BOUNDARY EXTENSION

IN THE AUDITORY DOMAIN

by

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Introduction

The situation is a common one: You are sitting in a room full of friends, discussing politics with your buddy from work, when your friend is called away. Later on that evening, as you are recalling your conversation, you might be able to remember exactly where your friend left off in the conversation, or you might fill in some of the blanks in your memory. Similarly, if you were listening to a piece of music and were interrupted, you might be able to recall exactly where the music stopped, or you might not. Is there any pattern to these misrememberings?

There is a strong rationale for predicting that memory might be biased toward an extended boundary (e.g., filling in details that were not yet spoken by your friend during your conversation, or remembering the music as continuing a little longer than it actually did) because of the evidence for memory to be biased toward extended boundaries with visual or haptic materials. There has not yet been empirical investigation of whether a similar extension of the boundaries of auditory scenes occurs, however. The purpose of the present experiments was to investigate the possible, and theoretically probable, phenomenon of auditory boundary extension.

Boundary Extension

Boundary extension is a well-documented perceptual/memory phenomenon (Bertamini, Jones, Spooner, & Hecht, 2005; Intraub, 1992; Intraub, Bender, & Mangels, 1992) in which a visual scene is erroneously remembered with its boundaries extended (e.g., Intraub et al., 1992; Intraub & Bodamer, 1993; Intraub, Gottesman, & Bills, 1998; Intraub, Gottesman, Willey, & Zuk, 1996; Intraub & Richardson, 1989; Munger, Owens, & Conway, 2005). As seen in Figure 1 (adapted from Intraub & Richardson, 1989), in the left column, one can see that the person drawing the scene recalled seeing the top of the fence and the entirety of the trash cans, effectively extending the boundaries of the scene. In the right column, one can see that this effect was not simply due to object completion, as boundaries on the second picture, which included complete fence and trash cans, were also extended.

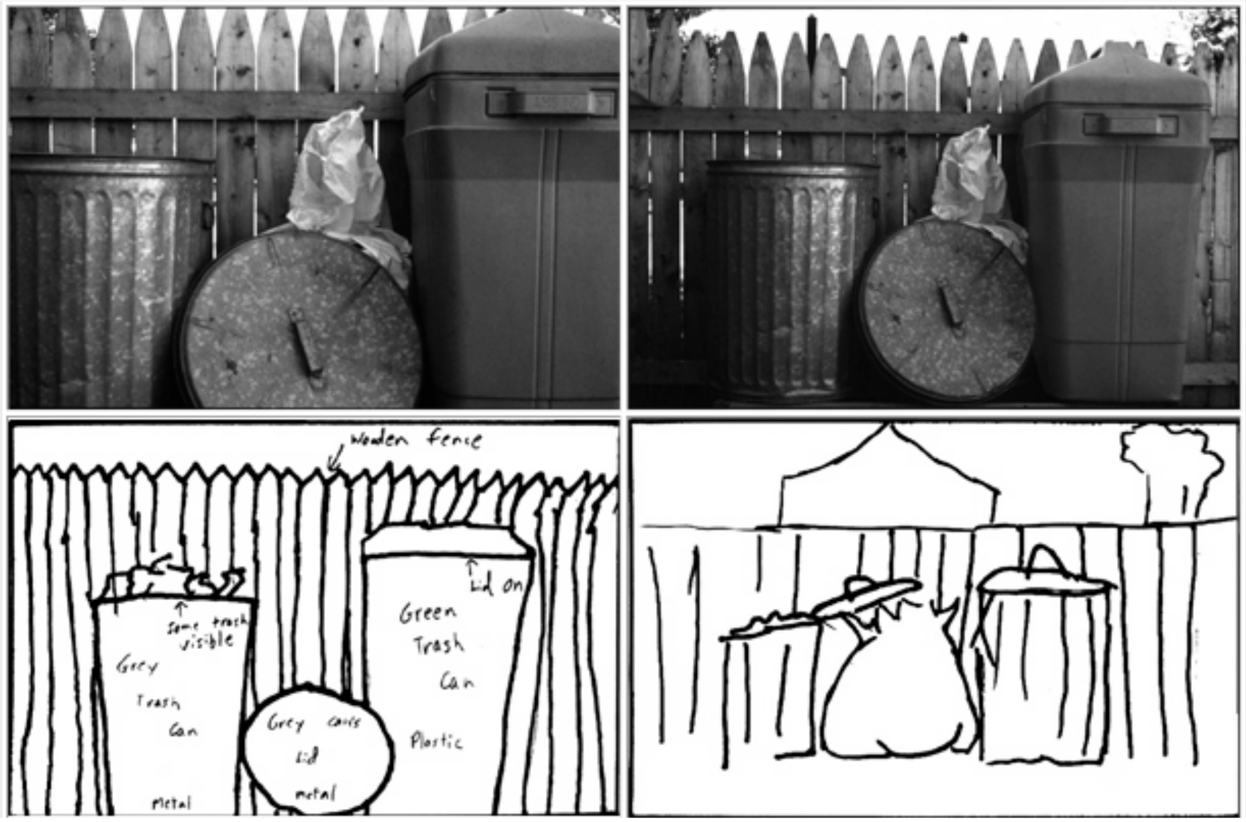

Figure 1. An illustration of visual boundary extension, adapted from Intraub and Richardson (1989). In the left column, the person recalling the scene completed the objects, effectively extending the boundaries of the scene. In the right column, one can conclude that the boundary extension effect was not due to object completion, as the boundaries of the scene were extended despite the complete view of the objects within the scene.

Boundary extension has been shown to be greatest for close-up stimuli (Bertamini et al., 2005; Intraub et al., 1992; Intraub & Berkowits, 1996; Intraub & Richardson, 1989) and relatively short retention intervals (e.g., Intraub et al., 1992), and has been shown to occur for haptic stimuli as well as for visual stimuli (Intraub, 2004; but for an argument regarding a need for further research in the haptic modality, see Bertamini et al.). Boundary extension is extremely robust; the effect persists even when persons are told about the phenomenon and asked to counteract it (Intraub & Bodamer, 1993), and it occurs with both recognition and reproduction tasks (Intraub et al., 1998; Intraub & Berkowits, 1996; Intraub & Richardson, 1989). Boundary extension also occurs in every season of life, with young children, adults, and elderly persons experiencing the phenomenon to approximately the same degree, with the possible exception of college students, who might experience less boundary extension than younger and older groups (Seamon, Schlege, Hiester, Landau, & Blumenthal, 2002).

Boundary Extension in the Visual Modality

Before delving into the probable phenomenon of auditory boundary extension, the boundary extension phenomenon should be examined in terms of its most-studied modality—vision. Understanding the phenomenon of boundary extension in the visual modality is important in this regard because auditory boundary extension should show the same characteristics as visual boundary extension if the two processes are to be considered as the same phenomenon (Bertamini et al., 2005).

Intraub and Richardson (1989) first documented visual boundary extension. In a set of two experiments, they examined picture memory utilizing both recognition and recall tasks; their goal was to determine the mental representation of picture boundaries and to determine if recall and recognition operated similarly or differently with respect to this mental representation. In Intraub and Richardson's first experiment, participants were presented with a set of pictures (such as those in the top row of Figure 1) that was later followed by a recall task in which participants were asked to draw some of the pictures that had been initially presented to them. Boundaries were extended outward on an overwhelming 95% of the drawings. In Intraub and Richardson's second experiment, participants were presented with a set of pictures depicting both close-up and wide-angle scenes, and test pictures likewise represented both close-up and wide-angle scenes such that all possible four presentation-test combinations (close-up/close-up, close-up/wide-angle, wide-angle/close-up, wide-angle/wide-angle) were presented. Some participants were asked to draw the pictures that they had seen prior to a recognition task; other participants received the recognition task only. The recognition task required participants to indicate that the picture at testing was, in comparison to the original picture, much closer-up (-2), a little closer-up (-1), the same (0), a little further away (+1), or a lot further away (+2). An effect of boundary extension was found both in the drawings and in the recognition task, with a larger effect of boundary extension for the close-up pictures (for more regarding the importance of a close-up view, see also Bertamini et al., 2005). In fact, pictures with extended boundaries were often misconstrued as being original pictures.

Since Intraub and Richardson's (1989) seminal work, it has been concluded that an object must be seen, inferred, or imagined within the context of a scene in order for boundary extension to take place (Bertamini et al., 2005; Gottesman & Intraub, 2002, 2003; Intraub et al., 1998; Legault & Standing, 1992; but see Hubbard, 1996). When Legault and Standing presented participants with both pictures and line drawings, they obtained data in concert with a perceptual schema boundary extrapolation (i.e., boundary extension occurring because of an incorporation of contextual scene schema information into memory) only for the pictures and not for the line drawings. Method of presentation was confounded with contextual scene information in Legault and Standing's experiment, however. The pictures included contextual scene information, whereas the line drawings did not. Intraub et al. (1998) tested memory for objects that were positioned in their appropriate backgrounds (i.e., in scenes) versus memory for objects that were positioned on a completely blank background (i.e., in non-scenes). Memory for objects in scenes indicated boundary extension, whereas memory for objects in non-scenes was more indicative of normalization (i.e., regression toward the mean of the stimulus set).

Even more compelling is work by Gottesman and Intraub (2002) in which participants were presented with pictures of objects located on either blank or more naturalistic backgrounds. Gottesman and Intraub (2002) hypothesized that pictures of objects within a more naturalistic background (and thus set within the context of a scene) would show evidence of boundary extension, whereas pictures of objects on blank backgrounds (and thus set within the context of no scene) would not. Surprisingly, boundary extension occurred with both types of pictures (i.e., those on blank backgrounds and those on naturalistic backgrounds); evidently observers construed the blank background as a type of scene, a finding consistent with Hubbard's (1996) conclusion that visual boundary extension can occur in the absence of meaningful contextual scene information. When participants watched the "blank background" photographs being cut out and physically placed on a blank background, however, boundary extension did not occur; participants no longer considered the object as belonging in the context of its blank surroundings. This finding strongly suggests that boundary extension occurs only under conditions in which the viewed scene is considered to be a truncation of a more continuous scene.

Boundary extension appears to follow a specific time course. Intraub et al. (1992) found evidence of boundary extension when participants were tested immediately after presentation of visual stimuli; however, they found evidence of a lesser degree of boundary extension, or even boundary restriction, if testing was delayed approximately 48 hours. Taken together, the findings regarding boundary extension and boundary restriction as a function of time suggest that boundary extension results from a dynamic aspect of mental representation (regarding properties of dynamic mental representation, see Freyd, 1987) and that normalization of the boundaries for a given scene occurs in memory over time (Intraub et al., 1992); this two-component model of processing for pictures/scenes is called the *extension-normalization model*.

The extension portion of the extension-normalization model (Intraub et al., 1992) is based on the perceptual schema hypothesis (Intraub et al., 1992; cf. Legault & Standing, 1992; for theoretical support, see Hochberg, 1986; for a review, see Intraub, 2002), in which one has a mental schema representing a viewed scene. In recalling the viewed scene, persons tend to extend the boundaries of the scene that was originally viewed in concert with their schema for that scene—that is, persons did not remember what elements were within the periphery of the original view (and the state of completion of those objects) versus what their schema, and thus their expectations, were for the periphery of the original view. Intraub et al. (1998) describe the perceptual schema hypothesis in the following manner:

> Presentation of a scene context would be expected to activate the observer's perceptual schema—a visuospatial representation of the anticipated layout of the scene just beyond the picture's boundaries. Aspects of the anticipated area would become incorporated in the observer's mental representation, thus yielding boundary extension (p. 198).

In boundary extension, recall is always expansive—that is, a person recalls more of the periphery of a scene than was actually presented; it is as if the person is in preparation for interacting with what lies just beyond the visible scene (e.g., Intraub, 2002; Intraub et al., 1992). Data have generally supported the perceptual schema hypothesis as a means to explain the expansive nature of boundary extension, particularly with close-up scenes and short temporal delays to test (Intraub et al., 1992; Intraub et al., 1996; Intraub et al., 1998; Intraub & Berkowits, 1996). For example, Intraub et al. (1992, Experiments 2 and 3) presented participants with sets of either mixed scenes (i.e., close-up, prototype, and wide-angle) or unmixed scenes (i.e., a given individual only received one of the three aforementioned scene types) and had them judge the closeness of the second picture relative to the first picture that was presented. A Likert scale from -2 to +2 was used to document these judgments, with -2 representing too close, 0 representing the same, and +2 representing much too far away. Close-up views of scenes leave the landscape truncated to a greater degree than do prototypical or wide-angle scenes. The perceptual schema hypothesis would suggest that an individual, in preparation for interaction with the environment, would tend to require more extrapolation when encountering close-up views, leading to a greater degree of boundary extension. Wide-angle scenes already depict much peripheral information, however, making extrapolation less useful. As predicted by the perceptual schema hypothesis, Intraub et al. (1992, Experiments 2 and 3) found close-up views to result in the greatest amount of boundary extension, followed by prototype views; wide-angle views either showed only a slight amount of directional distortion or none at all.

The normalization portion of the extension-normalization model (Intraub et al., 1992) refers to memory averaging and is based on the idea that, over time, all of the items in a given stimulus set tend to be remembered as closer to an average stimulus viewing distance for the set. With normalization, close-up views show evidence of boundary extension and wide-angle views show evidence of boundary restriction; in both cases, there is a regression to the mean of the stimulus set.

A competing hypothesis to explain boundary extension has been the memory schema hypothesis (Intraub et al., 1992; for theoretical support, see Bartlett, 1932). The memory schema hypothesis states that there is a prototypical object view and that memory shifts toward that prototypical view, with the effect gaining strength over time. The difference between normalization and the memory schema hypothesis is that normalization occurs with regard to the average stimulus size for a given set, whereas memory schema adjustments are hypothesized to occur with regard to a prototypical size for a given object that is derived from a pre-existing schema and not tied to the stimulus set (Intraub et al., 1992). However, prototypical scenes have been shown to yield boundary extension, refuting this hypothesis (Intraub et al., 1992; Intraub & Berkowits, 1996).

Additional hypotheses have been generated in an attempt to better understand boundary extension but have been met with little, if any, support (for reviews, see Bertamini et al., 2005; Intraub & Berkowits, 1996). These hypotheses have included the object completion hypothesis (for a discussion, see Intraub & Richardson, 1989; Intraub et al., 1992; for information regarding the Gestalt principle of object completion, see Ellis, 1955; regarding occluded viewing of shapes, cf. Kanizsa, 1979) in which boundaries are extended in an attempt to complete a partial view of an object (as opposed to the scene behind the object) and the magnification and minification hypothesis (Bertamini et al., 2005) in which boundary extension should only occur for images viewed under conditions of magnification.

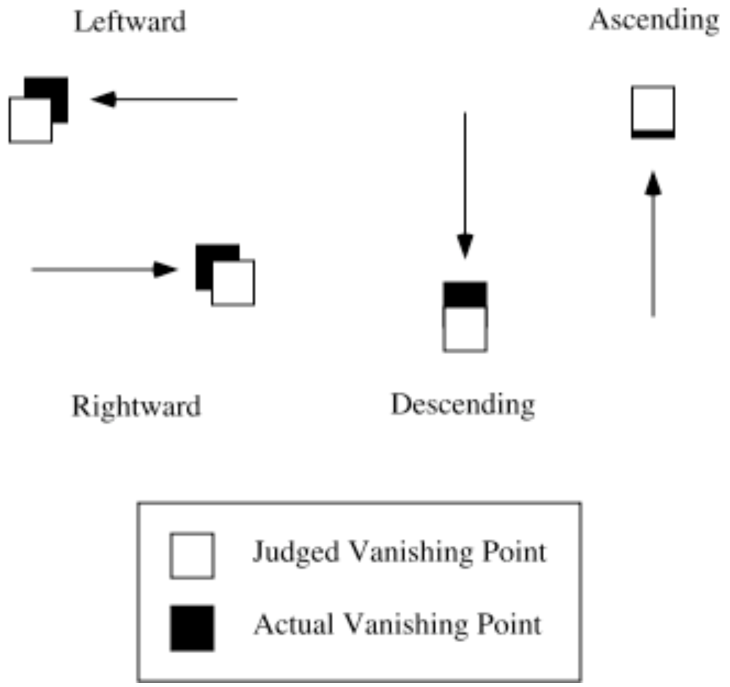

Figure 2. Judged versus actual vanishing points for an object in a representational momentum task, adapted from Hubbard (2005). As illustrated, judged vanishing points are typically further along in the direction of motion than actually occurred (and are also influenced by gravity).

Boundary Extension and Representational Momentum as Related Phenomena

Boundary extension appears to be a dynamic process in which a view is extrapolated in anticipation of interaction with one's environment (cf. Gottesman & Intraub, 2002; Intraub, 2002). Representational momentum is a similar dynamic process in which extrapolation occurs in anticipation of interaction with one's environment (Finke & Freyd, 1985; Freyd & Finke, 1984). Can the consideration of representational momentum suggest anything about boundary extension?

In representational momentum, memory for the stopping or disappearing point for a moving object is displaced further along in its trajectory (i.e., in the direction of motion) than actually occurred (see Figure 2; for a thorough review, see Hubbard, 2005). The memory asymmetry characteristic of representational momentum is implicit in definition: memory tends to be displaced in front of a moving object as opposed to behind a moving object. It has been suggested that both boundary extension and representational momentum are adaptive in that they prepare the individual for what is coming in the next moment of time or with the next fixation, even though the representation of current events is not accurate (Hubbard, 2006a; Intraub, 2002). This similarity suggests a possible correspondence between properties or parameters of boundary extension and representational momentum.

Boundary extension and representational momentum exhibit some of the same traits, such as extrapolation or anticipation beyond the available stimulus and time course patterns (cf. Freyd & Johnson, 1987; Intraub, 1992; for a discussion, see Hubbard, 1996; Intraub, 2002). Representational momentum has been documented in both visual (e.g., DeLucia & Maldia, 2006; Finke & Freyd, 1985; Finke, Freyd, & Shyi, 1986; Freyd & Finke, 1984; Freyd & Johnson, 1987; Freyd & Jones, 1994; Freyd, Panzer, & Cheng, 1988; Halpern & Kelly, 1993; Hayes & Freyd, 2002; Hubbard, 1990, 1994b, 1994c, 1998, 2001; Hubbard & Bharucha, 1988; Hubbard, Blessum, & Ruppel, 2001; Hubbard & Motes, 2002) and auditory (e.g., Freyd, Kelly, & DeKay, 1990; Getzmann, 2005; Getzmann, Lewald, & Guski, 2004; Hubbard, 1994a, 1995a; Johnston & Jones, 2006) domains, and has also been found to occur with visual stimuli as a function of auditory language comprehension (Zwaan, Madden, Yaxley, & Aveyard, 2004). Representational momentum is thus considered generalizable across sensory domains—much like boundary extension, which has been found to occur in both visual and haptic domains (Intraub, 2004). The similarities between boundary extension and representational momentum have led some to the conclusion that an underlying mechanism is potentially responsible for both phenomena (Hubbard, 1995b, 1996), although this has been a matter of debate (e.g., Intraub, 2002).

The relationship between boundary extension and representational momentum was recently examined in an experiment conducted by Munger et al. (2005). Participants made judgments for three blocks of experimental trials, always in the following order: boundary extension judgments for single pictures, boundary extension judgments for approach sequences (consisting of four still photographs), and representational momentum judgments for approach sequences (for which positive and negative shift positions were incorporated into the final photograph). Munger et al. found evidence of both boundary extension and representational momentum; however, the processes did not seem to interact with one another, as might be expected if stemming from exactly the same mechanism, but instead were sequential. Specifically, boundary extension appeared to precede representational momentum, allowing for the expanding of the boundaries of a scene prior to the extrapolation of movement within that scene.

DeLucia and Maldia (2006) presented participants with pictures that simulated motion of the self in the depth plane and found that boundary extension occurred using these motion-in-depth-depicting scenes. The mechanisms underlying boundary extension and representational momentum were differentiated, however. Optic flow information was not found to be important for eliciting scene schema, or one's expectations for global and spatial scene properties, and thus boundary extension. Optic flow information was found to be important in eliciting motion schema, or one's expectations for details and changes within a scene (of both local and global varieties), and thus representational momentum. Boundary extension was concluded to be a mechanism that processed spatial properties of a scene. In contrast, representational momentum appeared to process changes occurring within a scene.

DeLucia and Maldia's (2006) conclusion is in concert with the findings of Munger et al. (2005) in that one would expect the processing of a spatial layout (i.e., boundary extension) to occur prior to the processing of changes within that spatial layout or within the extrapolation of that spatial layout (i.e., representational momentum). One can therefore conclude that Hubbard (1996) was correct in his assertion that boundary extension and representational momentum are part of "a more general and deeper underlying extrapolation process" (p. 47), although the mechanisms and precise functions involved are not necessarily the same and are sequential to one another.

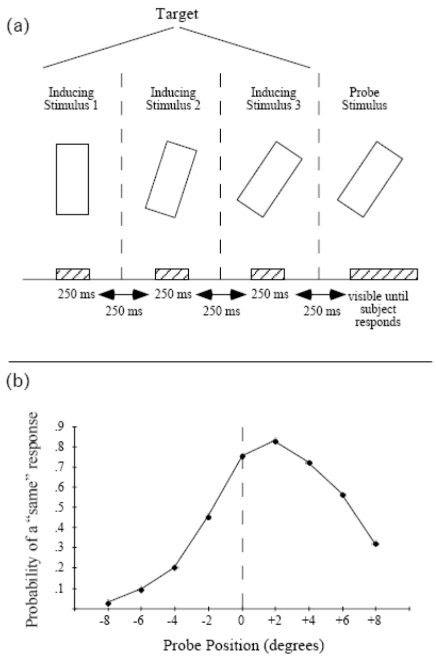

Figure 3. Research results of Freyd and Finke (1984), as adapted from Hubbard (2005). Panel (a) represents Freyd and Finke's method of presenting three discrete presentations of the target (referred to as inducing stimuli) followed by a probe. Panel (b) plots of a "same" response as a function of probe position, showing the memory asymmetry that is characteristic of representational momentum studies.

Auditory Representational Momentum

As previously mentioned, and as seen in Figure 2, a memory asymmetry occurs in visual representational momentum. As seen in Figure 3, Freyd and Finke (1984) clearly documented this memory asymmetry. Panel (a) of Figure 3 represents Freyd and Finke's method of presenting three discrete presentations of the target (referred to as *inducing stimuli*) followed by a probe. Panel (b) of Figure 3 plots probability of a "same" response as a function of probe position, showing the memory asymmetry that is characteristic of representational momentum studies (i.e., a greater probability of a same response for probes slightly beyond the final position of the target than for probes slightly behind the final position of the target).

The memory asymmetry characteristic of visual representational momentum has been documented in memory for pitch with participants lacking formal music training (Freyd et al., 1990;

Kelly & Freyd, 1987) and with participants having formal music training (Freyd et al., 1990). Much like its visual counterpart, auditory representational momentum is influenced by the velocity (Freyd et al., 1990; Hubbard, 1995a), the implied acceleration (Freyd et al., 1990), and the direction of motion (Hubbard, 1995a; Johnston & Jones, 2006) of the inducing stimuli, in addition to the duration of the final portion of the inducing stimulus (Hubbard, 1995a). Additionally, the stopping functions (i.e., retention intervals expressed as functions of estimated memory shifts) for representational momentum in the visual and auditory domains are similar to one another (Freyd et al., 1990)—that is, in both visual and auditory domains, memory shifts increase with retention intervals up to a certain point and then decrease as retention intervals become longer.

In a set of auditory representational momentum experiments in which participants were presented with a set of sequential pitches (Johnston & Jones, 2006), participants made systematic errors in memory consistent with auditory representational momentum when presented with either linear or periodic/oscillating pitch patterns. These errors in memory presumably occurred because the auditory sequences were predictable, and participants were extrapolating the motion implied by these predictable event sequences. Incoherent/random patterns did not elicit systematic error patterns in memory; the lack of a representational momentum effect under such conditions (i.e., random notes) was not surprising, as extrapolation is not possible in a completely random environment. Together, these findings support the hypothesis that auditory representational momentum, like visual representational momentum, is an extrapolation of implied motion from predictable events.

Auditory representational momentum has also been documented in spatial hearing (Getzmann, 2005; Getzmann et al., 2004). Getzmann and colleagues (2004) presented participants with either a pulsating auditory target or continuous noise that moved spatially within a dark, anechoic room, and the participants made judgments regarding the stopping location of the sound using a hand pointer. A strong effect of auditory representational momentum was found, with participants' judgments tending to extend beyond the trajectory of the sound in the direction of motion, and this occurred for both the pulsating and continuous target stimuli. The influence of sound velocity, however, was only exerted with continuous sounds and was in the direction opposite to that predicted (i.e., displacement was decreased instead of increased at higher velocity rates). Getzmann et al. interpreted this finding as reflecting an effect of the amount of spatial information that was available as opposed to velocity per se, and further suggested that even if the mechanisms driving visual and auditory representational momentum in spatial hearing were different (a possible conclusion based upon the differences found between visual and auditory representational momentum in spatial hearing with regard to velocity), it was clear that representational momentum-type effects were not strictly limited to vision.

Rationale for the Present Study

If boundary extension occurs prior to representational momentum in the visual domain (cf. Munger et al., 2005), then a question that follows is whether or not the same boundary extension-representational momentum pattern occurs in other sensory modalities. If the true functions of boundary extension and representational momentum have been uncovered, with boundary extension providing the appropriate layout within which representational momentum then occurs (i.e., the extrapolation of movement within the broader scene), the same pattern should be anticipated to occur in other modalities; after all, boundary extension has been shown to occur haptically (Intraub, 2004), and representational momentum has been documented in the auditory domain (e.g., Getzmann et al., 2004). Clearly, neither boundary extension nor representational momentum is unimodal. Given that representational momentum does exist in the auditory domain (e.g., Getzmann et al.) and that boundary extension is thought to precede representational momentum (cf. Munger et al.), auditory boundary extension should theoretically exist as a precursor to auditory representational momentum. The goal of the present paper is to investigate this hole in the literature[1]. The present experiments were designed to uncover auditory boundary extension and the parameters under which it operates,

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[1] Haptic representational momentum should likewise be investigated; however, this is beyond the scope of the present paper. The interested reader should refer to Brouwer, Franz, & Thornton (2004).

paving the way for future experiments in which the relationship between a potential auditory boundary extension and auditory representational momentum is clarified.

Auditory Scenes

Given the importance of a scene in visual boundary extension, it is reasonable to suggest a scene might be of similar importance in auditory boundary extension. Thus, it is important to determine what constitutes an auditory scene prior to embarking on a study of auditory boundary extension. Auditory scenes are much neglected in research, but not novel (e.g., Bregman, 1990). In fact, Bregman noted that, although vision and audition have much in common, perceptual research often has neglected the area of auditory scene analysis because of the problems inherent in sound mixtures. Bregman went on to propose that both innate and schema-driven perceptual representations exist in relationship to both speech and music, and that auditory scene analysis is important in augmenting Gestalt views of audition.

In the visual boundary extension literature, a scene has been defined as if one was looking through a window and receiving a partial view of the surrounding area; one knows that the boundaries to the scene extend beyond the current view although vision is limited (cf. Intraub, 2004). Likewise, music or language can be presented in auditory scenes, or auditory “chunks” that mimic a window. In fact, phrases may be much like the separate panes of a window—even though the scene is partially occluded, it is well understood that there is a continuous scene in the background based on the Gestalt principle of good continuation (Palmer, 2002). Whether a large window or smaller panes of a window are the appropriate analogs of given scenes, the same result should be obtained: the opportunity for the extension of boundaries when the available amount of information suggests a continuation of the auditory information and a benefit of extrapolation to the perceiver.

Auditory Boundary Extension and Duration Estimation Differentiated

It might be objected that a finding of auditory boundary extension would merely reflect a response bias in duration estimation tasks toward longer judgment ratings and is unrelated to the presence of an auditory scene per se. However, there are important differences between an auditory duration estimation task (e.g., Jones, Boltz, & Klein, 1993) and a potential auditory boundary extension task. In both an auditory boundary extension and an auditory duration estimation task, an auditory excerpt is played to the participant and then a second auditory excerpt is played after a pause for purposes of comparison; participants are then asked whether the second auditory excerpt was shorter, the same, or longer than the first auditory excerpt. For boundary extension studies, the goal is to assess the accuracy of memory for excerpt content. In duration estimation studies, however, the goal is to assess the accuracy of memory for excerpt duration; the excerpts can, in fact, be vastly different from one another because content is not of concern. The present auditory boundary extension studies are thus more perceptual and memory-based (i.e., Is this what was heard?) instead of duration-based (i.e., Are the excerpts of the same duration?). The present studies are therefore not simply a replication of the duration estimation literature but instead offer a novel contribution.

The Present Experiments

As suggested by Bregman (1990), speech and music offer an appropriate backdrop for the analysis of auditory scenes. In fact, the research reviewed here suggests that an individual is highly likely to experience boundary extension for a speech or lecture, conversation, or music listening. To strengthen this argument, representational momentum has been documented in regard to both language comprehension and a related systematic memory distortion with visual stimuli (Zwaan et al., 2004) and music (Freyd et al., 1990; Getzmann, 2005; Hubbard, 1993, 1995a; Johnston & Jones, 2006; but regarding potentially different mechanisms in the visual and auditory modalities, see Getzmann et al., 2004). In a recent study of representational momentum resulting from a verbal description of movement, Zwaan et al. concluded that language representation simulates dynamic perceptual events in much the same manner (though not necessarily in an identical manner) as does visually tracking a sequential picture sequence—that is, both language-tracking and visual-tracking exhibit representational momentum. As an example of representational momentum after hearing a musical note sequence, Freyd et al. (1990) found that participants extrapolated pitch sequences in a recognition task when they were asked to compare the third and fourth notes of pitch sequences. Music, which has been likened to language (e.g., Blacking, 1973; Drake, 1998; Krumhansl, 1998; Lerdahl & Jackendoff, 1983; Raffman, 1993; Sloboda, 1985; Swinney & Love, 1998; Wallin, Merker, & Brown, 2000; for an overview, see Besson & Friederici, 1998), and language are therefore prime candidates for the investigation of auditory boundary extension. Both media will therefore be included in the present investigation.

One might wonder what varieties of language and music stimuli should be used in a study of auditory boundary extension. The visual literature suggests that boundary extension only occurs for scenes in which a background scene is somehow construed (i.e., scenes that suggest there is more in the periphery than is actually seen). Experiment 1 investigated boundary extension using simple patterned and random stimulus sequences (i.e., presumed non-scene contexts), and Experiments 2 to 5 investigated boundary extension using relatively complex and more ecologically valid stimulus sequences (i.e., presumed scene contexts). The inclusion of the simple sequences provided an assessment of the necessity of complex auditory materials, and it also allowed for the assessment of sequential and random tone sequences (cf. Johnston & Jones, 2006). Simple sequences were constructed out of musical scale tones or spoken number sequences, and more complex stimuli were derived from published piano and literary works.

In all of the experiments in the present study, participants were presented with target auditory selections, each of which was followed immediately by a corresponding probe auditory selection. This procedure was undertaken in two blocks—one block consisting of musical stimuli, and the other block consisting of spoken stimuli, with order counterbalanced across participants. Participants made judgments comparing each probe to its corresponding target in terms of length and tempo, indicating whether the probe sounded shorter/the same length/longer and whether the probe sounded slower/the same tempo/faster than the target. In Experiments 1-3, this was accomplished by expanding the traditional five-point scale used in studies of boundary extension (i.e., -2 to +2, with -2 representing boundary extension, 0 representing the same as the target, and +2 representing boundary restriction) to a seven-point scale (i.e., -3 to +3, with -3 representing the greatest amount of boundary extension, 0 representing the same as the target, and +3 representing the greatest amount of boundary restriction; cf. Intraub & Richardson, 1989; Intraub et al., 1992). In Experiments 4 and 5, which were methodologically closer to the visual boundary extension literature (cf. Intraub et al., 1992), the traditional five-point scale was used for recording judgments. The idea of auditory boundary extension would be supported if participants extended boundaries for targets, judging probes as shorter than expected when compared to the corresponding targets. Significantly faster or slower tempo judgments would suggest a need for future research regarding a possible extension or contraction of time, as opposed to the content extrapolation inherent in the length judgments (and visual boundary extension experiments).

Experiment 1

Gottesman and Intraub (2002) suggested that boundary extension occurs in the visual domain only with a visual scene that is rich and complex yet incomplete at its periphery (in that the view of a continuous landscape is inevitably discontinuous at some point). Though even monophonic music has been considered as complex (cf. Hutchison & Hubbard, 2007; Lerdahl & Jackendoff, 1983; Temperley, 2001), it is unclear how complex an auditory scene must be in order for boundary extension to occur.

The goal of Experiment 1 was to determine whether or not boundary extension occurs with simple auditory sequences. Participants were presented with a sequential tonal sequence (i.e., an ascending Major scale, a descending Major scale, an arpeggiated/oscillating Major tonal sequence), or a random tonal sequence. The target tonal sequence was followed by a probe that was either shorter or the same length as the target; tempo was not manipulated. Testing occurred immediately after the presentation of each stimulus, at which time participants used Likert scales to indicate whether each probe was (a) shorter, the same length, or longer than its associated target, as a means to directly assess auditory boundary extension, and (b) slower, the same tempo, or faster than its associated target, as a means to determine whether or not an additional temporal element of boundary extension was occurring, opening up possibilities for future research. It was expected that if boundary extension did occur with these simple sequences, it would occur for sequential, non-random stimuli, but not for random stimuli (cf. Johnston & Jones, 2006).

Method

Participants

Forty participants enrolled in psychology courses at Texas Christian University were recruited for participation in the experiment. Six additional participants' data were eliminated from the analyses: four because of substantial fatigue and inattention (both self-reported and observed by the experimenter), and two because of failure to follow directions. Recruitment was not based on musical expertise, although musical experience (in terms of number of years) was documented at the conclusion of the experiment. All participants reported normal hearing and were compensated via extra credit toward their psychology courses.

Apparatus

The vehicle for recording the stimuli was a Samson C01U-USB (universal serial bus) 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 either to a boom arm (for piano recordings) or a small table top microphone stand (for verbal recordings). Recordings were laid down 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, such that identical information was present in both 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

Music stimuli. The music stimuli in Experiment 1 were constructed using a series of tones that were arranged in either sequential (ascending Major scale, descending Major scale, arpeggiated/oscillating Major scale) or random order, played by a professional pianist on a Steinway grand piano. Sequences included repetition to aid extrapolation. Thus, the 6 ascending scale stimuli and the 6 descending scale stimuli were comprised of 15 tones each, resulting in two-octave scales. The 18 random tone stimuli were also presented in sequences of 15 tones each. The 6 arpeggiated/oscillating sequences, however, were 25 tones in length to allow for the arpeggio to be completed for two complete sequences, similar to the two octave completion of the musical scales[2]. All tonal sequences were played at 60 beats per minute. For a catalogue of the sequential music target stimuli, see Appendix A.

Random tone sequences were composed using notes from C3 to C5 (approximately 130.82 Hz to 523.26 Hz, with 261.63 Hz, or C4, representing middle C; a 25 note span); all 25 notes in this pitch range were represented across every 2 stimuli (i.e., across each of 9 sets of 2 stimuli each). For a catalogue of the randomized target musical stimuli, see Appendix B. Ascending scale sequences

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[2] Although the length difference is technically a confound in the experiment, it was decided that musical meaningfulness was more important than sheer number of tones presented. Further, it was decided to err on the side of adding additional notes instead of subtracting additional notes when creating the complete arpeggiated sequence. So, if a bias were to exist due to the length of the stimulus, one would expect that the longer sequences would actually make it more difficult to reject the null hypothesis that boundary extension occurs with simple tonal sequences because there is more information available within the auditory scene and therefore less of a need for extrapolation (cf. Intraub et al., 1992).

were played in the following keys: C (C3 to C5, and C4 to C6), G (G2 to G4, and G4 to G6), and D (D3 to D5, and D4 to D6). Descending scale sequences were played in the following keys: C (C6 to C4, and C5 to C3), G (G6 to G4, and G4 to G2), and D (D6 to D4, and D5 to D3). Arpeggiated/oscillating sequences were played in the following keys: E (range: E4 to E6), A (range: A3 to A5), D (range: D4 to D6), G (range: G4 to G6), and C (ranges: C3 to C5, and C4 to C6).

Number stimuli. The number stimuli in Experiment 1 were constructed in a similar manner to the music stimuli, but using spoken numbers instead of musical tones. Ascending number sequences, descending number sequences, and oscillating number sequences were created within the range of 30-70 (see Appendix C). Random number sequences were created within the range of 38-62 (a 25-integer span; see Appendix D); all 25 numbers in this range were represented across every 2 stimuli (i.e., across each of 9 sets of 2 stimuli each). All number stimuli were recorded separately by both a female voice and a male voice. Each participant received only one version of each stimulus (i.e., either male or female voice); however, presentation was counterbalanced across participants, and each participant received an equal number of male-voice and female-voice stimuli.

Probes. Because of a concern that adding additional information to an auditory scene might fundamentally change the auditory scene instead of just giving a different perspective of the same auditory object, probes (i.e., testing stimuli) were always either shorter or the same length, never longer, than the associated targets and utilized the content from the target excerpt. Deleting notes would presumably not fundamentally alter the auditory scene because all of the auditory information, and thus the more full extent of the scene, was already made available in the target presentation of each stimulus.

Four probe types were constructed: *mm* (much cut off of the beginning and much cut off of the end of the target excerpt), *ms* (much cut off of the beginning and some cut off of the end of the target excerpt), *sm* (some cut off of the beginning and much cut off of the beginning of the target excerpt), *ss* (some cut off of the beginning and some cut off of the end of the target excerpt), and *itt* (identical to the target). “Much” was operationalized as 4 notes (i.e., approximately 26.7% of the target material for the 15 note excerpts), and “some” was operationalized as 1 note (i.e., approximately 6.7 % of the target material for the 15 note excerpts). Thus, the mm excerpts were the shortest (roughly 46.6% of target length), ms and sm excerpts were intermediate in length (roughly 66.6% of target length), ss excerpts were slightly shorter than the target (roughly 86.6% of target length), and the itt excerpts were the longest (identical to the target, and thus 100% of target length).

Response materials. Participants were given a paper response packet in which to indicate their judgments regarding probe/target length and tempo comparisons using a seven-point Likert scale, from –3 (shorter or slower) to +3 (longer or faster; for an example response sheet, see Appendix E).

Table 1

Schematic, Experiment 1

	LENGTH OF PROBE COMPARED TO TARGET				
STIMULUS TYPE	much shorter at beginning/ much shorter at end (mm)	much shorter at beginning/ some shorter at end (ms)	some shorter at beginning/ much shorter at end (sm)	some shorter at beginning/ some shorter at end (ss)	identical to target (itt)
music, sequential (15+3, total)					
ascending (5+1)	1	1	1	1	1 (+1)
descending (5+1)	1	1	1	1	1 (+1)
oscillating (5+1)	1	1	1	1	1 (+1)
music, random (15+3, total)					
random (15+3)	3	3	3	3	3 (+3)
numbers, sequential (15+3, total)					
ascending (5+1)	1	1	1	1	1 (+1)
descending (5+1)	1	1	1	1	1 (+1)
oscillating (5+1)	1	1	1	1	1 (+1)
numbers, random (15+3, total)					
random (15+3)	3	3	3	3	3 (+3)

Note: The probes were lengthened or shortened from the beginning and from the end, or were the same as the targets. The numeral in each cell represents the number of items per cell per participant. Additional target-length probes were included for purposes of quantitatively presenting more lengthy probes; however, these non-manipulated items were not included for purposes of data analysis and are shown in the table as the +1 and +3 items. Each participant received 72 items (of which 60 were used for analysis) delivered in two blocks with a break between: either music followed by numbers, or numbers followed by music, counterbalanced across participants. Much shorter means that 4 notes were eliminated; some shorter means that 1 note was eliminated.

Design

As seen in Table 1, the design of the experiment was probe length (5: mm, ms, sm, ss, itt) x stimulus type (2: music, numbers) x stimulus organization (2: sequential, random), with stimulus subtype (4: ascending, descending, oscillating, random) nested within stimulus type x stimulus organization. Given that the majority of probes were shorter than the target, twelve additional target-length probes were included for purposes of quantitatively presenting more lengthy probes; however, these non-manipulated items were not included for purposes of data analysis. Although data were collected for these additional items, the data from these items were not included in the analyses; therefore, 72 trials were conducted, but the data from only 60 of those trials were analyzed.

Each participant heard each target stimulus only once, and received one probe per stimulus. Four randomized target stimulus orders were generated, and a modified Latin square design was implemented to allow for the presentation of all probe types for each stimulus across participants (and likewise, randomized orders). This resulted in five randomized probe presentation orders per randomized target stimulus set, yielding a total of 20 randomized orders (for an example set of randomized orders, see Appendix F; items with itt across the entire row were the non-randomized items that were excluded from the analyses). Various aspects of stimulus presentation (i.e., order of presentation of music and number blocks, presentation of stimuli within each experimental block in the first or the second half of that block, probe types for each stimulus across participants, and male and female voices for spoken number trials across participants) were counterbalanced.

Procedure

Upon entering the lab, participants were told that they would be listening to some auditory stimuli presented as musical and spoken number sequences and that their task was to respond to these stimuli in a memory task. After giving their informed consent (see Appendix G), participants placed the headphones on their ears and pressed the space bar on the computer to begin the experiment. The computer gave the participant detailed instructions concerning the memory task using a female voice and accompanying print on the computer screen. It was emphasized that participants should compare the probe to the target in memory, not utilizing extraneous means to determine the relationship between probe and target lengths or probe and target tempos.

Target/stimulus pairs were presented in two blocks of 36 trials each (one block of music trials, one block of number trials), for a total of 72 experimental trials. Half of the participants

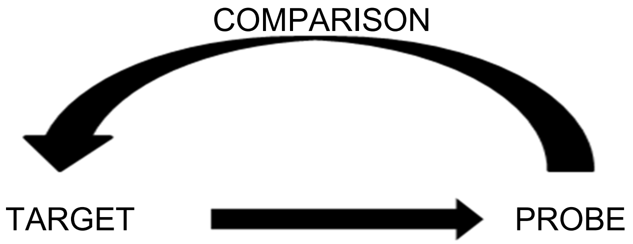

Figure 4. A schematic of the experimental procedure used in Experiment 1 (and subsequent experiments). An auditory target was presented, followed by a brief time lag (7 seconds), and then an auditory probe was presented. Participants were asked to compare the probe to the target using a Likert scale (-3 to +3) on two dimensions: Was the probe shorter/longer than the target? Was the probe slower/faster than the target? (Note: Tempo was not manipulated.)

listened to the music stimulus block first, and the other half of the participants listened to the number stimulus block first. One example trial and three practice trials were presented in the modality of the first block (i.e., either music or numbers), and participants were given an opportunity to ask the experimenter for clarification of the procedure and instructions, if necessary. The first block of trials was then presented. Between stimulus blocks, one additional example trial was presented in the modality that was represented in the second block of trials, and the second block of trials followed.

In the experimental task (see Figure 4), participants were presented with a target stimulus followed by a probe, and subsequently judged whether the probe was shorter (-), the same length (0) or longer (+) than the target on a scale from –3 to +3 (see Appendix E); participants made similar judgments with regard to whether the tempo was slower (-), the same (0), or faster (+) for each target/probe pairing (also see Appendix E), although tempo was never manipulated. The order in which participants were to make their length/tempo judgments was not specified in the experimental instructions. Participants were asked to make both length and tempo judgments for each trial, and because length judgments were of primary interest in the present experiment, length was always presented first on the response sheet (see Appendix E). Each target/probe pairing was presented to

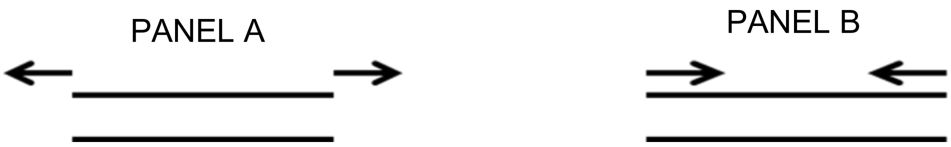

Figure 5. A guide to interpreting judgment results of Experiment 1 (and subsequent experiments). The upper lines in this figure represent targets, and the lower lines represent probes. If the target boundary was extended in memory, as in Panel A, then the probe would seem to be shorter. Judgments would be shorter than expected values, and t-values would be negative. If the target boundary was restricted in memory, as in Panel B, then the probe would seem to be longer. Judgments would be longer than expected values, and t-values would be positive.

participants only once with an ISI (interstimulus interval) of 7 seconds. The ITI (intertrial interval) was 9 seconds. Upon completion of the experimental trials, all participants received a brief background/debriefing questionnaire (see Appendix H) prior to debriefing. The entire procedure lasted approximately 70 to 80 minutes.

Results

Interpreting Judgment Results

Judgments were interpreted in comparison to their expected values, which were determined based on relative probe length or tempo. (Participants should have had a sense of the relative relationships prior to beginning the experimental trials because of the example and practice trials.) For the length data, the mm (i.e., shortest) probes were assigned an expected value of -3, the sm and ms probes were assigned an expected value of -2, the ss probes were assigned an expected value of -1, and the itt probes were assigned an expected value of 0 (cf. Table 2). For the tempo data, all judgments had an expected value of 0, as tempo was not manipulated. Judgments shorter than expected values were interpreted as consistent with boundary extension, as targets extended in memory would make an identical-length probe seem shorter; alternatively, judgments longer than expected were interpreted as consistent with boundary restriction, as targets with boundaries restricted in memory would make an identical-length probe seem longer (see Figure 5).

Data Analyses

Data were initially analyzed in terms of whether response patterns differed from chance. This was done by breaking the responses into <0, 0, and >0 categories (e.g., a –2 response would fall into the <0 category, a 0 response would fall into the 0 category, and a +2 response would fall into the >0 category) and comparing the obtained distribution of responses to a chance distribution of responses. Chi-square statistics clearly showed that responding differed significantly from chance across all probe types (see Appendix I), stimulus organizations (see Appendix J), and stimulus subtypes (also see Appendix J) in both the length and the tempo data, *p*s<.0001. The majority of responses regarding probe length were correct in terms of whether the probe was shorter or longer than the target, ranging from 51.04% (itt probes) to 75.63% (mm probes). The majority of responses regarding tempo were also correct, ranging from 51.67% (sm probes) to 59.38% (mm probes).

Data were then analyzed in terms of a mixed linear model using PROC MIXED in the SAS programming language. Using the length data only, a null model likelihood ratio test indicated that modeling the extra variance in the data was preferable to the null model, $\chi^2(1)=842.54$, $p<.0001$. The best model using a backward selection method determined significant effects of: probe type, $F(4, 2336)=89.39$, $p<.0001$; the stimulus type initially presented (i.e., music or literature), $F(1, 36)=4.23$, $p=.047$; an interaction between probe type and stimulus subtype, $F(12, 2337)=2.21$, $p=.009$; and an interaction between stimulus subtype and musical experience, $F(6, 2335)=2.19$, $p=.04$ (for the full model, including parameter estimates, see Appendix K).

Compared to the baseline target-length (i.e., itt) probe, the ss, $\beta=-.36$, $t(2336)=-3.45$, $p<.0006$, sm, $\beta=-1.00$, $t(2337)=-9.53$, $p<.0001$, ms, $\beta=-.93$, $t(2336)=-8.88$, $p<.0001$, and mm, $\beta=-1.46$, $t(2336)=-13.96$, $p<.0001$, probes were judged as significantly shorter. Additionally, compared to a baseline in which literature stimuli were presented in the first block of trials, probes were judged as shorter overall when the music stimuli were presented in the first block of trials,

β=-.57, *t*(36)=-2.06, *p*=.047. When compared to a baseline of itt probes and random stimulus organization, the oscillating stimuli were judged as longer with sm probes, β=.47, *t*(2338)=2.04, *p*=.04, ms probes, β=.53, *t*(2339)=2.32, *p*=.02, and mm probes, β=.50, *t*(2336)=2.17, *p*=.03. In contrast, the ascending stimuli were judged as shorter when ss probes were utilized, β=-.43, *t*(2337)=-2.14, *p*=.03.

Using the tempo data only, a null model likelihood ratio test indicated that modeling the extra variance in the data was preferable to the null model, $\chi^2(1)=17.89$, *p*<.0001. The best model using a backward selection method determined significant effects of: probe type, *F*(4, 2354)=3.47, *p*=.008, and voice, *F*(2, 2356)=4.01, *p*=.018 (for the full model, including parameter estimates, see Appendix L). Compared to baseline target tempo (i.e., itt), the mm stimuli were judged as slower, β=-.16, *t*(2354)=-2.92, *p*=.004; none of the other probe types were judged as being significantly different in tempo than the target. Compared to the piano stimuli, the female-voice stimuli were judged as faster, β=.11, *t*(2355)=2.77, *p*=.006, although the piano and male-voice stimuli were not judged significantly differently with regard to tempo, β=.01, *t*(2355)=.36, *p*=.72.

Finally, data were analyzed using a set of t-tests to determine whether responses per probe type differed significantly from expected responses, and if so, in what direction. In the length data, this translated into whether or not boundary extension or boundary restriction occurred in the data. In the tempo data, differences from expected responses (in this case, always 0) were not clearly interpretable, but remained of interest for purposes of developing a foundation for future research. In the length data, the overwhelming finding was not boundary extension, but boundary restriction, which was found for all probe types except for the probes that were exactly the same as the target (see Table 2), and this was true for all stimulus types and subtypes (see Appendix M), for random stimuli (see Appendix N), and for both the note and the number stimuli (see Appendix O). In the tempo data, the only probe type for which responses significantly differed from the expected value

Table 2

Length data t-tests comparing mean ratings to expected ratings, Experiment 1

probe type	E(x)	mean	sd	se	df	t	p	effect
mm	-3	-1.48	1.59	.25	39	6.05	<.0001	BR
ms	-2	-0.93	1.13	.18	39	6.00	<.0001	BR
sm	-2	-0.90	1.23	.19	39	5.67	<.0001	BR
ss	-1	-0.42	0.64	.10	39	5.70	<.0001	BR
itt	0	0.04	0.28	.05	39	0.97	.34	none

Note: Probe types are listed from shortest to longest. The E(x) column indicates the expected value to which the mean was compared. BR represents boundary restriction. The p value required for the Bonferroni correction was .05/5=.01.

Table 3

Tempo data t-tests comparing mean ratings to expected ratings, Experiment 1

probe type	E(x)	mean	sd	se	df	t	p	effect
mm	0	-0.14	0.24	.04	39	-3.79	.0005	slower
ms	0	-0.01	0.22	.03	39	-0.30	.76	none
sm	0	0.04	0.33	.05	39	0.80	.43	none
ss	0	-0.03	0.24	.04	39	-0.65	.52	none
itt	0	0.01	0.27	.04	39	0.35	.73	none

Note: Probe types are listed from shortest to longest. The E(x) column indicates the expected value to which the mean was compared; it is 0 in all cases because tempo was not manipulated. The p value required for the Bonferroni correction was .05/5=.01.

was mm, in which the shortest probes were compared to the targets (see Table 3); although the expected mean response was 0, as tempo was not manipulated, the actual mean response was -.14 (*SD*=.24), *t*(39)=-3.79, *p*=.0005 (the p value required for the Bonferroni correction was .05/5=.01). The trend of judging the probe as slower than the target for the mm stimuli continued for sequential stimuli overall, but this trend only reached significance for the ascending subtype (see Appendix P).

There was also a statistically nonsignificant[3] trend in the sequential data toward faster judgments for the sm probe type (see Appendix P). For random stimuli (see Appendix Q), judgments for both the mm stimuli, $t(39)=-3.40$, $p=.002$, and the sm stimuli, $t(39)=-5.52$, $p<.0001$, were significantly slower than the expected value of 0. For both the note and the number stimuli, there was a significant effect of judging the probe as slower than the expected value of 0 for the mm stimuli only (see Appendix R).

Discussion

To summarize the results of Experiment 1, boundary extension did not occur when using simple auditory stimuli. Instead, results consistent with boundary restriction dominated the length ratings, for both sequential and random stimuli, and for both note and number stimuli. The shortest (i.e., mm) probes did result in tempo ratings slower than the expected value of 0, but this result is not clearly interpretable; the tempo result is suggestive, however, of a need for future research, possibly with regard to a temporal dimension of boundary extension or boundary restriction that is unique to audition and/or other domains closely tied to time.

Focusing on the more clearly interpretable length data, it is puzzling that boundary restriction rather than the hypothesized boundary extension occurred. This might have happened for any of several reasons. One possibility is that the simple stimuli were so simple that the auditory excerpt was construed more as an auditory object as opposed to a portion of a continuous, yet truncated, auditory scene, preventing the boundary extension phenomenon from occurring (cf. Gottesman & Intraub, 2002). Another possibility is that some other specific aspect of the stimuli, or their presentation, prevented the expected effect of boundary extension—that is, the duration of the targets, probes, and ISIs might not have been optimal conditions for boundary extension to occur.

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[3] In the present paper, a statistically nonsignificant trend is defined as a statistic for which the p value is less than .05, but is greater than the p value required by the Bonferroni correction. These trends in the data are mentioned because of the conservative nature of the Bonferroni correction (cf. Benjamini & Hochberg, 2000) and the controversy surrounding its use (e.g., regarding limited use of the Bonferroni correction, see Perneger, 1998; regarding the use of effect sizes instead of multiple significance tests, see Garamszegi, 2006; but regarding the preference of significance tests over effect size estimates, see Chow, 1988).

Finally, there is also the possibility that boundary extension does not occur in the auditory domain. In fact, it was probable based on the present results that boundary restriction occurs in the auditory domain, rather like a time compression of events in memory, given the temporal nature of auditory stimuli.

Interestingly enough, participants who encountered music as the first block in the experiment exhibited less boundary restriction than did other participants. It is possible that the presence of music primed extrapolation mechanisms that continued to be active during the second (i.e., literature) block of trials. Along this line of reasoning, when participants received literature stimuli first, the extrapolation mechanisms were not as activated during the first block of trials. This asymmetry might have occurred because extrapolation is more likely for more continuous stimuli (Freyd, 1987), and music might be perceived as more continuous, whereas language might be perceived as more discrete (unless the continuous landscape is initially primed by first being exposed to music).

Concluding that conditions for boundary extension were not appropriate in Experiment 1, or that boundary extension does not occur in the auditory domain (possibly even being usurped by boundary restriction), is premature prior to an examination of boundary extension using more complex stimuli. Accordingly, Experiment 2 addressed the question of auditory boundary extension using more complex stimuli.

Experiment 2

Although boundary extension was not found in Experiment 1, very simple stimuli were being used that might not have been complex enough to be considered an auditory scene. Given that a complex scene is thought to be required for boundary extension to occur (cf. Bertamini et al., 2005; Gottesman & Intraub, 2002, 2003; Intraub et al., 1998; Legault & Standing, 1992), it was important to examine auditory boundary extension using stimuli that might be more clearly or strongly perceived to be part of an auditory scene. One possibility is to look for boundary extension in more complex and ecologically valid stimuli—that is, music from piano literature and English literature (in original or translated forms) instead of the more simplistic musical tones and numbers used in Experiment 1. Experiment 2 was therefore a replication of Experiment 1 (although the stimulus subtype was no longer valid as a nesting condition), but using more complex and ecologically valid stimuli.

Method

Participants

Forty-three participants with self-reported normal hearing were recruited and compensated in the same manner as in Experiment 1. Three participants' data were eliminated from the analyses: one because of a computer malfunction, one because of difficulty concentrating, and one because of confusion regarding the experimental task. As in Experiment 1, recruitment was not based on musical expertise, though musical experience was documented at the conclusion of the experiment. No participant had participated in Experiment 1.

Apparatus

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

Stimuli and Response Materials

Music stimuli. Music stimuli were taken from the piano literature, one stimulus per composer, composed over a wide range of dates. Most of the stimuli were gathered from the compilation entitled *Piano classics: 90 timeless pieces from the masters* (1987), although other sources were also utilized (for a full listing of the composers, dates, musical pieces, and the sources from which the written music was obtained, see Appendix S). As with Experiment 1, all of the musical stimuli were recorded by a professional pianist on a Steinway grand piano. Recordings were originally laid down as approximately one minute in duration and then were edited to excerpts that were between 9 and 14 seconds in duration (for the target stimuli), with the goal of making the stimuli as close to 12 seconds in duration as possible, but retaining musical integrity.

Literature stimuli. Literature stimuli were taken from English 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/, website accessed June 2007; for a full listing of the authors, dates, literary works, and the sources from which the works were obtained, see Appendix T). As with Experiment 1, all of the spoken stimuli were recorded separately by both a male voice and a female voice, and presentation of either male or female versions of each stimulus was counterbalanced across participants, with each participant receiving half of the stimuli spoken in a male voice and the other half of the stimuli spoken in a female voice.

Recordings of the female voice lasted approximately 1 minute in duration and were then edited down to between 9 and 22 seconds (for the target stimuli) using the Audacity editing program; although the goal was to get the target stimuli as close to 12 seconds in duration as possible, and meaningfulness was considered more important than was absolute length. By allowing some variability of stimulus length, we were able to maintain the desired meaningfulness, thus eliminating the possibility of boundary extension based on object completion (cf. Intraub et al., 2002). Once the female tracks were complete, then the male tracks were recorded using the excerpts retained in the female 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, and not exact duration. Although the durations of the male and female excerpts were similar, they were not identical.

Probes. The probes were designed in a similar fashion to the probes used in Experiment 1—that is, mm, ms, sm, ss, and itt probes were used. The probe types maintained roughly the same proportionate length to the target as those in Experiment 1 (i.e., “much” was operationalized as approximately 25% of target length, and “some” was operationalized as approximately 10% of target length); however, this did not translate into a particular number of notes or words. Rather, an effort was made to make the probes make sense, in terms of either music or the English language. Once again, completeness of a thought or a phrase was considered to be more important than the exact proportionate length. In all cases, the probe lengths maintained their length pattern, with the probes from shortest to longest being: mm, ms and sm, ss, itt. As in Experiment 1, each participant received one probe per target, but all participants received the same number of each of the probe lengths (i.e., mm, ms, sm, ss, itt) throughout the course of the experiment.

Response materials. Response materials were the same as those used in Experiment 1.

Table 4

Schematic, Experiment 2

	LENGTH OF PROBE COMPARED TO TARGET				
STIMULUS TYPE	much shorter at beginning/ much shorter at end (mm)	much shorter at beginning/ some shorter at end (ms)	some shorter at beginning/ much shorter at end (sm)	some shorter at beginning/ some shorter at end (ss)	identical to target (itt)t
music, authentic	6	6	6	6	12 (6+6)
literature, authentic	6	6	6	6	12 (6+6)

Note: The probes were lengthened or shortened from the beginning and from the end, or were the same as the targets. The numeral in each cell represents the number of items per cell per participant. Additional target-length probes were included for purposes of quantitatively presenting more lengthy probes; however, these non-manipulated items were not included for purposes of data analysis and are shown in the table as the +6 items. Each participant received 72 items (of which 60 were used for analysis) delivered in two blocks with a break between: either music followed by numbers, or numbers followed by music, counterbalanced across participants. Testing occurred immediately after each stimulus presentation. Much shorter means approximately 25% of the selection was eliminated; some shorter means that approximately 10% of the selection was eliminated, though there was some latitude to account for coherence within sound chunks; these percentages are similar to the percentages eliminated in Experiment 1 (after converting the number of notes that were eliminated into the proportion of the stimulus that was eliminated).

Design

As seen in Table 4, the design of the experiment was probe length (5: mm, ms, sm, ss, itt) x stimulus type (2: music, literature). As in Experiment 1, twelve additional target-length stimuli were included in the experimental trials that were not included in the probe manipulations but instead served as additional long probes, given that the majority of probes were shorter than the target. Although data were collected for these additional items, the data from these items were not included in the analyses.

Procedure

The procedure for Experiment 2 was similar to that of Experiment 1, with the only difference being in the type of stimuli presented to the participants (i.e., simple stimuli in Experiment 1 and more ecologically valid stimuli in Experiment 2).

Results

Interpreting Judgment Results

Judgments were interpreted in the same manner as Experiment 1 (cf. Figure 5).

Data Analyses

Data were initially analyzed in terms of whether the pattern of responses differed from chance. This was done by breaking down the responses in the same manner as in Experiment 1. As shown in Appendix U, and replicating the pattern of results from Experiment 1, Chi-Square statistics clearly showed that responding differed significantly from chance across all probe types, ps<.0001. The majority of responses regarding probe length were correct in terms of whether the probe was shorter or longer than the target, ranging from 64.53% (itt probes) to 86.82% (mm probes). The majority of responses regarding tempo were also correct, ranging from 51.36% (itt probes) to 60.08% (mm probes).

Data were then analyzed in terms of a mixed linear model using PROC MIXED in the SAS programming language. Using a compound symmetry covariance structure, when modeling the length data, the null model likelihood ratio test indicated that modeling the additional variance was preferable to the null model, $\chi^2(1)=846.85$, $p<.0001$. There were significant main effects of probe type, $F(4, 2512)=223.03$, $p<.0001$, block (literature or music), $F(1, 2526)=6.37$, $p=.01$, and stimulus voice (male, female, or piano), $F(2, 2516)=3.79$, $p=.02$, and significant interaction effects of probe type with musical experience, $F(8, 2512)=4.59$, $p<.0001$, and probe type with stimulus voice, $F(8, 2513)=2.56$, $p=.009$ (for the full model, see Appendix V).

The mm, $\beta=-2.34$, $t(2512)=-17.19$, $p<.0001$, ms, $\beta=-1.71$, $t(2512)=-12.55$, $p<.0001$, sm, $\beta=-1.68$, $t(2512)=-12.36$, $p<.0001$, and ss, $\beta=-1.12$, $t(2512)=-8.20$, $p<.0001$, probe types were all judged as significantly shorter than the itt probes. Additionally, ratings for literature stimuli were shorter than the ratings for music stimuli, $\beta=-.43$, $t(2526)=-2.52$, $p=.01$. Although there was a main effect of stimulus voice, the female-voice stimulus ratings only marginally differed from the piano stimulus ratings, $\beta=.37$, $t(2542)=1.84$, $p=.07$. Interestingly, when both probe type and stimulus voice were taken into account, the female-voice stimuli received greater boundary extension (or less boundary restriction) when compared to the piano stimuli, but only for the mm, $\beta=-.29$, $t(2513)=-2.02$, $p=.04$, sm, $\beta=-.40$, $t(2513)=-2.79$, $p=.005$, and ss, $\beta=-.54$, $t(2513)=-3.75$, $p=.0002$, probe types. When both probe type and musical experience were taken into account, persons with high and low amounts of musical experience significantly differed from those with medium amounts of musical experience; in this case, the ratings of those with medium experience reported judgments indicative of greater boundary restriction compared to the other two groups (cf. Appendix V). The effect was slightly more pronounced for those with low amounts of musical experience with the ms, $\beta=.59$, $t(2512)=4.09$, $p<.0001$, and the ss, $\beta=.46$, $t(2512)=3.15$, $p=.002$, stimuli, and slightly more pronounced for those with high amounts of musical experience with the mm, $\beta=.79$, $t(2512)=4.32$, $p<.0001$, and the sm, $\beta=.68$, $t(2512)=3.70$, $p=.0002$, stimuli.

When modeling the tempo data, the null model likelihood ratio test indicated that modeling the additional variance was preferable to the null model, $\chi^2(1)=81.30$, $p<.0001$. Only stimulus voice (female, male, or piano) was a significant factor in predicting responses, $F(2, 2552)=11.94$, $p<.0001$. The female-voice stimuli were judged as significantly faster than the piano stimuli, $\beta=.20$, $t(2562)=4.77$, $p<.0001$, although the male-voice stimuli were not judged as significantly differing in tempo from the piano stimuli, $\beta=.03$, $t(2560)=.78$, $p=.44$.

Table 5

Length data t-tests comparing mean ratings to expected ratings, Experiment 2

probe type	E(x)	mean	sd	se	df	t	p	effect
mm	-3	-1.78	1.10	0.17	42	7.29	<.0001	BR
ms	-2	-1.24	0.85	0.13	42	5.89	<.0001	BR
sm	-2	-1.33	0.90	0.14	42	4.85	<.0001	BR
ss	-1	-0.84	0.56	0.09	42	1.88	.07	none
itt	0	0.10	0.26	0.04	42	2.76	.009	BR

Note: Probe types are listed from shortest to longest. The E(x) column indicates the expected value to which the mean was compared. BR represents boundary restriction. The p value required for the Bonferroni correction was .05/5=.01.

Table 6

Tempo data t-tests comparing mean ratings to expected ratings, Experiment 2

probe type	E(x)	mean	sd	se	df	t	p	effect
mm	0	0.10	0.34	.05	42	1.89	.07	none
ms	0	0.09	0.28	.04	42	1.99	.05	none
sm	0	0.12	0.39	.06	42	1.97	.06	none
ss	0	0.06	0.30	.05	42	1.39	.17	none
itt	0	0.06	0.33	.05	42	1.20	.24	none

Note: Probe types are listed from shortest to longest. The E(x) column indicates the expected value to which the mean was compared; it is 0 in all cases because tempo was not manipulated. The p value required for the Bonferroni correction was .05/5=.01.

Finally, data were analyzed using a set of t-tests to determine whether responses per probe type differed significantly from expected responses, and if so, in what direction. In the length data, the overwhelming finding was once again not boundary extension, but boundary restriction, which was found for all but the ss probe type (see Table 5). A similar pattern of results was upheld for both the music and the literature stimuli: boundary restriction was found for all probe types for the music stimuli, and boundary restriction was likewise found for all but the ss and itt probe types for the literature stimuli (see Appendix W). In the tempo data, responses did not significantly differ from the expected value of 0 (see Table 6). Although none of the tempo ratings for music stimuli were significantly different from their expected value of 0, the tempo ratings for literature stimuli were faster than their expected value of 0 for the ms, and ss probe types, and there was a statistically nonsignificant trend toward faster tempo ratings for the mm probe type (see Appendix X).

Discussion

Boundary extension did not occur for more ecologically valid auditory stimuli in Experiment 2. As in the data of Experiment 1, results consistent with boundary restriction dominated the length ratings. Contrary to the data of Experiment 1, there was an indication of a trend toward faster (as opposed to slower) tempo ratings for some of the probes (i.e., mm, ms, and ss), although this effect was significant only for the literature stimuli. Again, the results with regard to tempo are not clearly interpretable, although they suggest a promising new line of research, and so discussion will henceforth focus on the length data.

The possibility suggested in Experiment 1 that the stimuli were too simple to evoke an auditory scene is inconsistent with the results of Experiment 2, which found boundary restriction with much more complex, ecologically valid stimuli. The other two explanations of the boundary restriction results from Experiment 1 are consistent with the results from Experiment 2: (a) either some specific aspect of the stimuli, or their presentation, prevented the expected effect of boundary extension, or (b) boundary extension does not occur in the auditory domain, but boundary restriction occurs instead. However, before drawing any conclusion regarding these options, it was necessary to further examine target/probe presentation.

Experiment 3

Experiment 3 was based upon Intraub et al.'s (1992, Experiment 3) study in which each participant was presented with only one type of view (close-up, prototypical, or wide-angle) for which an identical probe was presented. Intraub et al. (1992, Experiment 3) found boundary extension even when presentation types were not mixed (i.e., only one viewing distance—close-up, prototypical, or wide-angle—was presented to a given participant); that is, boundary extension was not due to normalization. In a modification of Intraub et al.'s (1992) procedure, participants in Experiment 3 were presented with target stimuli followed by only target-length probes. The purpose of Experiment 3 was to determine whether or not boundary restriction would still be found under such circumstances.

Method

Participants

Forty-three participants with normal hearing were recruited and compensated in the same manner as in Experiments 1 and 2. Three additional participants' data were eliminated from the analyses. One participant was confused regarding the directions, one participant reported having had two concussions during the month previous to the experiment and consequentially experiencing headaches and difficulty concentrating during the experiment, and one participant experienced an unanticipated disruption in the laboratory environment. As in Experiments 1 and 2, recruitment was not based on musical experience, though musical experience was documented at the conclusion of the experiment. No participant had participated in either Experiment 1 or Experiment 2.

Apparatus and Materials

The apparatus was the same as that of Experiments 1 and 2. The stimuli were a subset of 24 stimulus (12 music, 12 text) items from Experiment 2, utilizing only itt probes (thus leaving target and probe as identical; see Appendices S and T). The response sheets were the same as those used in Experiment 2, but adjusted from 72 items to 24 items.

Table 7

Schematic, Experiment 3

	LENGTH OF PROBE COMPARED TO TARGET
STIMULUS TYPE	same as target
music	12
text	12

Note: All target/probe presentations were identical in this experiment. The numeral in each cell represents the number of items per cell per participant; each participant received 24 items delivered in two blocks with a break between: either all music followed by all text, or vice versa. Testing occurred immediately after each stimulus presentation.

Design

The design for Experiment 3 was a simple manipulation of stimulus type (music or literature). The dependent measures were the same as those used in Experiments 1 and 2. For a schematic of the experimental design, see Table 7.

Procedure

The procedure for Experiment 3 was similar to that of Experiments 1 and 2, but with fewer trials. The duration of the experiment was approximately 30-35 minutes.

Results

Interpreting Judgment Results

As in Experiments 1 and 2, judgments were interpreted in comparison to their expected values, which were determined based on relative probe length. For Experiment 3, however, all expected values were 0, as all targets and probes were identical.

Data Analyses

Several participants were able to ascertain that all of the targets and probes were identical throughout the experiment. This realization typically occurred approximately halfway through the experimental trials. Data for all of the analyses were therefore examined not only in full, but also narrowing the data set to the first block of trials.

Data were initially analyzed in terms of whether the pattern of responses differed from chance. As in Experiments 1 and 2, Chi-Square analyses indicated that responding occurred at levels different from chance, $p<.0001$ (for further details, see Appendix Y). Approximately half of the length judgments were correct in both the overall data set (49.17% correct) and the block 1 data set (50.42% correct). Approximately one-third of tempo judgments were correct in both the overall data set (33.33% correct) and the block 1 data set (30.21% correct).

Data were then analyzed in terms of a mixed linear model using PROC MIXED in the SAS programming language. Using the length data and a backward selection method, a null model likelihood ratio test indicated that modeling the extra variance in the data was preferable to the null model, $\chi^2(1)=6.28$, $p=.01$; however, the last, and only remaining, parameter retained in the model, stimulus voice (female, male or piano), did not exert a statistically significant effect, $F(2, 918)=1.60$, $p=.20$, *ns*. Using the length data from block 1 only, the null model likelihood ratio test indicated that the null model was preferable, $\chi^2(1)=2.85$, $p=.09$, *ns*. Likewise, mixed linear models using tempo data indicated that the null models were preferable, for both the overall data set, $\chi^2(1)=.07$, $p=.79$, *ns*, and the data from block 1 only, $\chi^2(1)=.32$, $p=.57$, *ns*.

Finally, data were analyzed using a set of t-tests to determine whether responses per probe type differed significantly from expected responses. Expected responses were uniformly 0 for Experiment 3, given that each probe was identical to its associated target.

Table 8

Length data t-tests comparing mean ratings to expected ratings, All data, Experiment 3

Stimulus block	E(x)	mean	sd	se	df	t	p	effect
Overall	0	0.04	0.24	.04	39	1.16	.25	none
Music	0	0.09	0.36	.06	39	1.55	.13	none
Literature	0	0.00	0.32	.05	39	0.04	.97	none

Note: The E(x) column indicates the expected value to which the mean was compared. The p value required for the Bonferroni correction was .05/15=.003.

Table 9

Length data t-tests comparing mean ratings to expected ratings, Block 1 data only, Experiment 3

Stimulus block	E(x)	mean	sd	se	df	t	p	effect
Overall	0	0.12	0.30	.05	39	2.48	.02	trBR
Music	0	0.15	0.34	.08	19	2.03	.06	none
Literature	0	0.08	0.26	.06	19	1.41	.18	none

Note: Overall indicates the inclusion of data from both the music and the literature blocks of trials. The E(x) column indicates the expected value to which the mean was compared. trBR represents a statistically nonsignificant trend (i.e., p-value less than .05, but greater than the p-value required by the Bonferroni correction) toward boundary restriction. The p value required for the Bonferroni correction was .05/15=.003.

In the length data (for a brief overview of the results, see Table 8; for a more complete listing of results, see Appendix Z), there was neither a boundary restriction or boundary extension effect when all of the data were included (*M*=.04, *SD*=.24), *t*(39)=1.16, *p*=.25, *ns*. Restricting the analysis of the length data to block 1 data only (for a brief overview of the results, see Table 9; for a more complete listing of results, see Appendix AA) yielded a statistically nonsignificant trend toward boundary restriction (*M*=.12, *SD*=.30), *t*(39)=2.48, *p*=.02 (p required for Bonferroni=.05/15=.003).

Overall, there was no significant directional distortion in the tempo data, both when considering all of the data, *M*=.02, *SD*=.23, *t*(39)=.62, *p*=.54, *ns*, and when considering only the block 1 data, *M*=.06, *SD*=.30, *t*(39)=1.35, *p*=.18, *ns*. There was, however, a trend toward judging the probe as faster than the target for the literature trials in which the female voice was speaking, both when considering the aggregate data set (*M*=.21, *SD*=.42), *t*(39)=3.19, *p*<.003, and the data set that was limited to the first block only (*M*=.30, *SD*=.47), *t*(19)=2.87, *p*=.01, although the latter effect failed to reach statistical significance (for a full listing of results, see Appendices BB-CC).

Discussion

To summarize the results of Experiment 3, there was a statistically nonsignificant trend toward boundary restriction in the length data when considering only the data from the first block of trials. The effect of boundary restriction was weaker, but in the same direction, as the effects of boundary restriction in Experiments 1 and 2. The pattern of boundary restriction with mixed probe presentations (in Experiments 1 and 2) versus identical target/probe presentations (in Experiment 3) is in concert with Intraub et al.'s (1992) observation that wide-angle views exhibited more restriction when presented with prototypes than when presented with wide-angle (i.e., identical) views. This effect went away when including the overall data set, presumably because participants had realized that all target/probe presentations were identical within a given trial by the time the second block of trials commenced. There was no significant directional distortion in the tempo data, either for the overall data set or the block 1 data set.

The results from Experiment 3, along with the results from Experiment 1 and Experiment 2, initially appear inconsistent with the literature in visual boundary extension. However, before concluding that boundary restriction occurs in the auditory domain and that boundary extension does not occur, it is necessary to examine yet another alternative hypothesis. It is possible that the results from Experiment 3, along with the results from Experiments 1 and 2, are consistent with results in the visual boundary extension literature if consistently longer auditory targets were actually analogous to wide-angle stimuli. In this case, and if the extension-normalization hypothesis (Intraub et al., 1992) were to hold true at a delay test, then either boundary restriction or no effect would be expected to occur (cf. Intraub et al., 1992, Experiments 2 and 3), which is what was found in the present Experiments 1-3.

Building on the possibility that auditory stimuli might even be more analogous to visual stimuli than one might initially suspect, two additional experiments (Experiments 4 and 5) were designed to investigate close-up, prototypic, and wide-angle auditory scenes using the basic paradigms set forth in Intraub and Richardson's (1989) and Intraub et al.'s (1992) boundary extension experiments. Participants were required to compare/differentiate between the different auditory scene presentations (i.e., close-up, prototypic, and wide-angle), with each presentation being used as a target and as a probe across the entire stimulus set. Because of a concern regarding possible normalization, only two types of stimuli (i.e., close-up and prototype, or prototype and wide-angle) were compared against one another for a given participant, thereby eliminating the possibility of convergence upon the prototypical auditory scene. Experiment 4 focused on the comparison between close-up and prototype stimuli, and Experiment 5 focused on the comparison between prototype and wide-angle stimuli. Experiment 5 was a better examination of the perceptual schema and memory schema hypotheses. Any boundary restriction, which was expected to occur with the wide-angle stimuli only at a delay test, would run counter to the perceptual schema hypothesis, which always predicts boundary extrapolation. Any directional distortion for prototypical stimuli would run counter to the memory schema hypothesis, which predicts boundary restriction for wide-angle stimuli but no directional distortion for prototypical stimuli at a delay test (Intraub et al., 1992).

If the data of Experiments 1-3 indeed mirror those of Intraub et al. (1992) at a delayed test, it is probable that Experiment 5 should show normalization to the mean of the stimulus set, with boundary extension occurring for prototypical stimuli and boundary restriction occurring for wide-angle stimuli. Unfortunately, the appropriate ISI for an immediate test[4] has not yet been determined, but that will be an appropriate direction for future study should evidence of boundary extension be found in Experiments 4 and 5.

Simply stated, auditory boundary extension was expected to occur and to be greater for close-up auditory views than for prototypical auditory views (Intraub et al., 1992, Experiment 1). Further, boundary restriction was expected with wide-angle auditory views (Intraub et al., 1992, Experiment 2). If this pattern occurred, it would lend support to the extension-normalization model (Intraub et al., 1992), and would thus be evidence that boundary extension and boundary restriction are amodal[5] (cf. Intraub, 2002; Gottesman & Intraub, 2002) and multisensory (cf. Intraub, 2004) phenomena.

Experiment 4

Intraub and Richardson (1989, Experiment 2) examined boundary extension for close-up and wide-angle scenes using both recall and recognition tests with both immediate and 48-hour retention intervals between stimulus presentation and test. Intraub et al. (1992, Experiment 1) replicated Intraub and Richardson's recognition test results using close-up and prototypical versions of a different set of stimulus pictures. Likewise, Experiment 4 examined boundary extension for close-up and prototypic auditory scenes (see Intraub et al., 1992, Experiment 1) using a recognition task.

For each of the stimuli used in Experiment 2, close-up, prototype, and wide-angle stimuli were determined, effectively decreasing the number of possible probe types from 5 (the mm, ms, sm, ss, and itt probes from Experiment 2) to 3 (close-up, prototype, and wide-angle). Assuming that probe length, and thus total amount of information present in a scene (not simply the amount of information inherent in a given object itself) was related to stimulus length, the mm probes from Experiment 2 (i.e., the shortest probes, approximately 50% of the length of the itt probes) were

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[4] The immediate or delay tests, as defined here, are based on results that were analogous to those of Intraub et al. (1992). It is being suggested that the seven-second ISI in Experiments 1-3 was analogous to a delay test in the visual domain. In practical terms, testing was immediate, in that only seven seconds lapsed between target presentation and probe presentations.

[5] Amodal refers to the indefinite continuation or extrapolation of an object or scene behind an occluded view (e.g., Kellman & Shipley, 1991; Kellman, Yin, & Shipley, 1998).

chosen as the close-up stimuli, the itt probes from Experiment 2 (i.e., the longest probes) were chosen as the wide-angle stimuli, and the ss probes from Experiment 2 (i.e., the closest probe length to mid-way between the mm and the itt probes, at approximately 80% of the length of the itt probes[6]) were designated as prototype stimuli. The close-up and prototype stimuli were used as both targets and probes in Experiment 4; the prototype and wide-angle stimuli were used as both targets and probes in Experiment 5.

Intraub et al. (1992, Experiments 2 and 3) examined boundary extension using both immediate and delayed retention intervals and found differences between results at an immediate test versus results at a delay test; however, only the seven-second retention interval that was used in the present Experiments 1-3 was used in Experiments 4 and 5. This allowed for a simple determination of whether the delay condition in Intraub et al.'s (1992) study and the seven-second retention interval in Experiments 1-3 were analogous to one another—an expectation based on boundary restriction findings when using wide-angle stimuli in Intraub et al.'s (1992) results, as well as the results of the present Experiments 1-3. Results of Experiment 4 were expected to replicate the results of Intraub et al. (1992, Experiments 1 and 3) at a delay test, with the most boundary extension occurring with close-up scenes, due to the greater need for extrapolation, and either less boundary restriction or no directional distortion occurring with prototypical scenes, due to a lesser need for extrapolation combined with normalization to the mean of the stimulus set. If close-up and prototypic auditory scenes are analogous to close-up and prototypic visual scenes, as is being supposed in the current set of experiments, boundary restriction will not be theoretically relevant until Experiment 5, in which prototypic and wide-angle auditory scenes were examined.

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[6] The ms and sm probes from Experiment 2 were approximately 65% of the length of the itt probes. The ideal prototypical probe would have been 75% of the length of the itt probe. Because of the slight variability in probe lengths that was allowed for purposes of maintaining meaningfulness of the auditory excerpts, the ss (i.e., approximately 80% of itt-length) probes were considered to be acceptable prototypes.

Method

Participants

Thirty-five participants with self-reported normal hearing were recruited and compensated in the same manner as in Experiments 1-3. Three additional participants were eliminated from the analyses because they were confused over some aspect of the experimental task—one participant was confused on the literary portion only, one participant was initially confused regarding whether or not to make tempo judgments (it appeared to the experimenter that this participant could tell that tempo was not manipulated despite the instructions to make a judgment regarding tempo), and one participant was just generally confused. The remainder of the participants, however, found the task to be straightforward and easy to understand. No participant had participated in Experiments 1-3.

Apparatus and Materials

Apparatus. The apparatus was the same as those used in Experiments 1-3.

Materials. Close-up and prototypical stimuli were used in Experiment 4. As previously mentioned, stimuli were the same as in Experiment 2, except that mm stimuli were used to represent close-up stimuli (as both targets and probes) and ss stimuli were used to represent prototypic stimuli (as both targets and probes). Both music and language stimulus blocks were utilized.

Design

The design for the experiment was: 2 (stimulus type: music, literature) x 4 (test condition: CC, close-up target followed by close-up probe; PP, prototype target followed by prototype probe; CP, close-up target followed by prototype probe; and PC, prototype target followed by close-up probe). As in Experiments 1 and 3, each participant received only 1 target/probe pairing per stimulus, and stimulus presentation and stimulus order were counterbalanced across participants. Counterbalancing measures similar to those used in Experiment 2 were implemented. The dependent

Table 10

Schematic, Experiment 4

TARGET/PROBE COMPARISONS	STIMULUS TYPE music	literature
CC	9	9
PP	9	9
CP	9	9
PC	9	9

Note: C represents close-up presentation; P represents prototypic presentation. Numbers indicate the number of trials per individual per category, for a total of 72 trials.

measures were the same as those utilized in Experiments 1-3. For a schematic of the experimental design, see Table 10.

Procedure

The procedure was conducted in a similar manner to Experiments 1-3. Two blocks of counterbalanced music trials and literature trials were presented, with one quarter of the total stimulus set within each block of trials representing each of the CC, PP, CP, and PC test conditions. Each auditory probe was presented seven seconds after its associated target, and participants were asked to make judgments using the traditional five-point scale (-2 to +2) indicating their perception of the relative length of the probe compared to the target and the relative speed of the probe compared to the target (although tempo was not manipulated). Although an extended seven-point version of the scale was needed in Experiments 1-3 due to a larger number of probe types, this extended version was no longer necessary. The traditional scale provided both the benefit of simplicity and the benefit of a closer replication of the visual boundary extension methodology. As in Experiments 1-3, a brief questionnaire (see Appendix B) was administered to all participants at the conclusion of the experimental trials but prior to debriefing.

Results

Interpreting Judgment Results

Judgments were interpreted in comparison to their expected values, which were determined based on relative target/probe length or tempo. (Participants should have had a sense of the relative relationships prior to beginning the experimental trials because of the example and practice trials.) For the length data, the CC and PP comparisons were assigned an expected value of 0, the CP comparison was assigned an expected value of +1, as the probe was longer than the target, but not by an excessive amount, and the PC comparison was assigned an expected value of -1, as the probe was shorter than the target, but not by an excessive amount. For the tempo data, all judgments had an expected value of 0, as tempo was not manipulated. Again, judgments shorter than expected values were interpreted as consistent with boundary extension, as targets extended in memory would make an identical-length probe seem shorter, and judgments longer than expected were interpreted as consistent with boundary restriction, as targets with boundaries restricted in memory would make an identical-length probe seem longer (cf. Figure 5).

Data Analyses

Data were initially analyzed in terms of whether the pattern of responses differed from chance. As in Experiments 1-3, Chi-Square analyses indicated that responding occurred at levels different from chance, $p<.0001$ (for further details, see Appendix DD). The majority of responses in the length data were correct, with values ranging from 65.24% (PP comparisons) to 78.41% (PC comparisons). For the most part, the majority of responses in the tempo data were also correct, with values ranging from 49.37% (PP comparisons) to 57.30% (CC comparisons).

Data were then analyzed in terms of a mixed linear model using PROC MIXED in the SAS programming language. Using a compound symmetry covariance structure, when modeling the length data, the null model likelihood ratio test indicated that modeling the additional variance was preferable to the null model, $\chi^2(1)=34.22$, $p<.0001$. There were significant main effects of comparison type, *F*(3, 2470)=753.47, $p<.0001$, block (literature or music), *F*(1, 2470)=11.10, $p=.0009$, and significant interaction effects of comparison type with block, *F*(3, 2470)=27.24, $p<.0001$, and comparison type with musical experience, *F*(6, 2470)=6.10, $p<.0001$ (for the full model, see Appendix EE)[7].

PC comparisons were judged as significantly shorter than the baseline PP comparisons, $\beta=-1.37$, *t*(2470)=-16.04, $p<.0001$, as were CC comparisons, $\beta=-.32$, *t*(2470)=-3.75, $p=.0002$. Conversely, CP comparisons were judged as longer than the baseline PP comparisons, $\beta=.81$, *t*(2470)=9.48, $p=.0001$. Literature stimuli were judged as significantly shorter than the music stimuli, $\beta=-.14$, *t*(2470)=-2.29, $p=.02$. For the CC and CP comparisons, literature stimuli were judged as longer than baseline, $\beta=.19$, *t*(2470)=2.17, $p=.03$, and $\beta=.70$, *t*(2470)=8.16, $p<.0001$, respectively; however, the literature stimuli were not judged as significantly different from baseline for the PC comparisons, $\beta=.07$, *t*(2470)=.84, $p=.40$. CC comparisons were judged as longer than baseline when judged by participants with a high level of musical experience, $\beta=.25$, *t*(2470)=1.92, $p=.05$, but CC comparisons were not judged significantly different from baseline when judged by participants with a low level of musical experience, $\beta=.15$, *t*(2470)=1.54, $p=.12$. PC comparisons, however, were judged as longer than baseline when judged by participants with a low level of musical experience, $\beta=.27$, *t*(2470)=2.82, $p=.005$, but not when judged by participants with a high level of musical experience, $\beta=.11$, *t*(2470)=.87, $p=.38$. CP comparisons were judged as shorter than baseline when judged by participants with a low level of musical experience, $\beta=-.25$, *t*(2470)=-2.64, $p=.008$, but not when judged by participants with a high level of musical experience, $\beta=-.12$, *t*(2470)=-.91, $p=.36$.

When modeling the tempo data, the null model likelihood ratio test indicated that modeling the additional variance was marginally preferable to the null model, $\chi^2(1)=3.15$, $p<.08$. There was a

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[7] A model including the additional parameters of (a) the stimulus type presented in the first block of trials and (b) an interaction between comparison type and the stimulus type presented in the first block of trials, was also indicated as being preferable to the null model using the null model likelihood ratio test, $\chi^2(1)=34.22$, $p<.0001$. The model with the additional parameters included did not differ significantly from the model presented in the main text, however; differences in -2 log likelihood values and a Chi-Square distribution were utilized to make this assessment, $\chi^2(2)=2.7$, p>.05.

Table 11

Length data t-tests comparing mean ratings to expected ratings, Experiment 4

comparison	E(x)	mean	sd	se	df	t	p	effect
CC	0	-0.02	0.19	.03	34	-0.75	.46	none
CP	1	1.11	0.54	.09	34	1.19	.24	none
PC	-1	-1.09	0.55	.09	34	-1.01	.32	none
PP	0	0.09	0.20	.03	34	2.68	.01	BR

Note: The E(x) column indicates the expected value to which the mean was compared. BR represents boundary restriction. The p value required for the Bonferroni correction was .05/4=.0125.

Table 12

Tempo data t-tests comparing mean ratings to expected ratings, Experiment 4

comparison	E(x)	mean	sd	se	df	t	p	effect
CC	0	-0.03	0.17	.03	34	-1.11	.27	none
CP	0	-0.05	0.22	.04	34	-1.46	.15	none
PC	0	0.07	0.23	.04	34	1.82	.08	none
PP	0	-0.07	0.16	.03	34	-2.66	.01	slower

Note: The E(x) column indicates the expected value to which the mean was compared. The p value required for the Bonferroni correction was .05/4=.0125.

significant main effect of comparison type, $F(3, 2476)=3.79$, $p=.01$; however, none of the parameter estimates significantly differed from baseline, *p*s>.05 (for the full model, see Appendix FF). There was also a significant interaction between comparison type and block, $F(3, 2476)=2.72$, $p=.04$. The literature stimuli were judged as significantly faster than baseline for the PC comparisons, $\beta=.20$, $t(2476)=2.22$, $p=.03$.

Finally, data were analyzed using a set of t-tests to determine whether or not responses were directionally distorted compared to expected values. As seen in Table 11, for the length data, boundary restriction occurred for the PP comparison type, $t(34)=2.68$, $p=.01$. The same general pattern held for the music stimuli, with boundary restriction occurring for the PP comparison type, *t*(34)=2.84, *p*=.008; for the literature stimuli, boundary restriction occurred for the CP comparison type, *t*(34)=3.81, *p*=.0006 (see Appendix GG). The only directional distortion in the tempo data was with the PP comparisons, in which the probes were judged as slower than their associated targets, *t*(34)=-2.66, *p*=.01 (see Table 12).

Discussion

It was hypothesized that shorter-duration (and analogously more close-up) probes would lead to auditory boundary extension due to a need to fill in the periphery of the auditory scene. Although one might argue that the shorter-duration auditory stimuli are not perceived as being "closer," Bertamini et al. (2005) demonstrated that boundary extension is not due to the effects of object magnification; rather, boundary extension seems to be directly related to missing information peripheral to the visible scene (cf. Intraub et al., 1992; see also Hochberg, 1986). If auditory boundary extension was directly related to missing peripheral information leading to extrapolation, however, curtailing the available information within the auditory scene (i.e., when close-up targets were presented) should have been sufficient to provide an environment conducive to boundary extension. This was not the case. Although the data for the CC comparisons were in the direction of boundary extension (though nonsignificantly), the data for the CP comparisons were in the direction of boundary restriction, in the opposite direction from predictions (but also nonsignificantly). Additionally, prototypical target presentations were expected to evidence either boundary extension or no boundary distortion, based on the research of Intraub et al. (1992). Boundary restriction occurred with the PP comparisons, however, indicating that the prototypical stimuli were being construed as relatively wider-angle auditory scenes.

The results of Experiment 4 appear to possibly reflect the pattern of restrictive drift that Intraub et al. (1992, Experiment 3) found in their data, in which responses migrated to the restrictive end of the spectrum in memory over time—a process occurring in memory after the more immediate perceptual process of boundary extension. The nonsignificant direction of the data toward boundary extension for the CC comparisons, but the significant boundary restriction for the PP comparisons, is consistent with such a drift (but only if a significant effect of boundary extension would have otherwise occurred with the CC comparisons at an immediate test, as one would predict based on the findings of Intraub et al., 1992), possibly due to normalization to the mean of the stimulus set (cf. Intraub et al., 1992). Further research is warranted in which auditory boundary extension is investigated under conditions of both an immediate test and a delay test. If auditory boundary extension occurs across the board for all comparison types at an immediate test, but then all the responses shift toward the mean of the stimulus set over time (i.e., at a delay), then the two phases of boundary distortion (i.e., extension and normalization) suggested by Intraub et al. (1992) would be supported, and a strong argument would exist for a similar mechanism underlying boundary distortion in the visual and auditory modalities.

The results of Experiment 4 suggest that boundary restriction and possibly boundary extension occur in the auditory domain under certain presentation conditions. Experiment 5 served to further clarify the patterns of auditory boundary extension and auditory boundary restriction using prototype and wide-angle stimuli.

Experiment 5

Experiment 5 was similar to Experiment 4, except that the perceptual schema and memory schema hypotheses were more directly comparable, as the auditory scenes under examination were of the prototype and wide-angle varieties (cf. Intraub et al., 1992, Experiment 2). If the extension-normalization hypothesis (Intraub et al., 1992) were to hold at a delay test, then boundary extension would occur for the prototype stimuli, and boundary restriction would occur for the wide-angle stimuli.

Table 13

Schematic, Experiment 5

	STIMULUS TYPE	
TARGET/PROBE COMPARISONS	music	literature
WW	9	9
PP	9	9
WP	9	9
PW	9	9

Note: P represents prototypic presentation; W represents wide-angle presentation. Numbers indicate the number of trials per individual per category, for a total of 72 trials.

Method

Participants

Thirty-two participants with self-reported normal hearing were recruited and compensated in the same manner as in Experiments 1-4. Data from four additional participants were excluded from the analyses, two because of difficulty concentrating on the task, and two because of confusion regarding the experimental procedure. No participant had participated in Experiments 1-4.

Apparatus and Materials

The apparatus and materials were the same as those used in Experiment 4, with the exception that the target and probe stimuli were the prototype and wide-angle presentations of the stimuli.

Design

The design for the experiment was the same as that of Experiment 4, except that wide-angle instead of close-up stimuli were included in the four target/probe comparisons (i.e., WW, PP, WP, PW). For a schematic of the experimental design, see Table 13.

Procedure

The procedure was the same as that of Experiment 4, but using the prototype and wide-angle stimuli.

Results

Interpreting Judgment Results

Judgments were interpreted in the same fashion as in Experiment 4, but using the prototype and wide angle comparisons instead of the close-up and prototype comparisons. For the length data, the PP and WW comparisons were assigned an expected value of 0, the PW comparison was assigned an expected value of +1, as the probe was longer than the target, but not by an excessive amount, and the WP comparison was assigned an expected value of -1, as the probe was shorter than the target, but not by an excessive amount. For the tempo data, judgments had an expected value of 0, as tempo was not manipulated.

Data Analyses

Data were initially analyzed in terms of whether the pattern of responses differed from chance. As in Experiments 1-4, Chi-Square analyses indicated that responding occurred at levels different from chance, $p<.0001$ (for further details, see Appendix HH). The majority of responses in the length data were correct, with values ranging from 59.84% (WP comparisons) to 64.29% (PW comparisons). For the most part, the majority of responses in the tempo data were also correct, with values ranging from 45.71% (PW comparisons) to 53.17% (PP comparisons).

Data were then analyzed in terms of a mixed linear model using PROC MIXED in the SAS programming language. Using a compound symmetry covariance structure, when modeling the length data, the null model likelihood ratio test indicated that modeling the additional variance was preferable to the null model, $\chi^2(1)=31.37$, $p<.0001$[8]. There were significant main effects of comparison type, $F(3, 2459)=259.84$, $p<.0001$, and block (literature or music), $F(1, 2459)=11.47$, $p=.0007$, and significant interaction effects of comparison type with block, $F(3, 2459)=33.80$,

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[8] The data for stimulus voice and stimulus block were highly related and therefore only one of the two parameters could be entered into the model at a time. The model presented in the main body of the text includes stimulus block, as it is more theoretically relevant; however, an alternative model using stimulus voice was also viable in that the null model likelihood ratio test indicated that modeling the additional variance was preferable to the null model, $\chi^2(1)=32.71$, $p<.0001$. In this alternative model, there were effects of: comparison type, stimulus block, the stimulus block first presented, comparison by block, comparison by musical experience, and comparison by the stimulus block first presented.

p<.0001, comparison type with musical experience, *F*(6, 2459)=3.68, *p*=.001, and a three-way interaction between comparison type, block, and instruction voice, *F*(3, 2459)=5.04, *p*=.002 (for the full model, see Appendix II).

PW comparisons were judged as longer than the baseline WW comparisons, β=.42, *t*(2459)=3.41, *p*=.0007, and WP comparisons were judged as shorter than the baseline WW comparisons, β=-.50, *t*(2459)=-4.09, *p*<.0001. Literature stimuli were judged as longer than baseline with a PW comparison type, β=.42, *t*(2459)=3.41, *p*=.0007. When participants high in musical experience judged WP comparisons, they made judgments shorter than baseline, β=-.36, *t*(2459)=-2.46, *p*=.01, but when these same highly experienced musicians judged PW comparisons, they made judgments marginally significantly longer than baseline, β=.26, *t*(2459)=1.78, *p*=.08. Literature stimuli, when accompanied by instructions read by a female voice, were judged as longer for PW comparisons, β=.41, *t*(2459)=2.11, *p*=.04, but were judged as marginally shorter for WP comparisons, β=-.35, *t*(2459)=-1.78, *p*=.08.

When modeling the tempo data, the null model likelihood ratio test indicated that modeling the additional variance was preferable to the null model, $\chi^2(1)$=22.17, *p*<.0001 (for the full model, see Appendix JJ). There was a significant main effect of comparison type, *F*(3, 2472)=3.63, *p*=.01, but only the WP comparison even marginally differed from the baseline WW comparison, β=.09, *t*(2472)=1.87, *p*=.06. There was also a significant main effect of block, with stimuli in the literature block judged as longer than stimuli in the music block, β=.08, *t*(2472)=2.20, *p*=.03.

Table 14

Length data t-tests comparing mean ratings to expected ratings, Experiment 5

comparison	E(x)	mean	sd	se	df	t	p	effect
PP	0	-0.07	0.24	.04	34	-1.56	.13	none
PW	1	0.77	0.43	.07	34	-3.12	.004	BE
WP	-1	-0.64	0.58	.10	34	3.71	.0007	BR
WW	0	0.09	0.25	.04	34	2.07	.047	trBR

Note: The E(x) column indicates the expected value to which the mean was compared. BE represents boundary extension. trBR represents a statistically nonsignificant trend (i.e., p-value less than .05, but greater than the p-value required by the Bonferroni correction) toward boundary restriction. The p value required for the Bonferroni correction was .05/4=.0125.

Finally, data were analyzed using a set of t-tests to determine whether or not responses were directionally distorted compared to expected values. As seen in Table 14, for the length data, boundary restriction occurred for the WP, *t*(34)=3.71, *p*=.0007, comparison type, and there was a statistically nonsignificant trend in the direction of boundary restriction for the WW comparison type, *t*(34)=2.07, *p*=.047. Boundary extension occurred, however, for the PW comparison type, *t*(34)=-3.12, *p*=.004. Additionally, data were in the direction of boundary extension for the PP comparison type although this effect failed to achieve significance, *t*(34)=-1.56, *p*=.13. This basic pattern was maintained in an analysis of the judgments of music stimuli only (see Table 15), but only a statistically nonsignificant trend toward boundary restriction was evidenced for WW comparisons in an analysis of the literature stimuli, *t*(34)=2.14, *p*=.04 (see Table 16). The only significant effect of directional distortion in the tempo data was with the WP comparison type, in the direction of judging probes as faster than their associated targets, *t*(34)=2.94, *p*=.006 (see Table 17). The faster tempo judgments only occurred with the literature stimuli for the WP comparisons, *t*(34)=2.64, *p*=.01 (see Appendix KK).

Table 15

Length data t-tests comparing mean ratings to expected ratings, Music stimuli, Experiment 5

comparison	E(x)	mean	sd	se	df	t	p	effect
PP	0	-0.14	0.43	.07	34	-1.89	.07	none
PW	1	0.46	0.45	.08	34	-7.08	<.0001	BE
WP	-1	-0.48	0.56	.09	34	5.52	<.0001	BR
WW	0	0.08	0.37	.06	34	1.31	.20	none

Note: The E(x) column indicates the expected value to which the mean was compared. BE represents boundary extension. trBE represents a statistically nonsignificant trend toward boundary extension. BR represents boundary restriction. The p value required for the Bonferroni correction was .05/4=.0125.

Table 16

Length data t-tests comparing mean ratings to expected ratings, Literature stimuli, Experiment 5

comparison	E(x)	mean	sd	se	df	t	p	effect
PP	0	0.01	0.24	.04	34	.22	.83	none
PW	1	1.08	0.57	.10	34	.87	.39	none
WP	-1	-0.79	0.74	.13	34	1.65	.11	none
WW	0	0.09	0.25	.04	34	2.14	.04	trBR

Note: The E(x) column indicates the expected value to which the mean was compared. trBR represents a statistically nonsignificant trend (i.e., p-value less than .05, but greater than the p-value required by the Bonferroni correction) toward boundary restriction. The p value required for the Bonferroni correction was .05/4=.0125.

Table 17

Tempo data t-tests comparing mean ratings to expected ratings, Experiment 5

comparison	E(x)	mean	sd	se	df	t	p	effect
PP	0	0.06	0.25	.04	34	1.48	.15	none
PW	0	-0.01	0.24	.04	34	-0.22	.83	none
WP	0	0.15	0.31	.05	34	2.94	.006	faster
WW	0	0.06	0.30	.05	34	1.19	.24	none

Note: The E(x) column indicates the expected value to which the mean was compared. The p value required for the Bonferroni correction was .05/4=.0125.

Discussion

The pattern of results for Experiment 5 was generally as predicted (although the effect was less robust with regard to the PP and WW comparisons than expected), with boundary extension occurring for closer-up targets (in this case, prototypic targets), and boundary restriction occurring for wider-angle targets at a delay test. This validates the results of Experiments 1-3, in which all of the target stimuli were effectively wide-angle; therefore, it is no surprise that results from Experiments 1-3 converged on boundary restriction instead of boundary extension at a delay test. Certainly, the results of Experiment 5 suggest that both boundary extension and boundary restriction occur in the auditory domain in a manner very much paralleling that found in the visual boundary extension literature. The boundary extension pattern only occurred for the musical stimuli, however, and not for the literature stimuli. Given that boundary extension is only expected to occur within a continuous scene (e.g., Gottesman & Intraub, 2002), it might be that music is considered by most people as more of a flowing, continuous landscape than is literature. Thus, extension would occur with musical stimuli, but the more discrete nature of words might prevent boundary extension from occurring with the literature stimuli. Freyd (1987) similarly suggested that representational momentum would be expected for stimuli that changed along a continuous, but not a discontinuous, dimension.

General Discussion

In Experiment 1, participants were presented with simple auditory stimuli (i.e., note or number sequences) and made judgments regarding the length and tempo of a probe compared to a previously presented target. Results suggested boundary restriction. In Experiment 2, participants were presented with the same paradigm as in Experiment 1, except that the auditory stimuli were more complex/ecologically valid (i.e., excerpts from music or English literature). Results again suggested boundary restriction. In Experiment 3, using a subset of stimuli from Experiment 2, all presentations of each target/probe pair were identical. Although results from the overall data set were not significant, data in the first block of trials (prior to the realization of some participants that all target/probe pairs were identical) suggested a statistically nonsignificant effect of boundary restriction. The boundary restriction results from Experiments 1-3 appeared consistent with Intraub et al.'s (1992) results with wide-angle stimuli at a delay test. Accordingly, using a modified version of Intraub et al.'s (1992) paradigm and the mm (shortest), ss (mid-length), and itt (longest) probe types from Experiment 2, Experiments 4 and 5 examined auditory boundary extension using close-up (i.e., shorter) and prototype (i.e., mid-length) and prototype and wide-angle (i.e., longer) stimuli, respectively. The results of Experiment 4 (with close-up and prototypical stimuli) suggested that boundary restriction occurred when prototype probes followed prototypical targets; data from the CC comparisons were in the direction of boundary extension but results did not reach significance. The results of Experiment 5 suggested that a trend toward boundary extension occurred when prototypical targets were presented and that a trend toward boundary restriction occurred when wide-angle targets were presented.

Overall, results from Experiments 1-3 found a boundary restriction effect for auditory stimuli for length judgments; however, after noting that boundary restriction occurred at a time delay with wide-angled stimuli in Intraub et al.'s (1992) experiments, an examination of close-up, prototypic, and wide-angle auditory stimuli in Experiments 4 and 5 yielded similar results to those of Intraub et al. (1992)—that is, boundary extension occurred for relatively closer targets, and boundary restriction occurred for relatively wider-angle targets, in patterns reminiscent of both restrictive drift (in Experiment 4) and normalization to the mean of the stimulus set (in Experiment 5). Boundary extension only occurred for more continuous (i.e., music) stimuli, but did not occur for more discrete (i.e., literature) stimuli, in line with Freyd's (1987) assertion that dynamic mental representations require continuity in time. The discovery of auditory boundary extension and its similar properties to visual boundary extension is in concert with the assertion that boundary extension is a multisensory perceptual/memory phenomenon (Intraub, 2004).

Auditory length judgments were analogous to visual boundary extension judgments in that the issue in each case was the potential extrapolation of content. One might consider tempo judgments to be analogous to a container within which such content is housed—that is, by examining tempo judgments, one would be investigating the possible extension or restriction/compression of time itself, separate from the contents occurring within that time frame. Although tempo ratings were sometimes significantly faster or slower than their expected value of 0 (given that tempo was never manipulated) within the data presented here, a consistent pattern across experiments was not apparent. The present experiments were limited in their ability to discern anything beyond a need for future research in which tempo is a manipulated variable, and so the remainder of the discussion will focus on length judgments.

Theoretically, the present research appears to partially support the extension-normalization model (Intraub et al., 1992). Results of the present experiments converged on the finding that boundary restriction occurs for wide-angle auditory scenes at a delay test. In light of Intraub et al.'s (1992) research, this suggests that normalization of some variety might be occurring over time. Without an immediate condition in the present experiments, however, one can only speculate as to what results would be achieved at an immediate test, and therefore whether or not the extension portion of the model would be upheld in the auditory domain with continuous auditory stimuli. Though one could reasonably hypothesize that results would be similar to those found by Intraub et al. (1992) in their immediate condition, more research is required to make this determination.

Indeed, the present research raises at least as many questions as it answers. What is the appropriate resolution for close-up stimuli in auditory boundary extension experiments? What is the appropriate ISI for an immediate test in the auditory domain? Does the differing time course of auditory boundary extension (from that of visual boundary extension) mean that different memory processes are actually being invoked in the two modalities, whether or not the other mechanisms appear to be similar? What is the relationship between auditory representational momentum and

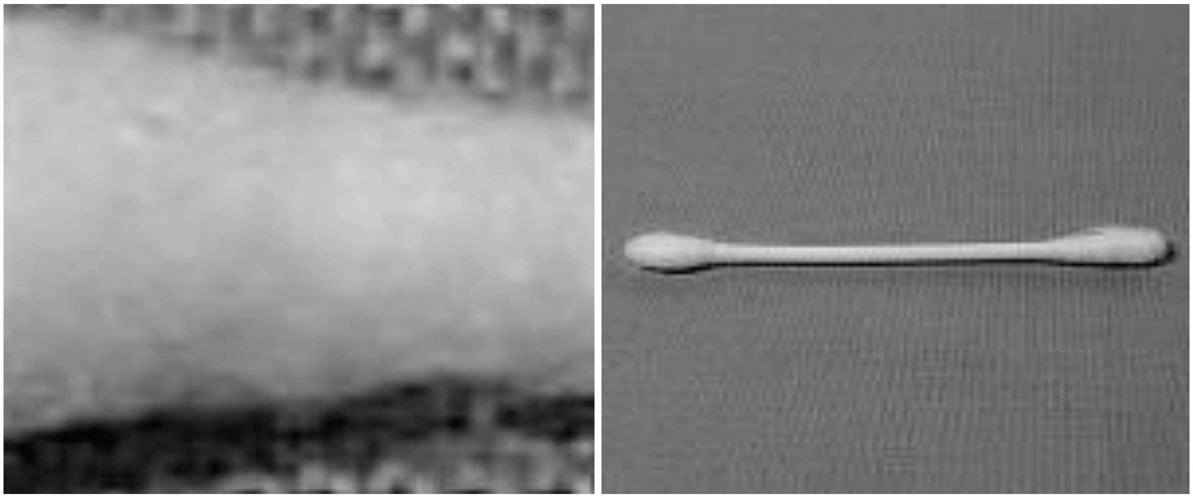

Figure 6. An illustration of the importance of stimulus resolution in the ability to extrapolate, and thus the opportunity to experience boundary extension, in the context of close-up scenes. In the leftmost frame, an extremely close-up view of an object makes extrapolation to the remainder of the scene extremely difficult. In the rightmost frame, one can see the fuller picture of a cotton swab on a piece of gauze. These pictures were adapted from http://www.whatsfordinner.net/What-Is-It-Close-Up.html (Alex's Mystery Pictures, Mystery Picture for March 20; website accessed June 2007).

auditory boundary extension? Are the mechanisms underlying visual and auditory boundary extension similar/the same, or are they different? Does repetition of the target stimulus affect auditory boundary extension? An examination of these questions is beneficial in guiding both the present understanding of auditory boundary extension and future research efforts.

Close-up Stimulus Resolution

One question regarding the results of the present experiments is why there was not a stronger pattern of boundary extension, particularly with close-up target presentation in Experiment 4. If Intraub et al.'s (1992) research and the present research had more closely converged, a strong boundary extension effect would have occurred in the present data for close-up targets, and that was not the case. It might be that the resolution of the close-up stimuli was such that extrapolation to the surrounding scene was extremely difficult, as in the case of an extremely close-up picture in a magazine when the reader is challenged to figure out what the ordinary object is that is represented in the picture (for an example, see Figure 6). Future research should examine the appropriate resolution for close-up auditory boundary extension targets.

Ideal Immediate-Test ISI for Auditory Boundary Extension Studies

The 7-second delay test condition in the auditory domain, as utilized in the present experiments, appears to be analogous to the 48-hour delay test condition in the visual boundary extension literature (e.g., Intraub et al., 1992). This conclusion is drawn from the fact that the results of the present experiments are in concert with Intraub et al.'s (1992) results. That is, boundary extension was evidenced when closer targets were presented (i.e., the prototypical targets of Experiment 5), but boundary restriction was evidenced when wider-angle targets were presented; however, why there would be such a similarity between such widely different delays is not clear. The similarity between Intraub et al.'s (1992) results and the present results is limited to Intraub et al.'s (1992) delay test condition, however. In Intraub et al.'s (1992) immediate test condition, a pattern of boundary extension was found for all viewing distances, and this effect did not present itself in the present data sets.

It remains unclear what the appropriate ISI would be for an immediate test in the auditory domain. Is the timing of boundary extension within the auditory domain such that it is feasible to replicate Intraub et al.'s (1992) results at an immediate test and thus possibly find boundary extension across the board with all presentation types (i.e., close-up, prototypic, wide-angle)? This is an empirical question. Whether or not boundary extension occurs at an immediate test in line with Intraub et al.'s (1992) findings, research involving several different retention intervals should serve to clarify the movement of directional distortion over time in memory for auditory stimuli.

The Time Course of Auditory Boundary Extension and Memory Mechanisms

Intraub et al.'s (1992) immediate test condition involved a delay of approximately 3 minutes, whereas Intraub et al.'s (1992) delay test condition involved a delay of 48 hours. The present study's testing delay lasted 7 seconds and has been suggested to be analogous to the delay condition (i.e., 48-hour delay) in Intraub et al.’s (1992) experiments based on the comparable pattern of results in the data. A 48-hour delay in the visual domain and a 7-second delay in the auditory domain do not initially appear to be analogous to one another. Given the spatial nature of vision and the temporal nature of audition, the more intuitive analog of a shorter visual latency would be a longer auditory latency. This is not the pattern that was found in the data, however. An interesting question that arises as a function of the apparent different time course of boundary extension/boundary restriction events in the visual and auditory modalities becomes the type of memory (e.g., working memory vs. long-term memory) that is involved in the different testing conditions in the different modalities.

In Intraub et al.’s (1992) immediate testing condition (i.e., a 3-minute delay), one would assume working memory to be involved in the recollection of the scene; however, in Intraub et al.’s (1992) delay test condition (i.e., a 48-hour delay), one would assume long-term memory to be involved in the recollection of the scene. On the other hand, if the delay test condition in the auditory domain is only seven seconds long, then it seems that working memory would be implicated in the recollection of the auditory scene whether the auditory event was in an immediate or a delay test condition. To reconcile the difference between the types of memory utilized in the delay test conditions across the respective modalities, it is possible to assume that the information stored in long term memory in a visual task is first retrieved into working memory and then utilized in the task, rendering all of the tasks within the boundary extension experiments to be tasks of perception and working memory.

Resolving the issue of the relative contribution of working vs. long-term memory to boundary extension still does not solve the problem of why the time course of the delay test conditions in the visual and auditory modalities are so discrepant from one another. There is the possibility that the 7-second delay test condition in the auditory modality is not truly analogous to Intraub et al.’s (1992) 48-hour delay test condition in the visual modality. Parsimony would suggest that this is improbable, however, because of the theoretical underpinnings of the extension-normalization model (Intraub et al., 1992) in concert with the pattern of extension and restriction in the present data, and in light of additional evidence that boundary extension is multisensory (Intraub, 2004). If the analogy between the delay test conditions across the two modalities fails to fit, then one is left asking the question of what process is driving the results of the present experiments.

Auditory Representational Momentum and Auditory Boundary Extension

Hubbard (1995b, 1996) was the first to point out the connection between visual boundary extension and representational momentum—a relationship that is now understood as important, if not vital, in guiding organisms through their environments (cf. DeLucia & Maldia, 2006; Munger et al., 2005). It appears that Hubbard (1995b, 1996) was correct in that the two processes are undeniably functionally linked (cf. Munger et al., 2005), albeit separate, in the visual domain; one process informs the other (boundary extension informs representational momentum, which informs boundary extension for the next scene, etc.) in a continual fashion as one navigates the world.

Munger et al. (2005) suggested that boundary extension occurs prior to representational momentum in vision, presumably as a means of expanding the periphery of a scene prior to an extrapolation of movement within that scene. Given that auditory representational momentum is a documented phenomenon (e.g., Getzmann et al., 2004), one would assume that auditory boundary extension must occur if the visual and auditory modalities function utilizing the same, or similar, perceptual and memory mechanisms. The present research suggests that this necessary condition is met—i.e., auditory boundary extension does occur.

Only if the mechanisms, and presumably the functions, behind boundary extension in the different modalities are similar can one argue that the phenomenon is singular as opposed to a variety of phenomena to which similar names are applied (e.g., visual boundary extension, haptic boundary extension, auditory boundary extension; cf. Bertamini et al., 2005). Future research should therefore focus on whether or not auditory boundary extension actually precedes auditory representational momentum (cf. Munger et al., 2005). If auditory boundary extension did not precede auditory representational momentum, then the functional nature of the relationship between boundary extension and representational momentum across the modalities would be in question. For example, it is the current understanding that the extension of boundaries of a visual scene occurs prior to an extrapolation of movement within that scene (Munger et al., 2005). For the sake of argument, if auditory boundary extension were to occur prior to auditory representational momentum, then the function of auditory boundary extension could function to prepare the individual to establish a scene prior to interacting with elements within that scene. Results indicating that auditory boundary extension precedes auditory representational momentum would provide further evidence supporting the contention that boundary extension is a multisensory perceptual/memory process (Intraub, 2004) that extrapolates a scene in an amodal fashion (cf. Gottesman & Intraub, 2002; Intraub, 2002) and is suggestive of the same mechanisms underlying those modalities (Intraub, 2004). The existence of the effects of boundary extension and representational momentum in multiple modalities should prompt further investigation with regard to the relationship between the two seemingly related processes.

Target Stimulus Repetition

It has been shown in the visual boundary extension literature that the duration of presentation of a visual stimulus does not affect the amount of boundary extension experienced (Intraub & Berkowits, 1996). Although duration of target presentation cannot be studied with regard to auditory stimuli without dragging out the sounds and effectively slowing the tempo and/or creating a drawl, one can investigate the effect of repetition of a target stimulus on auditory boundary extension. Often in conversation or music listening, a comment or phrase might be repeated several times; therefore, both in practical terms and in terms of a rough analog to the research in visual boundary extension regarding the duration of presentation of stimuli, repetition should be manipulated to determine whether repetition of an auditory stimulus affects boundary extension.

Extended exposure to a stimulus has been shown to influence perception in other domains. For example, in illusion decrement, the visual inspection of an illusory stimulus such as the Müller-

Lyer illusion (Coren & Porac, 1984), the Horizontal-Vertical illusion (Glaser & Slotnick, 1995), or the Poggendorff illusion (Predebon, 1990) often leads to a decrease in the strength of the illusion. Some studies have found illusion decrement to occur as a function of inspection time (e.g., Coren & Porac), but other studies have suggested that illusion decrement as a function of inspection time is a short-lived effect, with its total duration lasting for approximately the first minute or two of inspection time (e.g., Glaser & Slotnick; see also Predebon, 1998). Additionally, Predebon (2006) examined the Bretano Müller-Lyer illusion under both continuous inspection and repeated trial conditions, and found illusion decrement to be a function of neither repetition nor practice. Taken together, the results of Coren and Porac, Glaser and Slotnick, Predebon (1998), and Predebon (2006) suggest that a given window of inspection time, rather than stimulus repetition, drives visual illusion decrement. Extending this idea to the auditory domain, it is possible that a protracted listening/ruminating time or repeated stimulus presentations might affect boundary extension, but the empirical question still remains.

Conclusion

The goal in attempting to continue to replicate the findings from the visual boundary extension literature would ultimately be a determination of whether boundary extension in the visual modality and auditory modality are actually the same phenomenon, or if different processes actually underlie separate phenomena in the different modalities (cf. Bertamini et al., 2005)[9]. In time, the answer to this question will most likely become evident. Until then, the present research does offer some intermediate observations and conclusions: Boundary extension can occur in the auditory domain, and it appears to have many of the same attributes as boundary extension in the visual domain, although the discrete time course of events differs between the two modalities. In particular, boundary extension occurs with a continuous auditory landscape (e.g., music) and when relatively closer stimuli (cf. prototypic stimuli in Experiment 5) are presented as targets. In concert with Intraub

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[9] An analogous question from the representational momentum literature is whether implied motion and smooth motion are the same or different phenomena (e.g., Kerzel, 2006; but see Hubbard, 2006b).

et al.'s (1992) extension-normalization model, boundary restriction also occurs in the auditory domain with relatively wider-angle stimuli (cf. wide-angle stimuli in Experiment 5) at a time delay (cf. Intraub et al., 1992).

Appendix A

SEQUENTIAL MUSICAL STIMULI, EXPERIMENT 1

Items 1-18, 15-25 notes each

	1	2	3	4	5	6	7	8	9
1	c3	c4	g2	g4	d3	d4	c6	c5	g6
2	d3	d4	a2	a4	e3	e4	b5	b4	f#6
3	e3	e4	b2	b4	f#3	f#4	a5	a4	e6
4	f3	f4	c3	c5	g3	g4	g5	g4	d6
5	g3	g4	d3	d5	a3	a4	f5	f4	c6
6	a3	a4	e3	e5	b3	b4	e5	e4	b5
7	b3	b4	f#3	f#5	c#4	c#5	d5	d4	a5
8	c4	c5	g3	g5	d4	d5	c5	c4	g5
9	d4	d5	a3	a5	e4	e5	b4	b3	f#5
10	e4	e5	b3	b5	f#4	f#5	a4	a3	e5
11	f4	f5	c4	c6	g4	g5	g4	g3	d5
12	g4	g5	d4	d6	a4	a5	f4	f3	c5
13	a4	a5	e4	e6	b4	b5	e4	e3	b4
14	b4	b5	f#4	f#6	c#5	c#6	d4	d3	a4
15	c5	c6	g4	g6	d5	d6	c4	c3	g4

	10	11	12	13	14	15	16	17	18
1	g4	d6	d5	e4	a3	d4	g4	c3	c4
2	f#4	c#6	c#5	g#4	c#4	f#4	b4	e3	e4
3	e4	b5	b4	b4	e4	a4	d5	g3	g4
4	d4	a5	a4	e5	a4	d5	g5	c4	c5
5	c4	g5	g4	g#5	c#5	f#5	b5	e4	e5
6	b3	f#5	f#4	b5	e5	a5	d6	g4	g5
7	a3	e5	e4	e6	a5	d6	g6	c5	c6
8	g3	d5	d4	b5	e5	a5	d6	g4	g5
9	f#3	c#5	c#4	g#5	c#5	f#5	b5	e4	e5
10	e3	b4	b3	e5	a4	d5	g5	c4	c5
11	d3	a4	a3	b4	e4	a4	d5	g3	g4
12	c3	g4	g3	g#4	c#4	f#4	b4	e3	e4
13	b2	f#4	f#3	e4	a3	d4	g4	c3	c4
14	a2	e4	e3	g#4	c#4	f#4	b4	e3	e4
15	g2	d4	d3	b4	e4	a4	d5	g3	g4
16				e5	a4	d5	g5	c4	c5
17				g#5	c#5	f#5	b5	e4	e5
18				b5	e5	a5	d6	g4	g5
19				e6	a5	d6	g6	c5	c6
20				b5	e5	a5	d6	g4	g5
21				g#5	c#5	f#5	b5	e4	e5
22				e5	a4	d5	g5	c4	c5
23				b4	e4	a4	d5	g3	g4
24				g#4	c#4	f#4	b4	e3	e4
25				e4	a3	d4	g4	c3	c4

Appendix B

RANDOM MUSICAL STIMULI, EXPERIMENT 1

Items 1-18, 15 notes each

	1	2	3	4	5	6	7	8	9
1	d#4	f#4	f#4	d4	c#3	g#4	a3	g#4	c#4
2	f3	e3	a#3	g4	b3	d#3	a4	a#3	c3
3	d3	a4	c#4	c5	c3	g3	d#3	c5	b3
4	g4	f4	c3	b3	f#3	c#3	g3	g4	f#4
5	c4	b3	e3	c#3	a3	c#4	a#3	d4	g#3
6	c3	d#3	b4	a4	d3	c4	c4	d#3	c#3
7	a#3	g3	f#3	a#4	g3	a4	a#4	c3	g4
8	d4	a3	g#3	g#4	b4	f4	f#4	c#4	a4
9	d#3	a#4	e4	d3	g4	c5	f4	b3	f3
10	g#3	a#3	d#4	d#3	a#4	b3	c3	e4	e4
11	f4	f3	f3	f#4	g#4	a3	g#3	f#4	c5
12	b4	c4	g4	a3	d4	a#4	d#4	b4	f4
13	a4	c#4	g#4	e3	c5	b4	b4	g#3	g#4
14	c#4	g#3	d4	g3	d#4	d3	f#3	d3	a3
15	e4	d#4	c5	f3	e4	d#4	c5	a3	d#3

	10	11	12	13	14	15	16	17	18
1	a4	g4	c3	e3	c#4	c#4	f#3	c#3	e4
2	f3	a#4	a#3	c5	b3	g#3	g#4	a4	g#4
3	g#4	a3	g3	g4	e3	d3	c#3	g4	f3
4	a#3	b4	b4	c3	c4	c#3	f3	c3	a#4
5	f4	f4	g#3	b4	g#3	f#4	f4	c5	c5
6	c#3	c4	f#3	d#3	b4	f4	e3	d#3	d#3
7	c#4	f#3	c4	d4	d4	e4	a4	d3	d4
8	e4	a#3	a#4	g#3	f#3	a4	c4	a3	b3
9	d3	g3	f3	g3	f4	f3	d4	g#3	f4
10	a3	d3	d3	a#3	g4	a3	d3	d#4	b4
11	b3	c#3	c5	a4	f#4	g3	d#4	a#4	a#4
12	c5	d#4	e3	c#4	e4	a#3	c5	f3	c3
13	e3	e3	g#4	e4	a#3	e3	b3	g3	f#3
14	g4	a4	d4	a3	g#4	d#4	f#4	e4	g4
15	d4	f3	d#4	c#3	d#3	c5	a#4	f4	c4

Appendix C
SEQUENTIAL NUMBER STIMULI, EXPERIMENT 1

Items 1-18, 15 to 19 numbers each

	1	2	3	4	5	6	7	8	9
1	30	45	51	42	34	31	49	69	56
2	31	46	52	44	36	33	48	68	55
3	32	47	53	46	38	35	47	67	54
4	33	48	54	48	40	37	46	66	53
5	34	49	55	50	42	39	45	65	52
6	35	50	56	52	44	41	44	64	51
7	36	51	57	54	46	43	43	63	50
8	37	52	58	56	48	45	42	62	49
9	38	53	59	58	50	47	41	61	48
10	39	54	60	60	52	49	40	60	47
11	40	55	61	62	54	51	39	59	46
12	41	56	62	64	56	53	38	58	45
13	42	57	63	66	58	55	37	57	44
14	43	58	64	68	60	57	36	56	43
15	44	59	65	70	62	59	35	55	42

	10	11	12	13	14	15	16	17	18
1	70	64	61	31	40	53	70	38	43
2	68	62	59	33	50	54	65	37	42
3	66	60	57	35	60	55	70	36	41
4	64	58	55	37	50	56	65	37	40
5	62	56	53	35	40	55	70	38	41
6	60	54	51	33	50	54	65	37	42
7	58	52	49	31	60	53	70	36	43
8	56	50	47	33	50	54	65	37	42
9	54	48	45	35	40	55	70	38	41
10	52	46	43	37	50	56	65	37	40
11	50	44	31	35	60	55	70	36	41
12	48	42	39	33	50	54	65	37	42
13	46	40	37	31	40	53	70	38	43
14	44	38	35	33	50	54	65	37	42
15	42	36	33	35	60	55	70	36	41
16				37	50	56	65	37	40
17				35	40	55			
18				33		54			
19				31		53			

Appendix D

RANDOM NUMBER STIMULI, EXPERIMENT 1

Items 1-18, 15 numbers each

	1	2	3	4	5	6	7	8	9
1	47	52	57	41	51	39	39	62	53
2	42	42	40	50	43	53	41	54	43
3	55	41	55	48	58	51	43	51	56
4	56	59	48	45	46	52	51	40	61
5	38	38	62	47	50	50	60	50	46
6	57	57	50	43	61	56	40	55	57
7	61	47	53	62	62	58	56	57	38
8	44	56	43	40	44	54	50	45	42
9	39	60	41	38	40	49	45	60	44
10	58	39	61	44	49	40	59	41	50
11	53	48	47	59	48	59	55	49	41
12	52	45	42	52	39	45	44	38	51
13	43	53	44	51	55	38	61	43	59
14	60	43	60	49	54	62	42	44	62
15	54	40	51	46	45	46	48	61	55

	10	11	12	13	14	15	16	17	18
1	62	55	54	53	58	60	55	46	39
2	38	39	57	43	54	44	51	59	58
3	40	43	39	38	46	48	44	43	46
4	57	52	45	46	57	38	60	41	55
5	58	42	40	40	44	45	62	49	48
6	46	46	47	57	48	56	47	51	53
7	53	53	51	60	38	57	50	54	59
8	49	58	52	62	39	62	58	60	47
9	47	51	43	45	62	51	61	45	42
10	45	48	60	41	50	50	39	55	54
11	54	50	42	54	53	40	59	57	61
12	60	62	58	58	61	43	56	47	62
13	50	47	48	49	42	49	52	40	41
14	44	59	49	48	47	42	42	52	43
15	52	56	56	42	56	52	41	38	44

Appendix E
EXAMPLE RESPONSE SHEET

BLOCK 1: ________________

TRIAL 1

a.	-3	-2	-1	0	+1	+2	+3
	much shorter			the same			much longer
b.	-3	-2	-1	0	+1	+2	+3
	much slower			the same			much faster

TRIAL 2

a.	-3	-2	-1	0	+1	+2	+3
	much shorter			the same			much longer
b.	-3	-2	-1	0	+1	+2	+3
	much slower			the same			much faster

TRIAL 3

a.	-3	-2	-1	0	+1	+2	+3
	much shorter			the same			much longer
b.	-3	-2	-1	0	+1	+2	+3
	much slower			the same			much faster

TRIAL 4

a.	-3	-2	-1	0	+1	+2	+3
	much shorter			the same			much longer
b.	-3	-2	-1	0	+1	+2	+3
	much slower			the same			much faster

Appendix F
EXAMPLE RANDOMIZED PRESENTATION ORDERS, EXPERIMENT 1

Randomized orders 1a-1e

MUSIC BLOCK

item	Target music stimulus	Probe type				
		a	b	c	d	e
1	7	ss	itt	mm	ms	sm
2	15	itt	itt	itt	itt	itt
3	3	mm	ms	sm	ss	itt
4	19	ms	sm	ss	itt	mm
5	8	sm	ss	itt	mm	ms
6	27	itt	mm	ms	sm	ss
7	26	sm	ms	ss	mm	itt
8	1	ms	ss	mm	itt	sm
9	33	ss	mm	itt	sm	ms
10	31	mm	itt	sm	ms	ss
11	32	itt	sm	ms	ss	mm
12	25	mm	ss	sm	itt	ms
13	20	ss	sm	itt	ms	mm
14	13	itt	itt	itt	itt	itt
15	21	itt	ms	mm	ss	sm
16	14	itt	itt	itt	itt	itt
17	9	sm	mm	ms	ss	itt
18	2	mm	ms	ss	itt	sm
19	18	ms	ss	itt	sm	mm
20	12	itt	sm	mm	ms	ss
21	23	ss	itt	sm	mm	ms
22	36	itt	itt	itt	itt	itt
23	29	itt	ms	sm	mm	ss
24	17	ms	sm	mm	ss	itt
25	10	mm	sm	itt	ss	ms
26	4	sm	mm	ss	itt	ms
27	5	mm	ss	itt	ms	sm
28	24	ss	itt	ms	sm	mm
29	6	sm	itt	ss	ms	mm
30	28	itt	ss	ms	mm	sm
31	22	sm	itt	ms	mm	ss
32	11	ss	ms	mm	sm	itt
33	16	ms	mm	sm	itt	ss
34	34	itt	itt	itt	itt	itt
35	35	itt	itt	itt	itt	itt
36	30	ms	mm	ss	sm	itt

NUMBER BLOCK

item	Target number stimulus	Probe type				
		a	b	c	d	e
37	36	itt	itt	itt	itt	itt
38	19	mm	ms	sm	ss	itt
39	15	ss	itt	mm	ms	sm
40	14	ms	sm	ss	itt	mm
41	13	sm	ss	itt	mm	ms
42	26	sm	ms	ss	mm	itt
43	29	itt	sm	ms	ss	mm
44	27	itt	mm	ms	sm	ss
45	10	ms	ss	mm	itt	sm
46	22	ss	mm	itt	sm	ms
47	21	mm	itt	sm	ms	ss
48	34	itt	itt	itt	itt	itt
49	8	mm	ss	sm	itt	ms
50	9	ss	sm	itt	ms	mm
51	32	sm	mm	ms	ss	itt
52	3	itt	ms	mm	ss	sm
53	31	itt	itt	itt	itt	itt
54	33	mm	ms	ss	itt	sm
55	16	ss	itt	sm	mm	ms
56	5	itt	itt	itt	itt	itt
57	12	ms	sm	mm	ss	itt
58	17	itt	itt	itt	itt	itt
59	28	sm	mm	ss	itt	ms
60	11	itt	itt	itt	itt	itt
61	7	ms	ss	itt	sm	mm
62	18	itt	sm	mm	ms	ss
63	30	mm	ss	itt	ms	sm
64	20	sm	itt	ss	ms	mm
65	4	ms	mm	ss	sm	itt
66	2	itt	ms	sm	mm	ss
67	35	sm	itt	ms	mm	ss
68	23	ss	ms	mm	sm	itt
69	6	ms	mm	sm	itt	ss
70	1	mm	sm	itt	ss	ms
71	24	itt	ss	ms	mm	sm
72	25	ss	itt	ms	sm	mm

Appendix G

STATEMENT OF CONSENT

I, the undersigned, do hereby give my informed consent to my participation in the Mad Hatter Study. I have been informed about each of the following:

- The purposes of the study—The purpose of this experiment is to study auditory perception (i.e., perception in hearing). In studying auditory perception, the investigators hope to extend our understanding of how auditory perception operates and what factors influence auditory perception.
- The procedures—During the experiment you will be asked to give feedback with regard to auditory stimuli (i.e., music, language, or environmental sounds) using either a computer keyboard, a set of response keys, or pencil and paper. The auditory stimuli are played at what is a comfortable sound level for most people via either headphones (at the computer) or speakers. If the sound level is uncomfortable to you, please alert the experimenter and the situation will be rectified.
- The benefits—At the conclusion of the experiment, the more exact hypotheses and purposes of the experiment will be explained to you. You should therefore leave the experiment with a greater understanding of psychology in general, and perceptual phenomena, in particular. Additionally, participation in this experiment satisfies part of the research participation requirement of General Psychology (10213) or another psychology class. Understand that you may also satisfy a research participation requirement by taking part in other experiments or by completing an alternative activity designated by your professor that is equal in time and intensity to the present experiment. (This is solely a research project, and you will receive no additional compensation from your participation other than the partial satisfaction of the research participation requirement in your psychology class.)
- The risks—Understand that participation in this project involves minimal, if any, risks to most people**. In some people, however, auditory stimuli such as music or irregular or pulsating rhythms might trigger a seizure. The approximate risk of such an occurrence is .0001 percent. If you have a history of seizures (or a family history of seizures) and feel that this study places you in danger, please alert the experimenter. You will be issued full credit and allowed to leave without participating in the study.** The tasks will not be physically exerting.

I understand that I may withdraw at any time before or during the experiment at my option.
Recognizing the importance of avoiding bias in the results of this experiment, I agree not to discuss any of the details of the procedure with other participants. I understand that all of the research and evaluation materials will be confidentially maintained. The means used to maintain confidentiality are:

- My data will be given a code number for research identification, and my name will be kept anonymous.
- Data, along with consent forms, will be kept in a locked file cabinet.
- Only the investigators will have access to my identification data.

I understand that if I have questions concerning the research, I can call the following persons:

Joanna L. Hutchison, Principal Investigator
Department of Psychology
817-257-7414

Dr. Timothy L. Hubbard, Co-Principal Investigator
Department of Psychology
817-257-7410

Dr. Christie Scollon
Department of Psychology
Departmental Representative
817-257-7410

Jan Fox, TCU Coordinator
Research and Sponsored Projects
817-257-7515

Participant's Name (PLEASE PRINT)	Date
Participant's Signature	Phone Number
TCU ID#	Professor Course #

Appendix H

BACKGROUND/DEBRIEFING QUESTIONNAIRE

Experiment _________ Male or Female ___________

Subject Number ______ Right or Left Handed _______

Age ______

1. What do you think was the purpose of the experiment? Please explain.

2. Was the task difficult to you? If so, what was difficult about it?

3. Did you understand the procedure of the experiment? If not, please explain.

4. Do you have any suggestions on how this experiment could be improved, or suggestions for future studies?

5. Do you have any musical experience? If so, what kind of experience did you have (e.g., violin, choir, theory, etc.), and for how long? Do you have formal training? If yes, then for how many years and to what level of detail?

6. Have you studied or experienced anything else that you think may have affected your responses on the task today? If so, please describe.

7. Is there any reason your data should not be used in this study? If so, please explain.

Appendix I

CHI-SQUARE STATISTICS INDICATING NON-CHANCE LEVEL RESPONDING, BY PROBE TYPE, EXPERIMENT 1

response category	mm, length	%	test % (chance)	ChiSquare	df	p	correct
<0	363	75.63	43	208.81	2	<.0001	*
0	33	6.88	14				
>0	84	17.50	43				
	mm, tempo						
<0	124	25.83	43	827.62	2	<.0001	
0	285	59.38	14				*
>0	71	14.79	43				
	ms, length						
<0	325	67.71	43	139.67	2	<.0001	*
0	70	14.58	14				
>0	85	17.71	43				
	ms, tempo						
<0	105	21.88	43	683.90	2	<.0001	
0	266	55.42	14				*
>0	109	22.71	43				
	sm, length						
<0	322	67.08	43	135.32	2	<.0001	*
0	72	15.00	14				
>0	86	17.92	43				
	sm, tempo						
<0	109	22.71	43	566.10	2	<.0001	
0	248	51.67	14				*
>0	123	25.63	43				
	ss, length						
<0	270	56.25	43	88.59	2	<.0001	*
0	104	21.67	14				
>0	106	22.08	43				
	ss, tempo						
<0	113	23.54	43	650.01	2	<.0001	
0	261	54.38	14				*
>0	106	22.08	43				
	itt, length						
<0	113	23.54	43	547.21	2	<.0001	
0	245	51.04	14				*
>0	122	25.42	43				
	itt, tempo						
<0	106	22.08	43	630.17	2	<.0001	
0	258	53.75	14				*
>0	116	24.17	43				

Appendix J

CHI-SQUARE STATISTICS INDICATING NON-CHANCE LEVEL RESPONDING, BY STIMULUS ORGANIZATION AND SUBTYPE, EXPERIMENT 1

response category	seq, length	%	test % (chance)	ChiSquare	df	p	correct
<0	693	57.75	43	257.82	2	<.0001	*
0	263	21.92	14				
>0	244	20.33	43				
	seq, tempo						
<0	261	21.75	43	1758.17	2	<.0001	
0	672	56.00	14				*
>0	267	22.25	43				
	asc, length						
<0	251	57.05	43	76.28	2	<.0001	*
0	90	20.45	14				
>0	99	22.50	43				
	asc, tempo						
<0	98	22.27	43	691.73	2	<.0001	
0	253	57.50	14				*
>0	89	20.23	43				
	desc, length						
<0	274	62.27	43	101.50	2	<.0001	*
0	81	18.41	14				
>0	85	19.32	43				
	desc, tempo						
<0	100	22.73	43	486.51	2	<.0001	
0	222	50.45	14				*
>0	118	26.82	43				
	osc, length						
<0	168	52.50	43	100.21	2	<.0001	
0	92	28.75	14				*
>0	60	18.75	43				
	osc, tempo						
<0	63	19.69	43	601.28	2	<.0001	
0	197	61.56	14				*
>0	60	18.75	43				
	rand, length						
<0	700	58.33	43	265.79	2	<.0001	
0	261	21.75	14				*
>0	239	19.92	43				
	rand, tempo						
<0	296	24.67	43	1582.82	2	<.0001	
0	646	53.83	14				*
>0	258	21.50	43				

Note: seq. represents sequential, asc represents ascending, desc represents descending, osc represents oscillating, and rand represents random.

Appendix K
MIXED LINEAR MODEL, LENGTH DATA, EXPERIMENT 1†

parameter	num df	denom df	F	p						
probe type	4	2336	89.39	<.0001		estimate	se	df	t	p
					mm	-1.46	0.10	2336	-13.96	<.0001
					ms	-0.93	0.11	2336	-8.88	<.0001
					sm	-1.00	0.11	2337	-9.53	<.0001
					ss	-0.36	0.10	2336	-3.45	.0006
					itt	0	.	.	.	.
ssubtype	3	2335	1.95	.12		estimate	se	df	t	p
					ascending	0.28	0.16	2336	1.77	.08
					descending	-0.07	0.17	2336	-0.40	.69
					oscillating	-0.27	0.18	2336	-1.45	.15
					random	0	.	.	.	.
music experience	2	36.6	0.37	.69		estimate	se	df	t	p
					high	0.05	0.49	38.1	0.10	.92
					low	0.10	0.30	38.1	0.35	.73
					medium	0	.	.	.	.
block1	1	36	4.23	.047		estimate	se	df	t	p
					music	-0.57	0.28	36	-2.06	.047
					literature	0	.	.	.	.
pr*ssubtype	12	2337	2.21	.009		estimate	se	df	t	p
					mm_asc	-0.34	0.20	2337	-1.66	.10
					mm_desc	-0.35	0.20	2337	-1.70	.09
					mm_osc	0.50	0.23	2336	2.17	.03
					mm_rand	0	.	.	.	.
					ms_asc	-0.45	0.2	2337	-2.19	.03
					ms_desc	-0.13	0.2	2337	-0.65	.52
					ms_osc	0.53	0.23	2339	2.32	.02
					ms_rand	0	.	.	.	.
					sm_asc	-0.11	0.2	2338	-0.55	.58
					sm_desc	0.05	0.2	2338	0.23	.82
					sm_osc	0.47	0.23	2338	2.04	.04
					sm_rand	0	.	.	.	.
					ss_asc	-0.43	0.2	2337	-2.14	.03
					ss_desc	-0.16	0.2	2338	-0.76	.44
					ss_osc	-0.01	0.23	2337	-0.05	.96
					ss_rand	0	.	.	.	.
					itt_asc	0	.	.	.	.
					itt_desc	0	.	.	.	.
					itt_osc	0	.	.	.	.
					itt_rand	0	.	.	.	.

†continued on next page…

Appendix K

MIXED LINEAR MODEL, LENGTH DATA, EXPERIMENT 1, CONTINUED

parameter	num df	denom df	F	p						
ssubtype*mexp	6	2335	2.19	.04		estimate	se	df	t	p
					asc_high	0.27	0.23	2335	1.21	.22
					asc_low	0.06	0.14	2335	0.41	.68
					asc_med	0	.	.	.	.
					desc_high	0.47	0.23	2335	2.10	.04
					desc_low	0.08	0.14	2335	0.59	.55
					desc_med	0	.	.	.	.
					osc_high	0.05	0.25	2335	0.20	.84
					osc_low	0.40	0.15	2335	2.63	.01
					osc_med	0	.	.	.	.
					rand_high	0	.	.	.	.
					rand_low	0	.	.	.	.
					rand_med	0	.	.	.	.

Note: num represents numerator. denom represents denominator. ssubtype represents stimulus subtype. pr represents probe type. mexp represents musical experience. asc represents ascending, desc represents descending, osc represents oscillating, and rand represents random. med represents a medium level of musical experience.

Appendix L

MIXED LINEAR MODEL, TEMPO DATA, EXPERIMENT 1

parameter	num df	denom df	F	p						
probe type	4	2354	3.47	.008		estimate	se	df	t	p
					mm	-0.16	0.05	2354	-2.92	.004
					ms	-0.03	0.05	2354	-0.47	.64
					sm	0.03	0.05	2354	0.51	.61
					ss	-0.04	0.05	2354	-0.73	.46
					itt	0	.	.	.	.
voice	2	2356	4.01	.018		estimate	se	df	t	p
					female	0.11	0.04	2355	2.77	.006
					male	0.01	0.04	2355	0.36	.72
					piano	0	.	.	.	.

Note: num represents numerator and denom represents denominator.

Appendix M

LENGTH DATA T-TESTS COMPARING MEAN RATINGS TO EXPECTED RATINGS, SEQUENTIAL STIMULI BY PROBE TYPE, EXPERIMENT 1

Sequential stimuli, Overall

probe type	E(x)	mean	sd	se	df	t	p	effect
mm	-3	-1.48	1.52	.24	39	6.32	<.0001	BR
ms	-2	-0.91	1.24	.20	39	5.56	<.0001	BR
sm	-2	-0.86	1.30	.21	39	5.54	<.0001	BR
ss	-1	-0.46	0.70	.11	39	4.85	<.0001	BR
itt	0	0.07	0.37	.06	39	1.17	.25	none

Ascending stimuli

probe type	E(x)	mean	sd	se	df	t	p	effect
mm	-3	-1.48	1.72	.28	37	5.44	<.0001	BR
ms	-2	-1.10	1.29	.21	37	4.30	.0001	BR
sm	-2	-0.85	1.68	.28	35	4.09	.0002	BR
ss	-1	-0.53	1.01	.17	35	2.77	.009	BR
itt	0	0.13	0.62	.10	37	1.32	.20	none

Descending Stimuli

probe type	E(x)	mean	sd	se	df	t	p	effect
mm	-3	-1.56	1.87	.30	37	4.74	<.0001	BR
ms	-2	-0.98	1.50	.24	37	4.17	.0002	BR
sm	-2	-0.99	1.44	.25	33	4.10	.0003	BR
ss	-1	-0.50	0.99	.17	35	3.01	.005	BR
itt	0	-0.01	0.56	.09	37	-0.15	.89	none

Oscillating stimuli

probe type	E(x)	mean	sd	se	df	t	p	effect
mm	-3	-0.97	1.54	.27	31	7.43	<.0001	BR
ms	-2	-0.71	1.19	.22	27	5.78	<.0001	BR
sm	-2	-0.65	1.31	.23	31	5.82	<.0001	BR
ss	-1	-0.34	0.98	.16	37	4.13	.0002	BR
itt	0	0.07	0.89	.14	37	0.49	.63	none

Note: Probe types are listed from shortest to longest. The E(x) column indicates the expected value to which the mean was compared. BR represents boundary restriction. Ascending, descending, and oscillating stimuli were subtypes of sequential stimulus organization. The p value required for the Bonferroni correction was .05/5=.01.

Appendix N

LENGTH DATA T-TESTS COMPARING MEAN RATINGS TO EXPECTED RATINGS, RANDOM STIMULI BY PROBE TYPE, EXPERIMENT 1

Random stimuli

probe type	E(x)	mean	sd	se	df	t	p	effect
mm	-3	-1.51	1.73	.27	39	5.44	<.0001	BR
ms	-2	-0.97	1.22	.19	39	5.35	<.0001	BR
sm	-2	-0.99	1.13	.18	39	5.64	<.0001	BR
ss	-1	-0.42	0.69	.11	39	5.35	<.0001	BR
itt	0	0.05	0.40	.06	39	0.78	.44	none

Note: Probe types are listed from shortest to longest. The E(x) column indicates the expected value to which the mean was compared. BR represents boundary restriction. For random stimuli, stimulus organization and stimulus subtype were the same. The p value required for the Bonferroni correction was .05/5=.01.

Appendix O

LENGTH DATA T-TESTS COMPARING MEAN RATINGS TO EXPECTED RATINGS, NOTE AND NUMBER STIMULI BY PROBE TYPE, EXPERIMENT 1

Note stimuli

probe type	E(x)	mean	sd	se	df	t	p	effect
mm	-3	-1.49	1.74	.27	39	5.51	<.0001	BR
ms	-2	-0.95	1.22	.19	39	5.44	<.0001	BR
sm	-2	-0.90	1.31	.21	39	5.33	<.0001	BR
ss	-1	-0.43	0.81	.13	39	4.40	<.0001	BR
itt	0	0.08	0.39	.06	39	1.22	.23	none

Number stimuli

probe type	E(x)	mean	sd	se	df	t	p	effect
mm	-3	-1.47	1.52	.24	39	6.36	<.0001	BR
ms	-2	-0.90	1.14	.18	39	6.09	<.0001	BR
sm	-2	-0.91	1.22	.19	39	5.68	<.0001	BR
ss	-1	-0.41	0.61	.10	39	6.09	<.0001	BR
itt	0	0.01	0.46	.07	39	0.17	.86	none

Note: Probe types are listed from shortest to longest. The E(x) column indicates the expected value to which the mean was compared. BR represents boundary restriction. The p value required for the Bonferroni correction was .05/5=.01.

Appendix P

TEMPO DATA T-TESTS COMPARING MEAN RATINGS TO EXPECTED RATINGS, SEQUENTIAL STIMULI BY PROBE TYPE, EXPERIMENT 1

Sequential stimuli, Overall

probe type	E(x)	mean	sd	se	df	t	p	effect
mm	0	-0.09	.27	.04	39	-2.02	<.05	trslower
ms	0	0.04	.30	.05	39	0.78	.44	none
sm	0	0.12	.36	.06	39	2.15	.04	trfaster
ss	0	-0.05	.32	.05	39	-1.06	.30	none
itt	0	0.04	.35	.05	39	0.75	.46	none

Ascending stimuli

probe type	E(x)	mean	sd	se	df	t	p	effect
mm	0	-0.24	0.53	.09	37	-2.82	.008	slower
ms	0	0.06	0.55	.09	37	0.72	.48	none
sm	0	0.11	0.65	.11	35	1.05	.30	none
ss	0	-0.13	0.65	.11	35	-1.21	.23	none
itt	0	-0.06	0.73	.12	37	-0.46	.65	none

Descending Stimuli

probe type	E(x)	mean	sd	se	df	t	p	effect
mm	0	-0.07	0.48	.08	37	-0.92	.36	none
ms	0	0.09	0.62	.10	37	0.84	.40	none
sm	0	0.16	0.71	.12	33	1.27	.21	none
ss	0	0.03	0.54	.09	35	0.29	.77	none
itt	0	0.11	0.64	.10	37	1.09	.28	none

Oscillating stimuli

probe type	E(x)	mean	sd	se	df	t	p	effect
mm	0	0.07	.56	.10	31	0.68	.50	none
ms	0	-0.03	.58	.11	27	-0.27	.79	none
sm	0	-0.08	.60	.11	31	-0.73	.47	none
ss	0	-0.03	.62	.10	37	-0.28	.78	none
itt	0	-0.08	.78	.13	37	-0.63	.53	none

Note: Probe types are listed from shortest to longest. The E(x) column indicates the expected value to which the mean was compared; it is 0 in all cases because tempo was not manipulated. Ascending, descending, and oscillating stimuli were subtypes of sequential stimulus organization. trslower represents a statistically nonsignificant trend (i.e., p-value less than .05, but greater than the p-value required by the Bonferroni correction) toward judging probes as slower than their associated targets. trfaster represents a statistically nonsignificant trend toward judging probes as faster than their associated targets. The p value required for the Bonferroni correction was .05/5=.01.

Appendix Q

TEMPO DATA T-TESTS COMPARING MEAN RATINGS TO EXPECTED RATINGS, RANDOM STIMULI BY PROBE TYPE, EXPERIMENT 1

Random stimuli

probe type	E(x)	mean	sd	se	df	t	p	effect
mm	0	-0.22	0.41	.06	39	-3.40	.002	slower
ms	0	-0.01	0.32	.05	39	-0.22	.82	none
sm	0	-0.99	1.13	.18	39	-5.52	<.0001	slower
ss	0	0.01	0.30	.05	39	0.28	.78	none
itt	0	-0.01	0.44	.07	39	-0.15	.89	none

Note: Probe types are listed from shortest to longest. The E(x) column indicates the expected value to which the mean was compared; it is 0 in all cases because tempo was not manipulated. The p value required for the Bonferroni correction was .05/5=.01.

Appendix R

TEMPO DATA T-TESTS COMPARING MEAN RATINGS TO EXPECTED RATINGS, NOTE AND NUMBER STIMULI BY PROBE TYPE, EXPERIMENT 1

Note stimuli

probe type	E(x)	mean	sd	se	df	t	p	effect
mm	0	-0.15	0.35	.06	39	-2.63	.01	slower
ms	0	-0.07	0.34	.05	39	-1.30	.20	none
sm	0	0.04	0.40	.06	39	0.66	.51	none
ss	0	-0.07	0.37	.06	39	-1.15	.26	none
itt	0	-0.04	0.45	.07	39	-0.58	.56	none

Number stimuli

probe type	E(x)	mean	sd	se	df	t	p	effect
mm	0	-0.14	0.27	.04	39	-3.23	.003	slower
ms	0	0.05	0.30	.05	39	1.04	.31	none
sm	0	0.04	0.41	.07	39	0.64	.53	none
ss	0	0.02	0.33	.05	39	0.32	.75	none
itt	0	0.07	0.30	.05	39	1.51	.14	none

Note: Probe types are listed from shortest to longest. The E(x) column indicates the expected value to which the mean was compared. The p value required for the Bonferroni correction was . .05/5=.01.

Appendix S
MUSIC SELECTIONS FOR EXPERIMENTS 2-5†

exps 2, 4, 5	exp 3	composer	era	piece	source
1	1	Albeniz, I.	1860-1909	Tango	Piano classics (1987)
*		Bach, J. S.	1685-1750	Prelude, No. 1 from the Well-Tempered Clavier	Piano classics (1987)
2		Beethoven, L. van	1770-1817	Bagatelle, Op. 126, No. 5	Piano classics (1987)
3	2	Boccherini, L.	1743-1805	Minuet	Piano classics (1987)
4	3	Brahms, J.	1833-1897	Waltz in A Flat, Op. 39, No. 15	Piano classics (1987)
*		Chopin, F.	1810-1849	Nocturne, Posthumous	Piano classics (1987)
5	4	Daquin, L.-C.	1694-1772	Le Coucou	Piano classics (1987)
6	5	Dvorak, A.	1841-1904	Humoresque, Op. 101, No. 7	Piano classics (1987)
7	6	Field, J.	1782-1837	Nocturne	Piano classics (1987)
8		Diabelli, A.	1781-1858	Rondino	Piano classics (1987)
9		Fibich, Z.	1850-1900	Poem	Piano classics (1987)
10		Grieg, E.	1843-1907	Anitra's Dance, from Peer Gynt	Piano classics (1987)
11	7	Franck, C.	1822-1890	Les Plaintes d'une Poupee	Piano classics (1987)
12		Gossec, F. J.	1734-1829	Gavotte in D	Piano classics (1987)
13	*	Granados, E.	1867-1916	à Alfredo G. Faria Playera, Spanish Dance Op. 5, No. 5	Piano classics (1987)
14		Handel, G. F.	1685-1759	Air and Variations, The Harmonious Blacksmith from Suite No. 5	Piano classics (1987)
	*	Handel, G. F.	1685-1759	Largo	Piano classics (1987)
15	*	Haydn, J.	1732-1809	Sonata in D Major, mvt. 1	Piano classics (1987)
16	*	Joplin, S.	1868-1919	The Cascades: A Rag	Piano classics (1987)
17	8	Kabalevsky, D.	1904-1987	Having Fun, from Op. 27	Piano classics (1987)
18		Khachaturian, A.	1903-1978	Saber Dance, from "Gayne Ballet"	Piano classics (1987)
19		Liadov, A.	1843-1907	The Music Box, Op. 32	Piano classics (1987)
20		MacDowell, E.	1861-1908	To a Wild Rose, Op. 51, No. 1	Piano classics (1987)
21		Massenet, J.	1842-1912	Elegie, Melodie Op. 10	Piano classics (1987)
22		Mendelssohn, F.	1809-1847	Venetian Boat Song, Op. 19, No. 6	Piano classics (1987)
23		Mozart, W. A.	1756-1791	Sonata, K. 545, mvt. 2	Piano classics (1987)

†continued on next page…

Appendix S

MUSIC SELECTIONS FOR EXPERIMENTS 2-5, CONTINUED

exps 2, 4, 5	exp 3	composer	era	piece	source
24		Offenbach, J.	1819-1880	Barcarolle, from Tales of Hoffman	Piano classics (1987)
*		Prokofieff, S.	1891-1953	Peter and the Wolf	Piano classics (1987)
*		Satie, E.	1866-1925	Trois Gnossiennes	Piano classics (1987)
25		Scarlatti, D.	1685-1757	Sonata, L. 375	Piano classics (1987)
26		Tchaikovsky, P. I.	1840-1893	Italian Song, Op. 39, No. 15	Piano classics (1987)
27		Scriabin, A.	1872-1915	Album Leaf, Op. 45, No. 1	Piano classics (1987)
28		Schubert, F.	1797-1828	Serenade	Piano classics (1987)
29		Strauss, J.	1825-1899	The Beautiful Blue Danube, Tempo di Valse	Piano classics (1987)
30		Weber, C. M. von	1786-1826	Waltz	Piano classics (1987)
31		Kenny G	1988	Home (arr. P. Keveren)	Kenny G (1988/2004)
32		Ballard, G., & Silvestri, A.	2004	Believe, from Warner Bros. Pictures' The Polar Express	Ballard & Silvestri (2004/2005)
33	9	Gibb, R., Gibb, M., & Gibb, B.	1979	How Deep is Your Love, from the Motion Picture Saturday Night Fever	Gibb, Gibb, & Gibb (1979)
34	10	Lennon, J., & McCartney, P.	1968	Hey Jude	Lennon & McCartney (1968)
35	11	Gershwin, G., & Gershwin, I.	1937	A Foggy Day	Gershwin & Gershwin (1937)
36	12	Jordan, F.	1998	Danse Slave	http://icking-music-archive.org/ByComposer/Jordan.html

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

Appendix T

LITERATURE SELECTIONS FOR EXPERIMENTS 2-5†

exps 2, 4, 5	exp 3	author	era	literary work	source
1	1	Alcott, L. M.	1832-188	Eight Cousins	http://www.literature.org/authors/
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	2	Carroll, L.	1832-1898	Alice's Adventures in Wonderland	http://www.literature.org/authors/
8	3	Cather, W. S.	1873-1847	Alexander's Bridge	http://www.literature.org/authors/
9	4	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	5	Dostoevsky, F.	1821-1881	Crime and Punishment (C. Garnett, Trans.)	http://www.literature.org/authors/
*		Dumas père, 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	6	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	7	Montgomery, L. M.	1874-1942	Anne of Green Gables	http://www.literature.org/authors/
22	*	Nesbit, E.	1858-1924	Five Children and It	http://www.literature.org/authors/
23	8	Oppenheim, E. P.	1866-1946	The Illustrious Prince	http://www.literature.org/authors/

†continued on next page…

Appendix T

LITERATURE SELECTIONS FOR EXPERIMENTS 2-5, CONTINUED

exps 2, 4, 5	exp 3	author	era	literary work	source
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 (A. Maude & L. S. Maude, Trans.)	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	9	Hardy, T.	1840-1928	Tess of the d'Urbervilles	http://www.bibliomania.com/0/-/frameset.html
30		Funke, C.	1958-	Inkspell (A. Bell, Trans.)	Funke (2005)
31	10	Rand, A.	1905-1982	Atlas Shrugged	Rand (1957/1992)
32		Brown, D.	1964-	The DaVinci Code	Brown(2003)
33	11	Wallace, B.	1947-	A Dog Called Kitty	Wallace (1980)
34	12	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 (E. J. Richards, Trans.)	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 U

CHI-SQUARE STATISTICS INDICATING NON-CHANCE LEVEL RESPONDING, BY PROBE TYPE, EXPERIMENT 2

response category	mm, length	%	test % (chance)	ChiSq	df	p	correct
<0	448	86.82	43	406.62	2	<.0001	*
0	28	5.43	14				
>0	40	7.75	43				
	mm, tempo						
<0	82	15.89	43	913.89	2	<.0001	
0	310	60.08	14				*
>0	124	24.03	43				
	ms, length						
<0	407	78.88	43	297.78	2	<.0001	*
0	65	12.60	14				
>0	44	8.53	43				
	ms, tempo						
<0	83	16.09	43	840.62	2	<.0001	
0	300	58.14	14				*
>0	133	25.78	43				
	sm, length						
<0	424	82.17	43	333.07	2	<.0001	*
0	46	8.91	14				
>0	46	8.91	43				
	sm, tempo						
<0	87	16.86	43	684.38	2	<.0001	
0	277	53.68	14				*
>0	152	29.46	43				
	ss, length						
<0	348	67.44	43	239.53	2	<.0001	*
0	120	23.26	14				
>0	48	9.30	43				
	ss, tempo						
<0	94	18.22	43	773.38	2	<.0001	
0	291	56.40	14				*
>0	131	25.39	43				
	itt, length						
<0	74	14.34	43	1097.24	2	<.0001	
0	333	64.53	14				*
>0	109	21.12	43				
	itt, tempo						
<0	109	21.12	43	600.53	2	<.0001	
0	265	51.36	14				*
>0	142	27.52	43				

Appendix V

MIXED LINEAR MODEL, LENGTH DATA, EXPERIMENT 2†

param	num df	denom df	F	p						
probe	4	2512	223.03	<.0001		estimate	se	df	t	p
					mm	-2.34	0.14	2512	-17.19	<.0001
					ms	-1.71	0.14	2512	-12.55	<.0001
					sm	-1.68	0.14	2512	-12.36	<.0001
					ss	-1.12	0.14	2512	-8.20	<.0001
					itt	0	.	.	.	.
mexp	2	40	0.64	.53		estimate	se	df	t	p
					high	-0.19	0.35	50.7	-0.56	.58
					low	-0.12	0.27	50.9	-0.45	.65
					medium	0	.	.	.	.
pr*mexp	8	2512	4.59	<.0001		estimate	se	df	t	p
					mm_high	0.79	0.18	2512	4.32	<.0001
					mm_low	0.58	0.15	2512	3.99	<.0001
					mm_med	0	.	.	.	.
					ms_high	0.46	0.18	2512	2.53	.01
					ms_low	0.59	0.15	2512	4.09	<.0001
					ms_med	0	.	.	.	.
					sm_high	0.68	0.18	2512	3.70	.0002
					sm_low	0.41	0.15	2512	2.82	.005
					sm_med	0	.	.	.	.
					ss_high	0.32	0.18	2512	1.75	.08
					ss_low	0.46	0.15	2512	3.15	.002
					ss_med	0	.	.	.	.
					itt_high	0	.	.	.	.
					itt_low	0	.	.	.	.
					itt_med	0	.	.	.	.
block	1	2526	6.37	.01		estimate	se	df	t	p
					literature	-0.43	0.17	2526	-2.52	.01
					music	0	.	.	.	.
voice	2	2516	3.79	.02		estimate	se	df	t	p
					female	0.37	0.20	2542	1.84	.07
					male	0.21	0.20	2543	1.07	.28
					piano	0	.	.	.	.

†continued on next page…

Appendix V

MIXED LINEAR MODEL, LENGTH DATA, EXPERIMENT 2, CONTINUED

param	num df	denom df	F	p						
pr*voice	8	2513	2.56	.009		estimate	se	df	t	p
					mm_f	-0.29	0.14	2513	-2.02	.04
					mm_m	0.17	0.14	2513	1.20	.23
					mm_pi	0	.	.	.	.
					ms_f	-0.23	0.14	2513	-1.58	.12
					ms_m	-0.04	0.14	2513	-0.25	.80
					ms_pi	0	.	.	.	.
					sm_f	-0.40	0.14	2513	-2.79	.005
					sm_m	-0.07	0.14	2513	-0.52	.60
					sm_pi	0	.	.	.	.
					ss_f	-0.54	0.14	2513	-3.75	.0002
					ss_m	-0.06	0.14	2513	-0.43	.67
					ss_pi	0	.	.	.	.
					itt_f	0	.	.	.	.
					itt_m	0	.	.	.	.
					itt_pi	0	.	.	.	.

Note: param represents parameter. num represents numerator. denom represents denominator. mexp represents musical experience. pr represents probe. med represents a medium level of musical experience. f represents female reading voice. m represents male reading voice. pi represents piano.

Appendix W

LENGTH DATA T-TESTS COMPARING MEAN RATINGS TO EXPECTED RATINGS, MUSIC AND LITERATURE STIMULI BY PROBE TYPE, EXPERIMENT 2

Music stimuli

probe type	E(x)	mean	sd	se	df	t	p	effect
mm	-3	-1.67	1.08	.16	42	8.10	<.0001	BR
ms	-2	-1.10	0.73	.11	42	8.05	<.0001	BR
sm	-2	-1.15	0.87	.13	42	6.44	<.0001	BR
ss	-1	-0.60	0.52	.08	42	5.04	<.0001	BR
itt	0	0.18	0.36	.06	42	3.29	.002	BR

Literature stimuli

probe type	E(x)	mean	sd	se	df	t	p	effect
mm	-3	-1.88	1.22	.19	42	6.02	<.0001	BR
ms	-2	-1.37	1.04	.16	42	3.96	.0003	BR
sm	-2	-1.52	1.03	.16	42	3.09	.004	BR
ss	-1	-1.07	0.78	.12	42	-0.62	.54	none
itt	0	0.03	0.32	.05	42	0.71	.48	none

Note: Probe types are listed from shortest to longest. The E(x) column indicates the expected value to which the mean was compared. BR represents boundary restriction. The p value required for the Bonferroni correction was .05/5=.01.

Appendix X

TEMPO DATA T-TESTS COMPARING MEAN RATINGS TO EXPECTED RATINGS, MUSIC AND LITERATURE STIMULI BY PROBE TYPE, EXPERIMENT 2

Music stimuli

probe type	E(x)	mean	sd	se	df	t	p	effect
mm	-3	0.05	0.45	.07	42	0.68	.50	none
ms	-2	0.00	0.40	.06	42	0.00	1.00	none
sm	-2	0.12	0.50	.08	42	1.52	.14	none
ss	-1	-0.04	0.40	.06	42	-0.70	.49	none
itt	0	0.02	0.48	.07	42	0.26	.79	none

Literature stimuli

probe type	E(x)	mean	sd	se	df	t	p	effect
mm	-3	0.15	0.41	.06	42	2.41	.02	trfaster
ms	-2	0.17	0.34	.05	42	3.25	.002	faster
sm	-2	0.12	0.44	.07	42	1.81	.08	none
ss	-1	0.17	0.39	.06	42	2.90	.006	faster
itt	0	0.10	0.40	.06	42	1.65	.11	none

Note: Probe types are listed from shortest to longest. The E(x) column indicates the expected value to which the mean was compared. trfaster represents a statistically nonsignificant trend (i.e., p-value less than .05, but greater than the p-value required by the Bonferroni correction) toward judging probes as faster than their associated targets. The p value required for the Bonferroni correction was .05/5=.01.

Appendix Y

CHI-SQUARE STATISTICS INDICATING NON-CHANCE LEVEL RESPONDING, EXPERIMENT 3

response category	length	%	test % (chance)	ChiSq	df	p	correct
<0	221	23.02	43	988.63	2	<.0001	
0	472	49.17	14				*
>0	267	27.81	43				
	length, block 1 only						
<0	99	20.63	43	532.58	2	<.0001	
0	242	50.42	14				*
>0	139	28.96	43				

response category	tempo	%	test % (chance)	ChiSq	df	p	correct
<0	306	31.88	43	298.98	2	<.0001	
0	320	33.33	14				*
>0	334	34.79	43				
	tempo, block 1 only						
<0	151	31.46	43	107.37	2	<.0001	
0	145	30.21	14				*
>0	184	38.33	43				

Appendix Z

LENGTH DATA T-TESTS COMPARING MEAN RATINGS TO EXPECTED RATINGS, ALL DATA, BY PARAMETERS, EXPERIMENT 3

parameter	E(x)	mean	sd	se	df	t	p	effect
Overall	0	0.04	0.24	.04	39	1.16	.25	none
Music	0	0.09	0.36	.06	39	1.55	.13	none
Literature	0	0.00	0.32	.05	39	0.04	.97	none
High music experience	0	-0.06	0.26	.15	2	-0.36	.75	none
Low music experience	0	0.03	0.21	.04	23	0.72	.48	none
Medium music experience	0	0.09	0.30	.08	12	1.13	.28	none
Literature, High music experience	0	0.17	0.44	.25	2	0.65	.58	none
Literature, Low music experience	0	0.00	0.19	.04	23	0.09	.93	none
Literature, Medium music experience	0	-0.04	0.47	.13	12	-0.30	.77	none
Music, High music experience	0	-0.28	0.13	.07	2	-3.78	.06	none
Music, Low music experience	0	0.06	0.37	.08	23	0.79	.44	none
Music, Medium music experience	0	0.22	0.31	.09	12	2.57	.02	trBR
Female voice	0	0.05	0.37	.06	39	0.78	.44	none
Male voice	0	-0.04	0.38	.06	39	-0.69	.49	none
Piano	0	0.09	0.36	.06	39	1.55	.13	none

Note: trBR represents a statistically nonsignificant trend (i.e., p-value less than .05, but greater than the p-value required by the Bonferroni correction) toward boundary restriction. The p value required for the Bonferroni correction was .05/15=.003.

Appendix AA

LENGTH DATA T-TESTS COMPARING MEAN RATINGS TO EXPECTED RATINGS, BLOCK 1 DATA, BY PARAMETERS, EXPERIMENT 3

parameter	E(x)	mean	sd	se	df	t	p	effect
Overall	0	0.12	0.30	.05	39	2.48	.02	trBR
Music	0	0.15	0.34	.08	19	2.03	.06	none
Literature	0	0.08	0.26	.06	19	1.41	.18	none
High music experience	0	0.17	0.44	.25	2	0.65	.58	none
Low music experience	0	0.07	0.30	.06	23	1.21	.24	none
Medium music experience	0	0.19	0.30	.08	12	2.35	.04	trBR
Lit*High music experience	0	0.17	0.44	.25	2	0.65	.58	none
Lit*Low music experience	0	-0.01	0.19	.06	8	-0.15	.89	none
Lit* Medium music experience	0	0.16	0.27	.10	7	1.62	.15	none
Music* High music experience	0	n/a	n/a	n/a	n/a	n/a	n/a	n/a
Music* Low music experience	0	0.12	0.34	.09	14	1.39	.19	none
Music* Medium music experience	0	0.25	0.35	.16	4	1.58	.19	none
Female voice	0	0.13	0.40	.09	19	1.38	.18	none
Male voice	0	0.04	0.26	.06	19	0.72	.48	none
Piano	0	0.15	0.34	.08	19	2.03	.06	none

Note: Exptr represents an individual experimenter. trBR represents a statistically nonsignificant trend (i.e., p-value less than .05, but greater than the p-value required by the Bonferroni correction) toward boundary restriction. The p value required for the Bonferroni correction was .05/15=.003.

Appendix BB

TEMPO DATA T-TESTS COMPARING MEAN RATINGS TO EXPECTED RATINGS, ALL DATA, BY PARAMETERS, EXPERIMENT 3

parameter	E(x)	mean	sd	se	df	t	p	effect
Tempo	0	0.02	0.23	.04	39	0.62	.54	none
Music	0	-0.04	0.30	.05	39	-0.75	.46	none
Literature	0	0.08	0.30	.05	39	1.72	.09	none
High music experience	0	-0.04	0.22	.13	2	-0.33	.77	none
Low music experience	0	0.00	0.26	.05	23	-0.07	.95	none
Medium music experience	0	0.09	0.19	.05	12	1.66	.12	none
Literature* High music experience	0	-0.03	0.27	.15	2	-0.18	.87	none
Literature* Low music experience	0	0.01	0.29	.06	23	0.12	.91	none
Literature* Medium music experience	0	0.24	0.26	.07	12	3.38	.006	trfaster
Music* High music experience	0	-0.06	0.17	.10	2	-0.55	.63	none
Music* Low music experience	0	-0.01	0.33	.07	23	-0.21	.84	none
Music* Medium music experience.	0	-0.07	0.28	.08	12	-0.91	.38	none
Female voice	0	0.21	0.42	.07	39	3.19	<.003	faster
Male voice	0	-0.05	0.48	.08	39	-0.66	.51	none
Piano	0	-0.04	0.30	.05	39	-0.75	.46	none

Note: n/a represents not applicable, meaning no data were available for the cell. trfaster represents a statistically nonsignificant trend (i.e., p-value less than .05, but greater than the p-value required by the Bonferroni correction) toward judging probes as faster than their associated targets. The p value required for the Bonferroni correction was .05/15=.003.

Appendix CC

TEMPO DATA T-TESTS COMPARING MEAN RATINGS TO EXPECTED RATINGS, BLOCK 1 DATA, BY PARAMETERS, EXPERIMENT 3

parameter	E(x)	mean	sd	se	df	t	p	effect
Tempo	0	0.06	0.30	.05	39	1.35	.18	none
Music	0	0.03	0.32	.07	19	0.41	.69	none
Literature	0	0.10	0.29	.06	19	1.57	.13	none
High music experience	0	-0.03	0.27	.15	2	-0.18	.87	none
Low music experience	0	0.08	0.32	.07	23	1.21	.24	none
Medium music experience	0	0.06	0.28	.08	12	0.74	.47	none
Literature* High music experience	0	-0.03	0.27	.15	2	-0.18	.87	none
Literature* Low music experience	0	0.07	0.34	.11	8	0.65	.53	none
Literature* Medium music experience	0	0.18	0.23	.08	7	2.19	.07	none
Music* High music experience	0	n/a	n/a	n/a	n/a	n/a	n/a	n/a
Music* Low music experience	0	0.08	0.33	.08	14	0.99	.34	none
Music* Medium music experience.	0	-0.13	0.27	.12	4	-1.11	.33	none
Female voice	0	0.30	0.47	.10	19	2.87	.01	trfaster
Male voice	0	-0.10	0.54	.12	19	-0.82	.42	none
Piano	0	0.03	0.32	.07	19	0.41	.69	none

Note: trfaster represents a statistically nonsignificant trend (i.e., p-value less than .05, but greater than the p-value required by the Bonferroni correction) toward judging probes as faster than their associated targets. The p value required for the Bonferroni correction was .05/26=.002.

Appendix DD

CHI-SQUARE STATISTICS INDICATING NON-CHANCE LEVEL RESPONDING, EXPERIMENT 4

response category	CC, length	%	test % (chance)	ChiSq	df	p	correct
<0	89	14.13	40	1120.20	2	<.0001	
0	462	73.33	20				*
>0	79	12.54	40				
	CC, tempo						
<0	142	22.54	40	548.31	2	<.0001	
0	361	57.30	20				*
>0	127	20.16	40				
	CP, length						
<0	45	7.14	40	407.25	2	<.0001	
0	93	14.76	20				
>0	492	78.10	40				*
	CP, tempo						
<0	163	25.87	40	414.20	2	<.0001	
0	330	52.38	20				*
>0	137	21.75	40				
	PC, length						
<0	494	78.41	40	414.38	2	<.0001	*
0	93	14.76	20				
>0	43	6.83	40				
	PC, tempo						
<0	124	19.68	40	482.73	2	<.0001	
0	346	54.92	20				*
>0	160	25.40	40				
	PP, length						
<0	85	13.49	40	810.57	2	<.0001	
0	411	65.24	20				*
>0	135	21.27	40				
	PP, tempo						
<0	177	28.10	40	341.96	2	<.0001	
0	311	49.37	20				*
>0	142	22.54	40				

Note: Target/probe presentation is indicated by: CC (close-up/close-up), CP (close-up/prototype), PC (prototype/close-up), PP (prototype/prototype).

Appendix EE

MIXED LINEAR MODEL, LENGTH DATA, EXPERIMENT 4

param	num df	denom df	F	p		estimate	se	df	t	p
c	3	2470	753.47	<.0001	CC	-0.32	.09	2470	-3.75	.0002
					CP	0.81	.09	2470	9.48	.0001
					PC	-1.37	.09	2470	-16.04	<.0001
					PP	0	.	.	.	.
block	1	2470	11.1	0.0009		estimate	se	df	t	p
					literature	-0.14	.06	2470	-2.29	.02
					music	0	.	.	.	.
						estimate	se	df	t	p
c* block	3	2470	27.24	<.0001	CC*lit	0.19	.09	2470	2.17	.03
					CC*music	0	.	.	.	.
					CP*lit	0.70	.09	2470	8.16	<.0001
					CP*music	0	.	.	.	.
					PC*lit	0.07	.09	2470	0.84	.40
					PC*music	0	.	.	.	.
					PP*lit	0	.	.	.	.
					PP*music	0	.	.	.	.
mexp	2	32	0.13	.88		estimate	se	df	t	p
					high	-0.10	.11	116	-0.86	0.39
					low	-0.04	.09	116	-0.47	0.64
					med	.	.	.	.	.
c*mexp	6	2470	6.1	<.0001		estimate	se	df	t	p
					CC*high	0.25	.13	2470	1.92	.05
					CC*low	0.15	.10	2470	1.54	.12
					CC*med	0	.	.	.	.
					CP*high	-0.12	.13	2470	-0.91	.36
					CP*low	-0.25	.10	2470	-2.64	.008
					CP*med	0	.	.	.	.
					PC*high	0.11	.13	2470	0.87	.38
					PC*low	0.27	.10	2470	2.82	.005
					PC*med	0	.	.	.	.
					PP*high	0	.	.	.	.
					PP*low	0	.	.	.	.
					PP*med	0	.	.	.	.

Note: param represents parameter. num represents numerator. denom represents denominator. c represents comparison. mexp represents musical experience. lit represents literature. med represents medium musical experience. Target/probe presentation is indicated by: CC (close-up/close-up), CP (close-up/prototype), PC (prototype/close-up), PP (prototype/prototype).

Appendix FF

MIXED LINEAR MODEL, TEMPO DATA, EXPERIMENT 4

parameter	num df	denom df	F	p						
comparison	3	2476	3.79	0.01		estimate	se	df	t	p
					CC	0.05	0.06	2476	0.84	.40
					CP	0.01	0.06	2476	0.10	.92
					PC	0.04	0.06	2476	0.59	.56
					PP	0	.	.	.	.
block	1	2476	2.10	0.15		estimate	se	df	t	p
					literature	0.00	0.06	2476	0.00	1.00
					music	0	.	.	.	.
c* block	3	2476	2.72	0.04		estimate	se	df	t	p
					CC*lit	-0.03	0.09	2476	-0.40	.70
					CC*music	0	.	.	.	.
					CP*lit	0.02	0.09	2476	0.21	.83
					CP*music	0	.	.	.	.
					PC*lit	0.20	0.09	2476	2.22	.03
					PC*music	0	.	.	.	.
					PP*lit	0	.	.	.	.
					PP*music	0	.	.	.	.

Note: num represents numerator. denom represents denominator. c represents comparison. Target/probe presentation is indicated by: CC (close-up/close-up), CP (close-up/prototype), PC (prototype/close-up), PP (prototype/prototype).

Appendix GG

LENGTH DATA T-TESTS COMPARING MEAN RATINGS TO EXPECTED RATINGS, MUSIC AND LITERATURE STIMULI BY COMPARISON TYPE, EXPERIMENT 4

Music stimuli

comparison	E(x)	mean	sd	se	df	t	p	Effect
CC	0	-0.05	0.31	.05	34	-0.90	.37	none
CP	1	0.83	0.58	.10	34	-1.77	.09	none
PC	-1	-1.06	0.56	.09	34	-0.64	.52	none
PP	0	0.16	0.33	.06	34	2.84	.008	BR

Literature stimuli

comparison	E(x)	mean	sd	se	df	t	p	effect
CC	0	0.00	0.15	.02	34	0.00	1.00	none
CP	1	1.39	0.61	.10	34	3.81	.0006	BR
PC	-1	-1.13	0.60	.10	34	-1.25	.22	none
PP	0	0.02	0.18	.03	34	0.65	.52	none

Note: The E(x) column indicates the expected value to which the mean was compared. BR represents boundary restriction. Target/probe presentation is indicated by: CC (close-up/close-up), CP (close-up/prototype), PC (prototype/close-up), PP (prototype/prototype). The p value required for the Bonferroni correction was .05/4=.0125.

Appendix HH

CHI-SQUARE STATISTICS INDICATING NON-CHANCE LEVEL RESPONDING, EXPERIMENT 5

response category	PP, length	%	test % (chance)	ChiSq	df	p	correct
<0	134	21.27	40	714.57	2	<.0001	
0	394	62.54	20				*
>0	102	16.19	40				
	PP, tempo						
<0	127	20.16	40	436.68	2	<.0001	
0	335	53.17	20				*
>0	168	26.67	40				
	PW, length						
<0	70	11.11	40	231.01	2	<.0001	
0	155	24.60	20				
>0	405	64.29	40				*
	PW, tempo						
<0	170	26.98	40	260.37	2	<.0001	
0	288	45.71	20				*
>0	172	27.3	40				
	WP, length						
<0	377	59.84	40	177.01	2	<.0001	*
0	163	25.87	20				
>0	90	14.29	40				
	WP, tempo						
<0	115	18.25	40	358.58	2	<.0001	
0	312	49.52	20				*
>0	203	32.22	40				
	WW, length						
<0	106	16.83	40	633.17	2	<.0001	
0	378	60.00	20				*
>0	146	23.17	40				
	WW, tempo						
<0	146	23.17	40	299.93	2	<.0001	
0	299	47.46	20				*
>0	185	29.37	40				

Note: Target/probe presentation is indicated by: PP (prototype/prototype), PW (prototype/wide-angle), WP (wide-angle/prototype), WW (wide-angle/wide-angle).

Appendix II

MIXED LINEAR MODEL, LENGTH DATA, EXPERIMENT 5†

parameter	num df	denom df	F	p						
cn	3	2459	259.84	<.0001		est	se	df	t	p
					PP	-0.19	.12	2459	-1.59	.11
					PW	0.42	.12	2459	3.41	.0007
					WP	-0.5	.12	2459	-4.09	<.0001
					WW	0	.	.	.	.
block	1	2459	11.47	.0007		est	se	df	t	p
					literature	0.02	.09	2459	0.25	.80
					music	0	.	.	.	.
c*block	3	2459	33.80	<.0001		est	se	df	t	p
					PP*lit	0.12	.13	2459	0.94	.35
					PP*music	0	.	.	.	.
					PW*lit	0.42	.13	2459	3.22	.001
					PW*music	0	.	.	.	.
					WP*lit	-0.16	.13	2459	-1.23	.22
					WP*music	0	.	.	.	.
					WW*lit	0	.	.	.	.
					WW*music	0	.	.	.	.
mexp	2	31	0.74	.49		est	se	df	t	p
					high	0.09	.13	114	0.71	.48
					low	0.08	.10	114	0.84	.40
					med	0	.	.	.	.
c*mexp	6	2459	3.68	.001		est	se	df	t	p
					PP*high	0.11	.15	2459	0.77	.44
					PP*low	0.04	.11	2459	0.34	.73
					PP*med	0	.	.	.	.
					PW*high	0.26	.15	2459	1.78	.08
					PW*low	0.01	.11	2459	0.08	.94
					PW*med	0	.	.	.	.
					WP*high	-0.36	.15	2459	-2.46	.01
					WP*low	-0.07	.11	2459	-0.66	.51
					WP*med	0	.	.	.	.
					WW*high	0	.	.	.	.
					WW*low	0	.	.	.	.
					WW*med	0	.	.	.	.
instruct	1	31	0.17	.68		est	se	df	t	p
					female v	0.04	.11	293	0.40	.69
					male v	0.00	.	.	.	.

†continued on next page…

Appendix II

MIXED LINEAR MODEL, LENGTH DATA, EXPERIMENT 5, CONTINUED

b*instruct	1	2459	0.01	0.92		est	se	df	t	p
					lit*fv	-0.03	.14	2459	-0.22	.83
					lit*mv	0	.	.	.	.
					music*fv	0	.	.	.	.
					music*mv	0	.	.	.	.
c*instruct	3	2459	1.04	0.38		est	se	df	t	p
					PP*fv	-0.14	.14	2459	-1.05	.29
					PP*mv	0	.	.	.	.
					PW*fv	-0.19	.14	2459	-1.41	.16
					PW*mv	0	.	.	.	.
					WP*fv	0.08	.14	2459	0.55	.58
					WP*mv	0	.	.	.	.
					WW*fv	0	.	.	.	.
					WW*mv	0	.	.	.	.
c*b*instruct	3	2459	5.04	0.002		est	se	df	t	p
					PP*lit*fv	0.03	.19	2459	0.15	.88
					PP*lit*mv	0	.	.	.	.
					PP*mus*fv	0	.	.	.	.
					PP*mus*mv	0	.	.	.	.
					PW*lit*fv	0.41	.19	2459	2.11	.04
					PW*lit*mv	0	.	.	.	.
					PW*mus*fv	0	.	.	.	.
					PW*mus*mv	0	.	.	.	.
					WP*lit*fv	-0.35	.19	2459	-1.78	.08
					WP*lit*mv	0	.	.	.	.
					WP*mus*fv	0	.	.	.	.
					WP*mus*mv	0	.	.	.	.
					WW*lit*fv	0	.	.	.	.
					WW*lit*mv	0	.	.	.	.
					WW*mus* fv	0	.	.	.	.
					WW*mus* mv	0	.	.	.	.

Note: num represents numerator. denom represents denominator. est represents estimate. c represents comparison. b represents block. mexp represents musical experience. instruct represents instruction voice. fv represents female voice. mv represents male voice. mus represents music. Target/probe presentation is indicated by: PP (prototype/prototype), PW (prototype/wide-angle), WP (wide-angle/prototype), WW (wide-angle/side-angle).

Appendix JJ

MIXED LINEAR MODEL, TEMPO DATA, EXPERIMENT 5

parameter	num df	denom df	F	p						
comparison	3	2472	3.63	0.01		estimate	se	df	t	p
					PP	0.00	0.05	2472	0.00	.62
					PW	-0.07	0.05	2472	-1.42	1.00
					WP	0.09	0.05	2472	1.87	.06
					WW	0	.	.	.	.
block	1	2472	4.84	0.03		estimate	se	df	t	p
					literature	0.08	0.03	2472	2.20	.03
					music	0	.	.	.	.

Note: num represents numerator. denom represents denominator.

Appendix KK

TEMPO DATA T-TESTS COMPARING MEAN RATINGS TO EXPECTED RATINGS, MUSIC AND LITERATURE STIMULI BY COMPARISON TYPE, EXPERIMENT 5

Music stimuli

comparison	E(x)	mean	sd	se	df	t	p	effect
PP	0	0.06	0.32	.05	34	1.10	.28	none
PW	1	-0.08	0.35	.06	34	-1.38	.18	none
WP	-1	0.10	0.40	.07	34	1.57	.13	none
WW	0	0.03	0.32	.05	34	0.53	.60	none

Literature stimuli

comparison	E(x)	mean	sd	se	df	t	p	effect
PP	0	0.06	0.34	.06	34	1.10	.28	none
PW	1	0.07	0.31	.05	34	1.25	.22	none
WP	-1	0.20	0.45	.08	34	2.64	.01	faster
WW	0	0.09	0.40	.07	34	1.36	.18	none

Note: P represents a prototypical stimulus presentation, and W represents a wide-angle (i.e., relatively long duration) stimulus presentation. The E(x) column indicates the expected value to which the mean was compared. Target/probe presentation is indicated by: PP (prototype/prototype), PW (prototype/wide-angle), WP (wide-angle/prototype), WW (wide-angle/side-angle). The p value required for the Bonferroni correction was .05/4=.0125.

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ABSTRACT

BOUNDARY EXTENSION IN THE AUDITORY DOMAIN

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Memory for the boundaries of a scene is often extended outward—that is, observers remember a scene as containing information that was not directly perceived but that would have logically been present just beyond the observed boundaries of the scene (e.g., Intraub & Richardson, 1989). This bias is referred to as boundary extension. One reason why boundary extension might occur is that it prepares an observer to more efficiently process what might be perceived with the next fixation or in the next moment of time. Studies of boundary extension have used visual and haptic stimuli (e.g., Intraub, 2004), but boundary extension in the auditory domain has not yet been investigated despite evidence that boundary extension is multisensory in nature (Intraub, 2004).

Research with representational momentum, a tendency to remember an object as having traveled further than it actually traveled (e.g., Freyd & Finke, 1984), has found biases with auditory stimuli (e.g., Hubbard, 1993). Further, Munger, Owens, & Conway (2005) found boundary extension to occur prior to representational momentum in the visual domain, serving to establish the scene prior to the extrapolation of movement within the scene. It therefore stands to reason that auditory boundary extension exists and precedes any effects of auditory representational momentum.

The goal of the present experiments was to determine whether auditory boundary extension exists. Experiments 1-3 used relatively long probes followed by targets of equal or lesser length using either simple or complex stimuli; data in these experiments pointed toward boundary restriction. After noting that boundary restriction occurred at a time delay with wide-angled stimuli in

Intraub, Bender, & Mangels' (1992) experiments, an examination of close-up, prototypic, and wide-angle auditory stimuli in Experiments 4 and 5 yielded very similar results to that of Intraub et al. (1992)—that is, boundary extension occurred for relatively closer (i.e., shorter) targets, and boundary restriction occurred for relatively wider-angle (i.e., longer) targets. Boundary extension only occurred for more continuous (i.e., music) stimuli, but did not occur for more discrete (i.e., literature) stimuli, in line with Freyd's (1987) assertion that dynamic mental representations require continuity in time.