. Close-up views elicit more extrapolation than wide-angle views because they do not include peripheral information required for one to be prepared to actively engage with one’s environment. Thus, it is possible that the results of Experiment 1 were constrained by the use of stimuli containing relatively more content, negating the need for extrapolation. Experiments 2 and 3 examined this possibility by considering whether BE could be found in auditory stimuli containing less content (i.e., auditory stimuli with less surrounding context) where the need for extrapolation might be greater.

Experiment 2

Experiment 2 was similar to Experiment 1, except that the auditory stimuli were less- and mid-content stimuli (analogous to close-up and prototypical views, respectively, in Intraub et al., 1992). If auditory BE occurs, then larger BE would be expected to occur with auditory scenes containing less content (due to the greater need for extrapolation), and either smaller BE or no directional distortion would be expected to occur with mid-content auditory scenes (due to reduced extrapolation, Intraub et al., 1992). If, on the other hand, a central tendency process occurs, then the results of Experiment 2 would reflect a pattern of BE for the less-content stimuli and BR for the mid-content stimuli. Robust BR would be indicated by restriction for both less- and mid-content stimulus comparisons.

Method

Participants—Thirty-five participants with self-reported normal hearing were recruited and compensated in the same manner as in Experiment 1. Three additional participants were eliminated from the analyses because they were confused over some aspect of the experimental task. None of the participants had taken part in Experiment 1. The experimental protocol was approved by the TCU IRB.

Apparatus—The apparatus was the same as that used in Experiment 1.

Stimulus and response materials

Stimuli: Stimuli were a subset of those described in Experiment 1, including the less- and mid-content stimulus versions only, which were used as both targets and probes. As in Experiment 1, each participant received only one target/probe pairing per stimulus. One quarter of the trials represented each of the less-content/ less-content (less/less), less-content/mid-content (less/mid), mid-content/less-content (mid/less), and mid-content/mid-content (mid/mid) test conditions. Stimulus presentation was randomized.

Response materials: The response materials were the same as in Experiment 1.

Procedure—The procedure was the same as in Experiment 1 except that less- and mid-content stimuli, rather than mid-and more-content stimuli, were presented.

Results

Interpreting judgment results—Results were interpreted in the same manner as in Experiment 1. Female-voice excerpts and male-voice excerpts did not differ significantly in the responses they elicited (*p*s > .05), and so the data were collapsed across voice type. Absolute values were used in the mid/less and less/mid contrast analysis to compare estimated magnitude differences (cf. Intraub et al., 2008).

Data analyses—Stimulus content data were initially analyzed in terms of whether response patterns differed from chance. As in Experiment 1, chi-square analyses indicated that responding occurred at levels different from chance (*p*s < .001; see Table 3). The majority of responses were correct (overall mean accuracy 82.78%), with values ranging from 78.41% (mid/mid comparisons) to 88.57% (less/mid comparisons).

Stimulus content data were then analyzed using *t* tests to determine whether responses were directionally distorted compared with the expected value of 0 for the less/less and mid/mid comparisons. Less/less judgments ($M = -0.00$, $SD = 0.15$) were not significantly different from 0, $t(34) = -0.00$, $p = 1.000$, $d = 0.00$. Mid/mid judgments ($M = 0.02$, $SD = 0.18$), were also not significantly different from 0, $t(34) = 0.65$, $p = .520$, $d = 0.22$. A one-way dependent-measures ANOVA was used to contrast the extent of distortion in the mid/mid and more/more conditions, and there was no significant difference, $F(1, 34) = 0.25$, $p = .621$, $\eta_p^2 = .007$.

A paired *t* test comparing less/mid ($M = 1.39$, $SD = 0.61$) and mid/less ($M = -1.13$, $SD = 0.60$) judgments showed that responding was stronger in the direction of BR than in the direction of BE (*M* difference = 0.26, $SD = 0.38$), $t(34) = 4.08$, $p < .001$, $d = 0.43$ (as in Experiment 1, absolute values of mid/less judgments were used in this analysis). This result indicates that no directional memory distortion occurred with less- or mid-length matching target/stimulus pairings, but distortion in the direction of BR was introduced when judgments involved nonmatching target/stimulus pairings (i.e., mid/more, more/mid comparisons).

Tempo data were similarly analyzed. Response patterns in the tempo data differed from chance levels of responding (all *p*s < .001). Tempo data were analyzed using *t* tests to determine whether responses were directionally distorted compared with the expected value of 0. Mid/mid judgments ($M = -0.07$, $SD = 0.21$), $t(34) = -1.94$, $p = .060$, $d = 0.67$, less/less judgments ($M = -0.05$, $SD = 0.29$), $t(34) = -1.04$, $p = .304$, $d = 0.36$, and less/mid judgments ($M = -0.04$, $SD = 0.32$), $t(34) = -0.82$, $p = .417$, $d = 0.28$, indicated no directional distortion. Mid/less judgments ($M = 0.17$, $SD = 0.26$) were significantly greater than 0, $t(34) = 3.92$, $p < .001$, $d = 1.34$, indicating that probes were judged as faster than targets. This result was supported by a one-way repeated-measures ANOVA that indicated a significant effect of comparison type on tempo judgments, $F(3, 32) = 7.48$, $p < .001$, $\eta_p^2 = .157$.

Discussion

Consistent with the discussion of Experiment 1, there was an effect in the direction of BR for stimulus content judgments, and this pattern was most pronounced in nonmatching stimuli (i.e., less/mid and mid/less stimuli). Overall, the stimulus content data suggest BR occurs in memory for spoken prose. There was no evidence of BE. Tempo judgments were not systematically related to judgments of probe stimulus content; only in the mid/less condition were probes judged as faster than their associated targets. As was hypothesized in Experiment 1, it might be that stimuli in Experiment 2 contained too much content to evoke BE, and so a consideration of stimuli containing less content than those used in Experiments 1 and 2 might be more likely to evoke BE in the auditory domain. Additionally, the results of Experiments 1 and 2 suggest that nonmatching stimulus presentation might be an important factor in BE and/or BR.

Experiment 3

We hypothesized that if auditory BE occurred, it would most likely do so with less-content (and analogously more close-up) probes because of a tendency for participants to fill in the periphery of the auditory scene. Although it might be argued that the less-content auditory stimuli are not perceived as being “closer,” Bertamini et al. (2005) demonstrated that BE is not due to object magnification (or closeness) per se; rather, BE seems to be related to missing information peripheral to the visible scene (cf. Intraub et al., 1992; see also Hochberg, 1986). Excerpts with less content might be perceived as having a greater amount of potentially useful information beyond their boundaries, resulting in larger auditory BE. In this view, the less-content excerpts in Experiments 1 and 2 did not result in BE because the less-content stimuli still contained too much content. Accordingly, Experiment 3 was similar to Experiment 2, except that the less-content auditory stimuli were broken into three less-content stimulus subtypes, with two of the less-content stimulus subtypes containing less content than the less-content stimuli used in Experiment 2. This also allowed us to examine the effect of stimulus content variability on BE and BR effects.

Method

Participants—Forty-two participants with self-reported normal hearing were recruited on campus at the University of Texas at Dallas (UTD) and were compensated either via partial course credit in a psychology course or $10 per half hour of participation (for a total of $20). None of the participants had taken part in Experiment 1 or 2. The experimental protocol was approved by the UTD IRB.

Apparatus—The apparatus was the same as in Experiments 1 and 2, with the following exceptions: Stimuli were presented on two identical Dell (Dimension DM061) Celeron computers operating with a Microsoft Windows XP Professional 2002 Operating System. The stimulus presentation program E-Prime 2.0 was used to present stimuli and to record responses using the keyboard instead of a handwritten response packet.

Stimulus and response materials

Stimuli: The materials were the same less- and mid-content stimuli as those used in Experiment 2, with the exception that the less-content stimuli were edited down to three different content subtypes: less-content (l; the same as the less-content stimuli used in Experiment 2), lesser-content (ll; female voice: *M* = 4.5 s, *SD*= 1.3 s; male voice: *M* = 5.4 s, *SD* = 1.6 s), and least-content (lll; female voice: *M* = 2.5 s, *SD* = 0.8 s; male voice: *M* = 3.0 s, *SD*= 1.0 s) stimuli. The less-, lesser-, and least-content stimuli will be collectively referred to as *less-content stimuli* and *l, ll, lll stimuli* will be used to refer to the less-, lesser-, and least-content subtype versions, respectively. For each trial, if less-content stimuli were involved (i.e., in all trials except the mid/mid comparisons), only one less-content stimulus subtype was used, and equal numbers of l/ll/lll trials were presented (i.e., three of each less-content stimulus presentation subtype).

Response materials: Stickers were placed on the number keys of the keyboard, and the 2, 4, 6, 8, and 0 keys were labeled −2, −1, 0, +1, and +2, respectively, and were used for recording participant responses.

Procedure—The procedure was the same as that in Experiment 2 except for the less-content stimulus subtypes as described above.

Results

Interpreting judgment results—Results were interpreted in the same manner as in Experiments 1 and 2. Female-voice excerpts and male-voice excerpts did not differ significantly in the responses they elicited (*p*s > .05), and so the data were collapsed across voice type. Absolute values were used in the mid/less and less/mid contrast analyses to compare estimated magnitude differences (cf. Intraub et al., 2008).

Data analyses—Stimulus content data were initially analyzed in terms of whether response patterns differed from chance. As in Experiment 1, chi-square analyses indicated that responding occurred at levels different from chance (*p*s < . 001; see Table 4). The majority of responses were correct (overall mean accuracy = 87.50%), with values ranging from 77.51% (mid/mid comparisons) to 91.80% (less/less comparisons). Due to space constraints, the data for the different less stimulus subtypes are not shown in Table 4; however, the same pattern held for all comparison types, with all less stimulus subtypes (*all ps* < .001).

Stimulus content data were then analyzed using *t* tests to determine whether responses were directionally distorted compared with the expected value of 0 for the less/less and mid/mid comparisons. Overall, less/less judgments (*M* = 0.01, *SD* = 0.09) were not significantly different from 0, *t*(41) = 0.93, *p* = .358, *d*= 0.29. Broken down by lesser stimulus subtypes, there was not a significant pattern of directional distortion in responding: l, *M*= 0.05, *SD* = 0.19, *t*(41) = 1.64, *p* = .110, *d* = 0.51; ll, *M* = 0.02, *SD* = 0.19, *t*(41) = 0.53, *p* = .599, *d* = 0.17; lll, *M* = −0.03, *SD* = 0.15, *t*(41) = −1.23,*p* = .227, *d* = 0.38. Mid/mid judgments (*M* = 0.10, *SD* = 0.19) were significantly in the direction of BR, *t*(41) = 3.42, *p* = .001, *d* = 1.07. A one-way dependent-measures ANOVA showed a larger distortion in the mid/mid than the less/less conditions, *F*(1, 41) = 8.18, *p* = .007, $\eta_p^2=.166$.

A paired *t* test comparing less/mid (*M* = 1.64, *SD* = 0.66) and mid/less (*M* = −1.44, *SD* = 0.65) judgments showed that responding was stronger in the direction of BR than in the direction of BE (*M* difference = 0.20, *SD* = 0.43), *t*(41) = 3.06, *p* = .004, *d*= 0.31 (as in Experiments 1 and 2, absolute values of mid/less judgments were used in this analysis). This relationship was only significant for the l stimuli (*M* difference = 0.39, *SD* = 0.65), *t*(40) =

3.79, $p < .001$, $d = 0.52$; ll, *M* difference = 0.12, $SD = 0.60$, $t(41) = 1.25$, $p = .220$, $d = 0.15$; lll, *M* difference = 0.13, $SD = 0.52$, $t(41) = 1.60$, $p = .118$, $d = 0.18$. This result indicates that directional memory distortion occurred in the direction of BR with the mid-content stimuli in the overall stimulus set (i.e., l and mid-content stimuli) and with nonmatching target/probe pairings (i.e., less/mid, mid/less comparisons). In contrast to Experiments 1 and 2, the BR effect was evident even when the stimuli with relatively more content were presented as matching comparisons. The results supported the hypothesis that this enhanced BR effect was due to the greater variability of stimulus lengths presented in Experiment 3.

Tempo data were similarly analyzed. Response patterns in the tempo data differed from chance levels of responding (all *p*s < .001). Tempo data were analyzed using *t* tests to determine whether responses were directionally distorted compared with the expected value of 0. Mid/mid judgments ($M = -0.04$, $SD = 0.31$), $t(41) = -0.85$, $p = .399$, $d = 0.27$; less/less judgments ($M = 0.03$, $SD = 0.22$), $t(41) = 0.94$, $p = .352$, $d = 0.29$; less/mid ($M = 0.05$, $SD = 0.35$), $t(41) = 0.90$, $p = .375$, $d = 0.28$; and mid/less judgments ($M = 0.07$, $SD = 0.26$), $t(41) = 1.69$, $p = .099$, $d = 0.53$, indicated no significant directional distortion. A one-way repeated-measures ANOVA indicated no significant effect of comparison type on tempo judgments, $F(3, 39) = 1.43$, $p = .248$, $\eta_p^2 = .032$.

Discussion

Judgments in the direction of BR occurred for mid/mid and nonmatching stimulus comparisons. No significant memory distortion occurred in the tempo judgment data. There was no significant evidence of auditory BE for any of the stimuli. If auditory BE was related to the information potentially available beyond the boundary of the stimulus, then curtailing information within the auditory scene itself (i.e., when less-content targets were presented) should have increased the reliance on information potentially available beyond the boundary and thus should have been sufficient to produce BE. The overall data pattern from Experiment 3 is most consistent with BR in the memory for spoken prose.

Experiment 4

It is possible that the pattern of results in Experiments 1–3 resulted from the concurrence of stimulus content and overall stimulus duration. To examine this possibility, we standardized overall perceptual stimulus duration (i.e., the actual amount of time that sound was presented for each stimulus) by adding in white noise at the beginning and end of all stimuli from Experiment 3. This ensured that the total duration of each excerpt remained constant across all of the excerpts. If the pattern of results is the same as that of Experiment 3, we can be more confident that BR occurs in auditory memory based upon stimulus content and not simply perceptual duration variability, and we can thus be more certain about our conclusions regarding distortions in auditory memory.

Method

Participants—Fifty-four participants with self-reported normal hearing were recruited on campus at UTD and were compensated via partial course credit in a psychology course. None of the participants had taken part in Experiments 1–3. The experimental protocol was approved by the UTD IRB.

Apparatus and response materials—The apparatus and response materials were the same as those used in Experiment 3.

Stimuli—The materials were the same less- and mid-content literature stimuli as those used in Experiment 3, with the exception that white noise was added equally to the beginning and the end of each stimulus to achieve the following text-plus-noise stimulus durations, which were identical for both male and female voices: mid-content, 20 s; less (l), 14 s; lesser (ll), 11s; and least (lll), 8 s. Again, for each trial, if less-content stimuli were involved (i.e., in all trials except the mid/mid comparisons), only one less-content stimulus subtype was used, and equal numbers of l/ll/lll trials were presented (three of each less-content stimulus presentation subtype).

Procedure—The procedure was the same as that in Experiment 3 except that white noise was added to the beginning and end of the stimuli as described above.[1]

Results

Interpreting judgment results—Results were interpreted in the same manner as in Experiments 1 through 3. Female-voice excerpts and male-voice excerpts did not differ significantly in the responses they elicited (*p*s > .05), and so the data were collapsed across voice type. Absolute values were used in the mid/less and less/mid contrast analyses to compare estimated magnitude differences (cf. Intraub et al., 2008).

Data analyses—Stimulus content data were initially analyzed in terms of whether response patterns differed from chance. As in Experiment 1, chi-square analyses indicated that responding occurred at levels different from chance (*p*s < .001; see Table 5). The majority of responses were correct (overall mean accuracy = 84.93%), with values ranging from 70.58% (mid/mid comparisons) to 93.83% (less/mid comparisons). Due to space constraints, the data for the different less-content stimulus subtypes are not shown in Table 5; however, the same pattern held for all comparison types, with all less-content stimulus subtypes (all *p*s < .001).

Stimulus content data were then analyzed using *t* tests to determine whether responses were directionally distorted compared with the expected value of 0 for the less/less and mid/mid comparisons. Overall, less/less judgments ($M = 0.07$, $SD = 0.23$) were significantly different from 0 in the direction of BR, $t(53) = 2.11$, $p = .039$, $d = 0.58$. Broken down by less-content stimulus subtype, no significant patterns of directional distortion in responding were evident in the less/less comparison judgments: l, $M = 0.10$, $SD = 0.37$, $t(53) = 1.88$, $p = .066$, $d = 0.52$; ll, $M = 0.09$, $SD = 0.42$, $t(53) = 1.56$, $p = .124$, $d = 0.43$; lll, $M = 0.02$, $SD = 0.23$, $t(53) = 0.60$, $p = .553$, $d = 0.16$. Mid/mid judgments ($M = 0.18$, $SD = 0.33$) were significantly in the direction of BR, $t(53) = 4.09$, $p < .001$, $d = 1.12$. A one-way dependent-measures ANOVA showed a larger distortion in the mid/mid than the less/less conditions, $F(1, 53) = 7.98$, $p = .007$, $\eta_p^2 = .131$.

A paired *t* test comparing less/mid ($M = 1.62$, $SD = 0.28$) and mid/less ($M = -1.33$, $SD = 0.54$) judgments showed that responding was stronger in the direction of BR than in the direction of BE (M difference = 0.29, $SD = 0.54$), $t(53) = 3.95$, $p < .001$, $d = 0.67$ (as in Experiments 1–3, absolute values of mid/less judgments were used in this analysis). This relationship was significant for all less-content stimulus subtypes: l, M difference = 0.35, $SD = 0.90$, $t(53) = 2.85$, $p = .006$, $d = 0.56$; ll, M difference = 0.28, $SD = 0.63$, $t(53) = 3.30$, $p = .002$, $d = 0.52$; lll, M difference = 0.24, $SD = 0.74$, $t(53) = 2.37$, $p = .022$, $d = 0.46$. This result indicates that directional memory distortion occurred in the direction of BR with the stimuli in the overall stimulus set containing the most content (i.e., l and mid-content

[1]Only literature stimuli were presented to participants in Experiment 4 to accommodate the longer-duration stimuli due to the addition of white noise. As presentation of musical stimuli did not affect literature stimulus ratings in Experiments 1–3 (i.e., participants completing the literature block first performed similarly to those completing the literature block second), this procedural change was not of concern.

stimuli) and with nonmatching target/probe pairings (i.e., less/mid, mid/less comparisons). Similar to Experiment 3, the BR effect was evident even when the stimuli containing relatively content were presented as matching target/probe comparisons.

Tempo data were similarly analyzed. Response patterns in the tempo data differed from chance levels of responding (all *p*s < .001). Tempo data were analyzed using *t* tests to determine whether responses were directionally distorted compared with the expected value of 0. Mid/mid judgments (*M* = 0.06, *SD* = 0.45), *t*(53) = 0.96, *p* = .339, *d* = 0.26; less/less judgments (*M* = 0.09, *SD* = 0.37), *t*(53) = 1.85, *p* = .069, *d* = 0.51; less/mid judgments (*M* = 0.12, *SD* = 0.48), *t*(53) = 1.78, *p* = .081, *d* = 0.49; and mid/less judgments (*M* = 0.06, *SD* = 0.41), *t*(53) = 1.17, *p*= .249, *d* = 0.32, did not differ significantly from 0. A one-way repeated-measures ANOVA indicated no significant effect of comparison type on tempo judgments, $F(3, 51) = 0.43$, $p = .732$, $\eta_p^2 = .008$.

Discussion

Participants’ stimulus content judgments were significantly in the direction of BR, with the strongest restriction evident for the stimuli with relatively more content. No significant memory distortion occurred in the tempo judgment data. Experiment 4 maintained the same pattern of results found in Experiments 1–3, even with the addition of white noise to the beginning and end of the stimuli and thus ensuring constant total stimulus durations. If auditory perceptual stimulation, and not stimulus content, was driving the BR effect, we would have expected the less/mid and mid/less comparison to have been washed out in Experiment 4, but responding consistent with BR was maintained. Indeed, it might be that changes in perceptual duration helped to compensate for BR, because when changes in perceptual duration were removed, BR appeared to be enhanced. The white noise could have potentially served as a frame around the stimulus, accentuating boundaries and possibly leading to more accurate judgments—that is, eliminating directional boundary distortion. However, such a pattern was not found, so even if the white noise did serve to frame the prose much like a picture, such a focus on the word boundaries did not eliminate, or even decrease, BR. There was no evidence of auditory BE for any of the spoken prose/white noise stimuli presented in Experiment 4.

Experiment 5

It is possible that the pattern of results in Experiments 1–4 was constrained by the participants’ lack of familiarity with the auditory scenes, which were stories drawn from classic English literary sources. A lack of familiarity can influence BE; for example, Munger et al. (2005) found individual differences in BE ratings to scenes at baseline versus scenes after an approach sequence, suggesting that familiarity with a scene could impact BE ratings. Similarly, familiarity with a word influences the ability to perceive that word in the presence of a superimposed burst of white noise (Samuel, 2001). Given the role of familiarly in visual BE in Munger et al. (2005) and in word recognition in Samuel (2001), familiarity might influence other aspects of cognition such as auditory BE or BR. Given an unfamiliar auditory landscape, it might be difficult or impossible to extrapolate and extend boundaries in memory. Thus, we implemented an auditory prose training paradigm in which participants were presented with a set of stories. These stories were presented aurally multiple times prior to memory testing, thereby removing the possibility that participants were not familiar enough with the auditory landscapes to extrapolate, even under circumstances in which extrapolation might otherwise be the default perceptual mechanism.

Method

Participants—Forty-one participants with self-reported normal hearing were recruited on campus at UTD and were compensated via partial course credit in a psychology course. None of the participants had taken part in Experiments 1–4. The experimental protocol was approved by the UTD IRB.

Apparatus and response materials—The apparatus was the same as that in Experiments 3 and 4, with a single exception. Due to deterioration of the soft padding material encircling the ear area on the headphones, new Koss UR21v full-size headphones were used.

The response materials were also the same as those in Experiments 3 and 4. In addition, the “y” and “n” keys were used to denote “yes” and “no,” respectively, for the 12 quiz items that were presented to participants at the conclusion of the training phase of the experiment.

Stimuli—Six short stories were created for the purpose of the experiment, plus an additional story that was used as an example stimulus (see Appendix B). In creating these stories, we attempted to use names and situations with which most people in Western culture are familiar. Stories were created from a variety of common scenarios: outdoor (country), outdoor (city), indoor, school, work, grocery store, theme park, dentist or doctor office, vacation, science fiction. Language was simple but descriptive, including adjectives and adverbs. Varying sentence structures were used, but we attempted to allow for excerpts in which key information could be added or taken away from both the beginning and end of the segments. Six additional stimuli were generated (in their more-content form) for use as foils during the training quiz as the items that had not been previously heard. These stimuli were unique items that were generated using the same criteria as the six training stories.

The full stories used for training (*M* duration = 71.2 s, *SD* = 14.7 s; range = 50–90 s) consisted of enough content to allow for four more/mid/less stimuli to be drawn from each of them. Editing proceeded as in previous experiments, with content being eliminated from both the beginning and end of the stimuli for cuts containing successively less content. More-content stimuli were used for the recognition quiz, whereas mid-content and less-content stimuli were used in the boundary extension task. Excerpts were not necessarily presented in the same voice (male or female) during training and testing.

The 12-item recognition quiz involved one more-content excerpt from each of the six stories, plus the six foil items, randomly ordered for presentation. For the sake of simplicity, and because this quiz was a screening tool, all participants received the same 12 questions, in the same randomly generated order (unlike the boundary extension portion of the task; cf. Experiment 1, Method section). Participants answered whether they recognized the excerpt from the training by indicating yes or no to a prompt; a yes response was correct for half of the questions on the quiz, and a no response was correct for half of the questions on the quiz.

The l/ll/lll distinction used in Experiments 3 and 4 was eliminated; less-content stimuli were only used in their complete form (cf. Experiment 2 and the l subtype of Experiments 3 and 4). No white noise was added to the beginning or the end of the stimuli. Durations by cuts and voice type were as follows: female voice more-content, *M* duration = 14.8 s, *SD* = 3.2 s; female voice mid-content, *M* = 8.5 s, *SD* = 1.8 s; female voice less-content, *M* = 3.0 s, *SD* = 1.9 s; male voice more-content: *M* = 12.5 s, *SD* = 2.8 s; male voice mid-content, *M* = 7.1 s, *SD* = 1.7 s; male voice less-content, *M* = 2.4 s, *SD* = 1.5 s. Foils presented during the training quiz were similar in duration to the other more-content stimuli (*M* duration = 13.7 s, *SD* = 1.4 s; range = 12–16 s).

Procedure—A training paradigm was implemented at the beginning of the experimental session. During training, participants were familiarized with six stories by hearing each story repeated three times in block fashion (story one repeated three times, story two repeated three times, etc.), until all six stories had been presented three times each. At the conclusion of the training, a 12-question quiz was posed to the participants during which they were asked to indicate if they had heard a given excerpt during the experiment training (yes or no). Participants alerted the experimenter when their training phase and quiz were complete, and the experimenter started the boundary extension/restriction program as in Experiments 3 and 4, using excerpts from the trained stories for stimuli as described above. As in Experiments 2–4, the memory distortion task required stimulus content and tempo judgment responses for all trials, with one quarter of the trials representing each of the less/less, less/mid, mid/less, and mid/mid test conditions.

Results

Interpreting judgment results—Results were interpreted in the same manner as in Experiments 1–4. Female-voice excerpts and male-voice excerpts did not differ significantly in the responses they elicited (*p*s > .05), and so the data were collapsed across voice type. Absolute values were used in the mid/less and less/mid contrast analysis to compare estimated magnitude differences (cf. Intraub et al., 2008).

Data analyses—Quiz data were examined to ensure that participants were learning the stories presented to them during the training phase well enough to differentiate between excerpts drawn from the training stories versus completely novel excerpts. Mean accuracy across participants was 98.2% (*SD* = 4.4%), with an accuracy range of 83.3% to 100%, meaning that no participants missed more than two out of 12 questions on the quiz.

Stimulus content data were initially analyzed in terms of whether response patterns differed from chance. As in Experiments 1–4, chi-square analyses indicated that responding occurred at levels different from chance (*p*s < .001; see Table 6). The majority of responses were correct (overall mean accuracy = 93.90%), with values ranging from 90.24% (mid/mid comparisons) to 97.56% (less/less comparisons). It is notable that training induced a dramatic increase in accuracy compared with the previous experiments, which had lower end accuracy values ranging from 66.67% to 78.41%. Because the lower end accuracy values in the present experiment were at 90.24%, there were fewer perceptual errors, effectively weakening the power for the analysis of directional distortion data.

Nonetheless, stimulus content data were analyzed using *t* tests to determine whether responses were directionally distorted compared with the expected value of 0 for the less/less and mid/mid comparisons. Overall, less/less judgments (*M* = 0.00, *SD* = 0.05) were not significantly different from 0, $t(40) = 0.00$, $p = 1.000$, $d = 0.00$. Mid/mid judgments (*M* = 0.02, *SD* = 0.17) were also not significantly different from 0, $t(40) = 0.90$, $p = .372$, $d = 0.28$. A one-way dependent-measures ANOVA was used to contrast the extent of distortion in the mid/mid and more/more conditions, and there was no significant difference, $F(1, 40) = 0.78$, $p = .383$, $\eta_p^2 = .019$.

A paired *t* test comparing less/mid (*M* = 1.71, *SD* = 0.49) and mid/less (*M* = −1.52, *SD* = 0.68) judgments, however, showed that responding was stronger in the direction of BR than in the direction of BE (*M* difference = 0.19, *SD* = 0.54), $t(40) = 2.26$, $p = .029$, $d = 0.32$. This analysis indicates that even under conditions of extremely high accuracy, recall of auditory prose stimuli was distorted in the direction of BR with nonmatching stimuli.

Tempo data were similarly analyzed. Response patterns in the tempo data differed from chance levels of responding (all *p*s < .001). Tempo data were analyzed using *t* tests to determine whether responses were directionally distorted compared with the expected value of 0. Mid/mid judgments ($M = -0.02$, $SD = 0.22$), $t(40) = -0.72$, $p = .474$, $d = 0.23$; less/less judgments ($M = 0.03$, $SD = 0.20$), $t(40) = 1.05$, $p = .299$, $d = 0.33$; less/mid judgments ($M = -0.06$, $SD = 0.40$), $t(40) = -0.91$, $p = .367$, $d = 0.29$; and mid/less judgments ($M = 0.03$, $SD = 0.21$), $t(40) = 0.88$, $p = .384$, $d = 0.28$, indicated no directional distortion. A one-way repeated-measures ANOVA indicated no significant effect of comparison type on tempo judgments, $F(3, 38) = 0.95$, $p = .424$, $\eta_p^2 = .026$.

Discussion

Even though participants had a high level of familiarity with the stimuli and made few judgment errors after training, memory distortion in the direction of BR still occurred with nonmatching stimuli. No directional distortion was found in memory for auditory prose excerpts for either mid- or less-content stimuli with matching target/probe stimulus presentation (i.e., less/less or mid/ mid). No significant memory distortion occurred in the tempo judgment data. The use of highly familiar stimuli in Experiment 5 did not result in BE, and so it is unlikely that the lack of BE in Experiments 1–4 simply reflected a lack of familiarity with the stimuli in those experiments.

Experiment 6

Although BR might be the default mechanism of the auditory domain when memory errors occur, it remains possible that the pattern of results in Experiments 1–5 was constrained by the type of stimuli used in the experiments—that is, spoken words and phrases that are not necessarily encountered in the course of daily living. To examine this possibility, it was necessary to examine whether BR might be found in memory for another type of well-known auditory stimulus. One such type of stimulus would be well-known music. Thus, in Experiment 6 we used popular music from a variety of genres to assess whether familiar, more continuously flowing stimuli (compared with words, which could be construed as more discrete; cf. Gottesman & Intraub, 2002) would evoke BE in the auditory domain.

Method

Participants—Forty-four participants with self-reported normal hearing were recruited on campus at UTD and were compensated via partial course credit in a psychology course. None of the participants had taken part in Experiments 1–5. The experimental protocol was approved by the UTD IRB.

Apparatus and response materials—The apparatus and response materials were the same as those used in Experiment 5, with the addition of a familiarity rating scale. Participants rated their familiarity with the more-content (i.e., more musical notes) excerpt from each selection on a scale of 1 to 7, with 1 representing never having heard the song before, 4 representing a moderate level of familiarity with the song, and 7 indicating a high enough level of familiarity that the participant knew the title of the song and/or its artist. Participants indicated their familiarity ratings by pressing the appropriate number key on the 10-key portion of the keyboard.

Stimuli—Thirty-six songs were selected as stimuli for the experiment, in addition to an example stimulus (see Appendix C). These songs were selected from the following four genres of popular music (nine songs each): classical pops, film scores, classic rock, and current pop. Songs in the "current pop" classification were selected from songs on the Billboard Top 20 Pop Songs list (http://www.billboard.com/#/charts/pop-songs) at the time of the study. Songs in the other three genres were selected based on the researchers' judgments of what songs were likely to be highly familiar. Some of the songs chosen contained words, but some did not (see Appendix C). Ideally, there would have been equal representation within each genre between songs containing or not containing words, but this proportionality was not representative of the music available and was not feasible given the music that was available and that would be familiar to a wide audience.

Songs were edited for stimulus content in Audacity, and this was similar to the editing of spoken prose in Experiment 1. First, a more-content selection (*M* = 23.19 s, *SD* = 2.1 s, range = 19–28 s) was taken from each song to be used for familiarity ratings. An effort was made to select a segment that would be easily recognized by most people (e.g., the chorus). For the more-content excerpts only, a 1-s fade-in was placed at the beginning of the excerpt, and a 1-s fade-out was placed at the end of the excerpt. This avoided abrupt sounds and thus provided for more naturalistic listening during the familiarity rating portion of the experiment. Then mid-content (*M* = 9.06 s, *SD* = 0.8 s) and less-content (*M*= 6.00 s, *SD* = 0.5 s) excerpts were taken from within the more-content selections in the same manner described in Experiment 1. No fade-ins or fade-outs were placed at the beginning and end of these excerpts, as these were the excerpts to be tested in the memory distortion task, and we did not want them to differ from their original presentation except in the amount of content presented. No additional editing was done to the less- and mid-content excerpts.

Procedure—The procedure was similar to Experiment 5, with a few exceptions. Familiarity judgments replaced the training phase of Experiment 5. After listening to instructions for the familiarity task, participants listened to the more-content stimulus excerpts. Following presentation of each excerpt, a slide appeared on the computer monitor with the question, "How familiar is this song to you?" The rating scale was provided below the question on the same screen, and participants recorded their familiarity judgments. At the conclusion of the familiarity portion of the experiment, the program automatically proceeded to instructions regarding comparisons of the probe stimuli to the target stimuli. This portion of the experiment began without the need for the experimenter to intervene to begin the experiment program. Instructions for the memory distortion task specified that participants would hear a target excerpt followed a probe excerpt, and then they were to make two judgments: first, whether the probe contained less, the same, or more music content (i.e., music notes) than the target and, second, whether the probe was played at a slower, the same, or a faster tempo than the target.

Results

Interpreting judgment results—Results were interpreted in the same manner as in Experiments 1–5. Absolute values were used in the mid/less and less/mid contrast analysis to compare estimated magnitude differences (cf. Intraub et al., 2008).

Data analyses—Familiarity data were examined to ensure that participants were actually familiar with the music that was presented to them. On a scale from 1 to 7 (with 1 being *not at all familiar* and 7 being *most familiar*), the mean familiarity judgment across participants was 5.3 (*SD* = 2.2). Broken down by genre, familiarity ratings were as follows: classic rock, *M* = 5.4, *SD*= 1.9; classical pops, *M* = 5.6, *SD* = 2.1; current pop, *M* = 6.0, *SD* = 2.0; film scores, *M* = 4.5, *SD* = 2.4. There was no correlation between familiarity ratings in the first portion of the experiment and boundary judgments in the second portion of the experiment. Furthermore, there was no effect of whether the excerpts contained words.

Stimulus content data were initially analyzed in terms of whether response patterns differed from chance. As in Experiments 1–5, chi-square analyses indicated that responding occurred at levels different from chance (*p*s < . 001; see Table 7). The majority of responses were correct (overall mean accuracy = 66.42%), with values by comparison type ranging from 44.95% (mid/mid comparisons) to 83.59% (less/mid comparisons).

Stimulus content data were analyzed using *t* tests to determine whether responses were directionally distorted compared with the expected value of 0 for the less/less and mid/mid comparisons. Mid/ mid judgments ($M = 0.16$, $SD = 0.45$) were significantly in the direction of BR, $t(43) = 2.33$, $p = .025$, $d = 0.71$. However, less/less judgments ($M = 0.01$, $SD = 0.37$) were not significantly different from 0, $t(43) = 0.18$, $p = .858$, $d = 0.05$. A one-way dependent-measures ANOVA showed a larger distortion in the mid/mid than the less/less conditions, $F(1, 43) = 8.77$, $p = .005$, $\eta^2_p = .169$.

A paired *t* test comparing less/mid ($M = 1.23$, $SD = 0.52$) and mid/less ($M = -1.05$, $SD = 0.44$) judgments showed that judgments were stronger in the direction of BR than in the direction of BE (M difference = 0.18, $SD = 0.60$), $t(43) = 2.02$, $p = .049$, $d = 0.37$. This analysis indicates that BR was robust to stimulus type, even occurring with familiar music stimuli.

Tempo data were similarly analyzed. Response patterns in the tempo data differed from chance levels of responding (all *p*s < .001). Tempo data were analyzed using *t* tests to determine whether responses were directionally distorted compared with the expected value of 0. Mid/mid judgments ($M = 0.01$, $SD = 0.29$), $t(43) = 0.23$, $p = .818$, $d = 0.07$; less/mid judgments ($M = 0.08$, $SD = 0.38$), $t(43) = 1.33$, $p = .191$, $d = 0.41$; and mid/less judgments ($M = -0.05$, $SD = 0.36$), $t(43) = -0.98$, $p = .331$, $d = 0.30$, indicated no directional distortion. Less/less judgments ($M = 0.10$, $SD = 0.23$) were significantly greater than 0, $t(43) = 2.81$, $p = .008$, $d = 0.86$, indicating that probes were judged as faster than targets. This result was supported by a one-way repeated-measures ANOVA that indicated a significant effect of comparison type on tempo judgments, $F(3, 41) = 2.91$, $p = .046$, $\eta^2_p = .052$.

Discussion

In Experiment 6, popular musical stimuli elicited BR for stimulus content in the auditory domain under conditions of relatively more content (in this case, mid-content stimuli) or nonmatching stimulus presentations. It thus appears that the results of Experiments 1–5 were not constrained by auditory stimulus type. Even though both prose and music are composed of individual and discrete elements (words and notes, respectively), individual words might generally be perceived as more meaningful than individual notes. Thus, music might be represented as less discrete than text—that is, as more continuous or flowing. We had hypothesized that the discrete nature of words and sentences might be contrary to the continuously yet artificially truncated scene required to evoke BE (e.g., Gottesman & Intraub, 2002), whereas the more flowing nature of music might elicit the extrapolation required by a more continuous landscape. However, there was no evidence of BE in the stimulus content judgments. BR was robust to stimulus differences and thus seems to be the default mechanism of auditory memory when errors are made. More research will be required to test this hypothesis, as the types of auditory stimuli used in boundary distortion studies are still rather limited in scope. Tempo judgments were not systematically related to judgments of probe stimulus content; only in the less/less condition were probes judged as faster than their associated targets.

General Discussion

Memory for auditory spoken prose stimuli was examined in five experiments, followed by an examination of memory for musical stimuli in a sixth experiment. Participants were presented with target/probe pairings consisting of spoken prose or musical excerpts; each probe was either identical to its associated target or contained more or less prose or musical content than its associated target. Participants made judgments as to whether each probe contained more or less stimulus content compared with its associated target, and although tempo was not manipulated, participants also made judgments comparing the tempos of the probes to the tempos of their associated targets.

With spoken prose stimuli, stimulus content results indicated a pattern of responding in the direction of BR, with participants recalling less of the initial target stimulus than was actually presented, and this effect was more pronounced for nonmatching stimuli. More specifically, response patterns in all experiments were significantly in the direction of BR with nonmatching stimulus/probe presentation (i.e., mid/more and more/mid, or less/mid and mid/less) and in experiments in which a greater variety of stimulus content was used (i.e., Experiments 3 and 4). Results of the present experiments thus indicate a robust effect of BR in auditory memory, at least within the time frame under investigation (i.e., stimuli lasting between 2 and 24 s in duration with a 7-s interstimulus interval) and with the type of stimuli presented (i.e., spoken prose and popular music, with a variety of stimulus durations). The less-content musical stimuli of Experiment 6 elicited the same pattern of results as the spoken prose of Experiments 1–5. This suggests that BR in the auditory domain is robust to properties that differentiate spoken prose and popular music stimuli, such as familiarity and differences in stimulus continuity.

Results from the tempo judgment data were not consistent. When distortions in memory judgments did occur (under some stimulus presentation conditions in Experiments 1, 2, and 6), probes were judged as being presented at a faster rate compared with their associated targets. Had the tempo judgments varied consistently with the stimulus content judgments, it might have been informative regarding the nature of auditory memory distortions. Because the tempo results were not consistent it is difficult to ascertain what sort of memory distortion they reflect, unlike the stimulus content results that were consistent across experiments, thus suggesting a robust BR of auditory memory.

Studies of memory for scenes in the visual domain show both BE and BR distortions depending on the angle-width of the stimulus and the retention interval (e.g., Intraub et al., 1992); however, only significant BR distortions were observed in the present auditory experiments. In visual studies (e.g., Intraub et al., 1992), BR has been interpreted as a regression to the mean of the stimulus set (i.e., a central tendency) that occurs over time following an initial BE. In Experiments 1–6, we observed robust BR in the absence of any BE. Curiously, the BR we observed was stronger for non-matching stimuli that contained more stimulus content. This content effect seems reminiscent of the larger BE Intraub reports for close-up (less content) pictures. It could be that some aspect of content such as the number of words (cf. Craik, 1968), phrases (cf. Roberts & Gibson, 2002), or sentences (depending on one's familiarity with the stimuli; cf. Glanzer & Razel, 1974) constitute the dimension affected most directly by a central tendency mechanism, and this might account for the relative strength of BR in the current experiment. Further research is certainly required to understand the prevalence of the BR distortions found in the present experiments and potential BE distortions that might occur under particular stimulus conditions.

Our study is the first to our knowledge to investigate memory distortion for auditory boundaries regarding content, as opposed to investigating auditory boundaries regarding duration estimation, and our overall pattern of results suggests that auditory memory distortions predominantly involve a restriction of boundaries in memory. Although we posited that limited familiarity with the literary scenes in Experiments 1– 4 could have limited the participant's ability to extrapolate for less-content stimuli, leading to a failure to find significant BE, the induction of familiarity in Experiment 5 did not induce BE, and the popular music stimuli of Experiment 6 also did not induce BE. Thus, we can rule out familiarity as sufficient for inducing BE for auditory stimuli.

It could be that BE is a property of spatial perception, and neither prose nor music stimuli used in the current experiments were sufficiently spatial in nature to evoke BE (in contrast, cf. Dreyfus, Fetterman, Smith, & Stubbs, 1988). Alternatively, it might be that gist abstraction (cf. Schacter, Guerin, & St. Jacques, 2011) occurs in memory for stimuli that are presented over time and that it is this gist abstraction that results in a restriction in the remembered boundaries. In fact, the present BR phenomena share some properties with gist abstraction as specified in theories of schema and category development. For instance, schema and category development are known to be influenced by the extent of exemplar variability (e.g., Castro, Young, & Wasserman, 2006; Lively, Logan, & Pisoni, 1993; Murphy, 2002; L. K. Perry, Samuelson, Malloy, & Shiffer, 2010). Participants do tend to remember gist or general schemas more than absolute wording when presented with stories or scripts (see Bartlett, 1932/1967; Bransford & Franks, 1972; e.g., Bransford & Franks, 1971; Franks & Bransford, 1972). It is possible that gist is analogous to restricting boundaries or averaging over values, especially when participants might have had more than one exposure to the stimulus. Novel schema-relevant stimuli are even often recognized as having been previously presented (e.g., Aminoff, Schacter, & Bar, 2008). Thus BR of textual or musical material could be equivalent to an abstracted gist. Finally, a TOE mechanism might account for our results. If all of our stimuli, including the less-content stimuli, contained sufficient amounts of content, and more-content probes tend to be judged as containing more content than identical target stimuli (cf. Tse et al., 2004), then the result would be a robust restriction effect for stimulus content in memory. Further research will be required to determine the precise mechanism that underlies the robust BR that we have discovered in auditory memory.

Nevertheless, the results of our experiments illustrate a succinct picture. Specifically, memory judgments for spoken prose and musical content exhibit robust BR when presented in the context of varying content. This restriction of memory-representation boundaries occurs over time, foreshortening the recollection of spoken or musical passage content.

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Williams, V. On Best of the millennium: Top 40 classical hits [CD]. Santa Monica, CA: Utv Records; 1999. Fantasia on Greensleeves. Composed in 1934

Wright, S. On Drum heroes [CD]. Los Angeles, CA: Deadline Music; 2007. Back in black [Recorded by AC/DC]. Composed in 1980

Appendix A

Auditory Stimulus Selections, Experiments 1–4

Selection	Author	Era	Work	Source
1	Montgomery, L. M.	1832–1888	*Eight Cousins*	http://www.bibliomania.com/0/-/frameset.html
2	Barrie, J. M.	1860–1937	*The Adventures of Peter Pan*	http://www.literature.org/authors/
3	Baum, L. F.	1856–1919	*The Wonderful Wizard of Oz*	http://www.literature.org/authors/
4	Bronte, A.	1820–1849	*Agnes Grey*	http://www.literature.org/authors/
5	Bronte, C.	1816–1855	*Jane Eyre*	http://www.literature.org/authors/
6	Bronte, E.	1818–1848	*Wuthering Heights*	http://www.literature.org/authors/
*	Burroughs, E. R.	1875–1950	*Jungle Tales of Tarzan*	http://www.literature.org/authors/
7	Carroll, L.	1832–1898	*Alice's Adventures in Wonderland*	http://www.literature.org/authors/
8	Cather, W. S.	1873–1847	*Alexander's Bridge*	http://www.literature.org/authors/
9	Collins, W.	1824–1889	*The Frozen Deep*	http://www.literature.org/authors/
10	Crane, S.	1871–1900	*Maggie: A Girl of the Streets*	http://www.literature.org/authors/
11	Darwin, C.	1809–1882	*The Voyage of the Beagle*	http://www.literature.org/authors/
12	de Balzac, H.	1799–1850	*Bureaucracy*	http://www.literature.org/authors/
13	Defoe, D.	1661–1731	*Robinson Crusoe*	http://www.literature.org/authors/
14	Dickens, C.	1812–1870	*A Christmas Carol*	http://www.literature.org/authors/
15	Doyle, A. C.	1859–1930	*The Lost World*	http://www.literature.org/authors/
16	Dostoevsky, F.	1821–1881	*Crime and Punishment*	http://www.literature.org/authors/
*	Dumas pe`re, A.	1802–1870	*The Black Tulip*	http://www.literature.org/authors/
17	Eliot, G.	1819–1880	*The Mill on the Floss*	http://www.literature.org/authors/
18	Holley, M.	1836–1926	*Samantha Among the Brethren*	http://www.literature.org/authors/
19	Lawrence, D. H.	1885–1930	*The Fox*	http://www.literature.org/authors/
20	London, J.	1876–1916	*Jerry of the Islands*	http://www.literature.org/authors/
21	Montgomery, L. M.	1874–1942	*Anne of Green Gables*	http://www.literature.org/authors/

Selection	Author	Era	Work	Source
22	Nesbit, E.	1858–1924	*Five Children and It*	http://www.literature.org/authors/
23	Oppenheim, E. P.	1866–1946	*The Illustrious Prince*	http://www.literature.org/authors/
24	Poe, E. A.	1809–1849	*The Cask of Amontillado*	http://www.literature.org/authors/
*	Shelley, M. W.	1797–1851	*Frankenstein*	http://www.literature.org/authors/
25	Stoker, B.	1847–1912	*Lair of the White Worm*	http://www.literature.org/authors/
26	Tolstoy, L. N.	1828–1910	*Master and Man*	http://www.literature.org/authors/
27	Twain, M.	1835–1910	*A Connecticut Yankee in King Arthur's Court*	http://www.literature.org/authors/
28	Verne, J.	1828–1905	*Dick Sand: A Captain at Fifteen*	http://www.literature.org/authors/
*	Voltaire	1694–1778	*Candide*	http://www.literature.org/authors/
29	Hardy, T.	1840–1928	*Tess of the d'Urbervilles*	http://www.bibliomania.com/0/-/frameset.html
30	Funke, C.	1958–	*Inkspell*	Funke (2005)
31	Rand, A.	1905–1982	*Atlas Shrugged*	Rand (1957/1992)
32	Brown, D.	1964–	*The DaVinci Code*	Brown (2003)
33	Wallace, B.	1947–	*A Dog Called Kitty*	Wallace (1980)
34	Rowling, J. K.	1965–	*Harry Potter and the Half-Blood Prince*	Rowling (2005)
35	de Pizan, C.	1364–1430	*The Book of the City of Ladies*	de Pizan (1405/1988)
36	Gimenez, M.	1955–	*The Color of Law*	Gimenez (2005)

* Indicates the stimulus was used in either an example trial or a practice trial.

Appendix B

Auditory Stimulus Selections, Experiment 5

Training Stories 1– 6 were read seamlessly. Breaks below are for ease of viewing extracted stimuli, and numbers delineate the excerpts that were used as more-content stimuli. [] indicate more-content excerpts, {} indicate mid-content excerpts, and || indicate less-content excerpts. Four stimuli were drawn from six stories, for a total of 24 stimuli for the boundary distortion experiment. Only one more-content excerpt was used from each story in the training quiz, in addition to six foils, as listed below.

Story 1: Outdoor (Country), Stimuli 1–4

The trip had been a long one.

1 [Charles and {Kim approached the house in the pickup truck. |The truck was old and rusted and creaky,| which reflected how Charles felt} when climbing out of the truck.]

2 [His knees did not work like they used to when he was younger, and {it took him a minute to work the kinks out and manage to stand up straight. | Charles looked back wistfully| along the pitted dirt road} that he and Kim had just traveled.]

3 [Things were so different now. But {Kim didn't seem to notice, or else |she didn't mind. Kim bounded out of the truck| and jumped into a large pile of hay,} laughing and enjoying herself immensely.]

4 [Betsy the cow came over and nuzzled Kim's shoulder. {The dogs ran up to greet them both, slobbering and making a scene. |Even the ducks seemed excited| at the homecoming,} which was evident by all of their loud quacking.]

Ah, it was definitely good to be back.

Story 2: Outdoor (City), Stimuli 5–8

It was a quiet day in New York City.

5 [As quiet as days there get, that is. {In fact, I was marveling over how quiet New York City can actually be at times. |It was early Sunday morning and most people were sleeping,| jogging, gardening, going to church,} and engaging in other similar sorts of quiet activities.]

6 [That is why I, Isabelle Gardenia, heard *the noise*. {I normally would have ignored the noise, mind you. But |I was sitting on the little balcony outside my apartment, writing a story| for my freelance magazine job} and listening to the birds and the quiet humming of traffic below me.]

And

7 [then I heard a distinct, rhythmic beat coming from below. {At first I thought it was a kid practicing for band or something, with a loud metronome going. |But as I looked around, there was no evidence of a kid,| and there was no music} to go along with the droning beat.]

8 [Whatever was going on, {there was an eerie feeling in the air, and | something that told me in my gut that this was no normal noise. I needed to investigate.| And I was right.} But that is when my troubles started.]

And being originally from Alaska, I don't do anything on a small scale, mind you. No, my troubles were huge.

Story 3: Indoor, Stimuli 9–12

Speaking of families that aren't exactly harmonious,

9 [Cheyenne and Grayson were not the best of friends. {They tolerated one another simply because |they were brother and sister. But Mom recently instituted "Family Dining Time"|—or FDT,} as she liked to call it.]

And that meant that

10 [Cheyenne and Grayson had to put all of their differences aside every Thursday night, sit down at the table together with Mom, and talk about life. {Neither Cheyenne nor Grayson cared about such "fluff." And, |to make things even more complicated, once a month Mom made Cheyenne and Grayson actually prepare the meal.| Together. Not cool at all.} First off, they had to find recipes that they could both tolerate.]

and that weren't overly difficult to make.

11 [This was a challenge given the dietary restrictions in their family. {Grayson was vegetarian, |Cheyenne was essentially a carnivore, and Mom was allergic to garlic, onions, and tomatoes.| Meal choices were limited.} Very limited.]

At least Grayson wasn't vegan.

12 [Unfortunately, the family realized all too soon that the recipes needed to stay simple. {The rubberized |vege-tarian "beef" Stroganoff was more than enough to convince them that grilled cheese sandwiches and vegetable soup constituted what was comparably a gourmet meal.| Fried pies were always a hit, too,} even though they weren't very healthy.]

Mom let the pies slide, though, because even though they were definitely fattening, everyone seemed to be in a better mood when pie was on the menu for dessert.

Story 4: School, Stimuli 13–16

Mason loves math.

13 [Math is so predictable! {Every single time you do an equation there is only one right answer. |So once you know the algorithm, life is good.| If only all of life worked that way!} Unfortunately, math teachers can be much less predictable than the math that they teach.]

14 [Dr. Storme in Mason's first semester of College Algebra was a perfect example of this unfortunate fact. {He seemed nice, |he taught well, and life was indeed good for Mason,| following the prescribed freshman college algorithm,} if such a thing exists. And then life with Dr. Storme became–well, stormy.]

15 [At first Mason didn't think too much about Dr. Storme's somewhat erratic behavior. {Dr. Storme missed one class, then two. |Later in the semester, Dr. Storme forgot about an important exam.| He just didn't show up. Mason had stayed up late} and had studied very hard for that exam, and he was pretty angry.]

16 [It just wasn't fair! But forget about fair. {Creepy things started happening in class. |These things were much more disturbing to Mason| than a postponed exam. What was going on?} Mason had to get to the bottom of this problem,]

and quickly, before it caught up to his math grade.

Story 5: Work, Stimuli 17–20

Sara likes her job.

17 [Sara works as an attorney for a big firm downtown. {She likes her clients and she likes her pay. |She even likes going to court.| She likes her bosses, and the majority of her colleagues.} Sara does not, however, care for office politics.]

But because of where her cube is situated in the office, next to the water cooler and not far from the receptionist's desk,

18 [Sara hears most of the office gossip as {it floats off the lips of one or another of her less-than-subtle colleagues. |Sara usually simply ignores the jabber. After all, she has better things to do.| But when she was working late last Thursday night,} Sara heard a conversation that she simply could not ignore.]

What to do? Ugh.

19 [That's another thing that Sara hates. {Moral dilemmas. She always seems to get caught up in the middle of them, and |she is always compelled to do what is "right"| instead of what is "convenient" or simple.} Sara hates that about herself,]

even though

20 [Sara's mom says that is part of what makes Sara a good person. {Nevermind that, though. |You are probably wondering what is involved in this moral dilemma| and exactly what Sara overheard.} Although that is reasonable,]

it is probably best to start with when the police got involved.

Story 6: Grocery Store, Stimuli 21–24

The two little boys were ecstatic!

21 [Dad was giving them a treat because they had both made all A's and B's on their report cards! {This was huge, particularly for Tom. |Tom was a great kid, and relatively smart,| but he usually managed to forget to turn in a paper,} or he would get nervous and bomb an exam.]

Needless to say, Tom's report card was usually not the prettiest one on the block. But this time he did it!

22 [Tom and his little brother Fred climbed into the car, huge smiles on their faces, and buckled up. {They sang silly songs and laughed all the way to the store. |They couldn't stop giggling.| George stopped the car in the parking lot} and smiled at his boys. He was so proud of them.]

As soon as they entered the store,

23 [the boys ran to the candy aisle ahead of their dad. {Little hands grabbed around one piece of candy and then switched to another, over and over again, as if |this decision would change the course of the world.| Dad left the boys for just a moment} and went and picked out an extra surprise in another part of the store.]

Finally, with selections in hand, the little family of three proceeded to the checkout counter and made their purchases.

24 [Fred couldn't wait. {He opened up his candy in the parking lot to take his first bite, and |because he wasn't looking at where he was going, he tripped and fell,| and the candy went flying.} Tom made a valiant effort to catch the candy, to no avail.]

Of course, George took Fred back into the store and bought him a new piece of candy, but not before many tears had been shed.

Foil 1, Theme park—[Hiram and Jessie waited patiently in line. They sang and danced, either amusing or annoying their neighbors. Why stand around bored, they figured? Finally, another half an hour later, Hiram and Jessie got in the car, buckled up, and took off on the ride.]

Foil 2, Dentist or Doctor office—[But it was so awkward in the waiting room. She was surrounded by a bunch of junior high kids with pimples all over their faces. And they stunk because they didn't have time to shower after gym class. Well, at least the odor was strong enough that probably the majority of them came straight from gym class.]

Foil 3, Vacation—[The sand squished between my toes as I stood on the beach, looking out over the horizon and breathing in the fresh, salty air. After pausing for a moment, Julia and I sat down on a blanket and put out the finger sandwiches, the fruit and the drinks, and then we paused to observe a crab.]

Foil 4, Science fiction—[A spaceship was landing in the middle of the field! Jolie was stunned. Was there really life on other planets? Life that was conscious, that knew we existed here on Earth? Life that cared to show up to visit, and that had the technology to do so?]

Foil 5, School—[How was Harry going to get his work turned in on time? Yes, he was sure that he could eventually recover the files from his hard drive, but this was an urgent matter. Mr. Smith was not one to take excuses, regardless of how legitimate they were.]

Foil 6, Work/Travel—[Right about now Ron was wondering why he had agreed to work in the middle of nowhere in Zimbabwe, studying the behavior of some exotic monkeys. He hadn't had what he would consider real food for days, and he really needed a good, hot shower, and a soft bed.]

Example, Outdoor—[Kyle rubbed his hands together and he jumped up and down to stay a little warmer while waiting for the bus. His heavy winter coat wasn't enough in the sub-freezing temperature, but there wasn't much he could do about that. Why did he move to Wisconsin? Oh yeah, that thing called a job.]+

Appendix C

Auditory Stimulus Selections, Experiment 6

Selection	Work	Composer/performer	Genre	Words
Example	Symphony No. 5: Mvt. 1	Ludwig van Beethoven (1808/1996)	Classical pops	no
1	Moonlight sonata	Ludwig van Beethoven (1801/1996)	Classical pops	no
2	Pomp and Circumstance	Edward Elgar (1901/1999)	Classical pops	no
3	Hallelujah	George Frideric Handel (1741/1999)	Classical pops	yes
4	1812 Overture	Pyotr Tchaikovsky (1880/1999)	Classical pops	no
5	O Fortuna	Carl Orff (1935/1999)	Classical pops	yes
6	Canon in D	Johann Pachelbel (1919/1999)	Classical pops	no
7	Greensleeves	Vaughan Williams (1934/1999)	Classical pops	no
8	William Tell Overture	Gioachino Rossini (1829/1999)	Classical pops	no
9	Ride of the Valkyries	Richard Wagner (1851/1999)	Classical pops	no
10	*Star Wars* main theme	John Williams (1977)	Film score	no
11	Olympic fanfare	John Williams (1984/1999)	Film score	no
12	The Raiders' March	John Williams (1981/1999)	Film score	no
13	*Jurassic Park* theme	John Williams (1993/1999)	Film score	no
14	The Black Pearl (*Pirates of the Caribbean*)	Klaus Badelt (2003)	Film score	no
15	May It Be (*Lord of the Rings*)	Enya (2001)	Film score	yes

Selection	Work	Composer/performer	Genre	Words
16	The Final Bell (*Rocky*)	Bill Conti (1976/2006)	Film score	no
17	*The Good, the Bad, and the Ugly*	Ennio Morricone (1967/1990)	Film score	no
18	My Heart Will Go On (*Titanic*)	James Horner (1997)	Film score	yes
19	All Shook Up	Elvis Presley (1957/2002)	Classic rock	yes
20	Hit the Road Jack	Ray Charles (Mayfield, 1961/2010)	Classic rock	yes
21	I Wanna Hold Your Hand	Beatles (Lennon, 1963/1988)	Classic rock	yes
22	My Girl	Temptations (White, 1964/2008)	Classic rock	yes
23	I'm a Believer	The Monkees (Diamond, 1966/2003)	Classic rock	yes
24	Hey Jude	Beatles (Lennon, 1968/1988)	Classic rock	yes
25	Back in Black	AC/DC (Wright, 1980/2007)	Classic rock	no
26	We Are the Champions	Queen (Mercury, 1977/1992)	Classic rock	yes
27	Respect	Aretha Franklin (1965/1994)	Classic rock	yes
28	Rolling in the Deep	Adele (Epworth, 2011)	Current pop	yes
29	Moves Like Jagger	Maroon 5 (Levine, 2011)	Current pop	yes
30	Pumped Up Kicks	Foster the People (Foster, 2010)	Current pop	yes
31	Just the Way You Are	Bruno Mars (2010)	Current pop	yes
32	Teenage Dream	Katy Perry (2010)	Current pop	yes
33	We R Who We R	Ke$ha (Hindlin, 2010)	Current pop	yes
34	What's My Name	Rihanna (Eriksen, 2011)	Current pop	yes
35	Edge of Glory	Lady Gaga (Garibay, 2011)	Current pop	yes
36	Love Story	Taylor Swift (2008)	Current pop	yes

Table 1

Assumptions and Predictions for the Different Theoretical Perspectives in Explaining Auditory Memory Distortions

Perspective	Assumption	Prediction
Boundary extension (BE)	Boundaries are uniformly extended for targets in memory	Judgments consistent with auditory BE for all targets
Central tendency	*Memory averaging explanation:* Target stimuli in memory are recalled as more typical of the overall stimulus set: – Less-content targets are remembered as containing more content – More-content targets are remembered as containing less content *Time order error explanation:* Order of stimulus presentation affects judgments, making them more extreme: – Less-content probe following a identical target is judged as having less content (target thus seems to have more content) – More-content probe following an identical target is judged as having more content (target thus seems to have less content)	Judgments consistent with BE for less-content targets and consistent with BR for more-content targets
Boundary restriction (BR)	Boundaries are uniformly restricted for targets in memory	Judgments consistent with auditory BR for all targets

Table 2

Chi-Square Values Indicating Content Response Rates as Different From Chance, Experiment 1

Comparison	Response category	No. of responses	%	Chance %	*df*	χ^2	*p*
mid/mid	<0	42	13.33	40	2	560.00	<.001
	0	**231**	**73.33**	20			
	>0	42	13.33	40			
mid/more	<0	26	8.25	40	2	216.10	<.001
	0	37	11.75	20			
	>0	**252**	**80.00**	40			
more/mid	**<0**	**210**	**66.67**	40	2	108.21	<.001
	0	60	19.05	20			
	>0	45	14.29	40			
more/more	<0	36	11.43	40	2	497.24	<.001
	0	**221**	**70.16**	20			
	>0	58	18.41	40			

Note. The response category shown in bold indicates the correct response.

Table 3

Chi-Square Values Indicating Content Response Rates as Different From Chance, Experiment 2

Comparison	Response category	No. of responses	%	Chance %	*df*	χ^2	*p*
less/less	<	25	7.94	40	2	801.61	<.001
	0	**264**	**83.81**	20			
	>0	26	8.25	40			
less/mid	<0	14	6.98	40	2	312.02	<.001
	0	22	4.44	20			
	>0	**279**	**88.57**	40			
mid/less	**<0**	**253**	**80.32**	40	2	218.94	<.001
	0	36	11.43	20			
	>0	26	8.25	40			
mid/mid	<0	31	9.84	40	2	671.89	<.001
	0	**247**	**78.41**	20			
	>0	37	11.75	40			

Note. The response category shown in bold indicates the correct response.

Table 4

Chi-Square Values Indicating Content Response Rates as Different From Chance, Experiment 3

Comparison	Response category	No. of responses	%	Chance %	*df*	χ^2	*p*
less/less	<0	16	4.23	40	2	1,217.89	<.001
	0	**347**	**91.80**	20			
	>0	15	3.97	40			
less/mid	<0	19	5.03	40	2	418.40	<.001
	0	13	3.44	20			
	>0	**346**	**91.53**	40			
mid/less	**<0**	**337**	**89.15**	40	2	384. 06	<.001
	0	27	7.14	20			
	>0	14	3.70	40			
mid/mid	<0	29	7.67	40	2	783.87	<.001
	0	**293**	**77.51**	20			
	>0	56	14.81	40			

Note. The response category shown in bold indicates the correct responses.

Table 5

Chi-Square Values Indicating Content Response Rates as Different From Chance, Experiment 4

Comparison	Response category	No. of responses	%	Chance %	*df*	χ^2	*p*
less/less	<0	31	6.38	40	2	1,299.04	<.001
	0	**415**	**85.39**	20			
	>0	40	8.23	40			
less/mid	<0	21	4.32	40	2	586.73	<.001
	0	9	1.85	20			
	>0	**456**	**93.83**	40			
mid/less	**<0**	**437**	**89.92**	40	2	505.27	<.001
	0	23	4.73	20			
	>0	26	5.35	40			
mid/mid	<0	52	10.70	40	2	780.89	<.001
	0	**343**	**70.58**	20			
	>0	91	18.72	40			

Note. The response category shown in bold indicates the correct response.ss

Table 6

Chi-Square Values Indicating Content Response Rates as Different From Chance, Experiment 5

Comparison	Response category	No. of responses	%	Chance %	*df*	χ^2	*p*
less/less	<0	3	1.22	40	2	924.91	<.001
	0	**240**	**97.56**	20			
	>0	3	1.22	40			
less/mid	<0	7	2.85	40	2	320.70	<.001
	0	3	1.22	20			
	>0	**236**	**95.93**	40			
mid/less	**<0**	**226**	**91.87**	40	2	275.78	<.001
	0	7	2.85	20			
	>0	13	5.28	40			
mid/mid	<0	9	3.66	40	2	758.82	<.001
	0	**222**	**90.24**	20			
	>0	15	6.10	40			

Note. The response category shown in bold indicates the correct response.

Table 7

Chi-Square Values Indicating Content Response Rates as Different From Chance, Experiment 6

Comparison	Response category	No. of responses	%	Chance %	*df*	χ^2	*p*
less/less	<0	82	20.71	40	2	378.22	<.001
	0	**234**	**59.09**	20			
	>0	80	20.20	40			
less/mid	<0	25	6.31	40	2	319.82	<.001
	0	40	10.10	20			
	>0	**331**	**83.59**	40			
mid/less	**<0**	**309**	**78.03**	40	2	261.84	<.001
	0	64	16.16	20			
	>0	23	5.81	40			
mid/mid	<0	87	21.97	40	2	160.17	<.001
	0	**178**	**44.95**	20			
	>0	131	33.08	40			

Note. The response category shown in bold indicates the correct response.