Does the survival-processing effect occur for environmental sounds?

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Abstract

The ‘survival-processing effect’ refers to a phenomenon in which recall is significantly improved when items are processed for their relevance in a survival scenario compared to non-survival contexts. Since its introduction by Nairne et al. (2007), this effect has been shown to be robust. Whereas Nairne et al. (2007) examined this phenomenon through the use of words, we on the other hand examined the survival-processing effect by using environmental sounds. To examine the survival-processing effect, a pleasantness control condition and two distinct recognition tests were employed in our current study: a categorical- and exemplar-level test. We predicted that the use of environmental sounds would reveal a survival-processing effect, considering how the memory processing of environmental sounds relates to image processing and that images show significant survival-processing effects. At the same time, we also expected that this effect would be limited to categorical-level testing, as it has been demonstrated that the survival-processing effect does not appear to exist at the detail level. Consistent with our hypothesis, the results showed a significant recall advantage of environmental sounds processed in the survival condition versus the control condition, but only for categorical-level testing. Remarkably, a superior recall advantage was observed for the pleasantness condition for exemplar-level testing. These findings appear to show similarities between visual and auditory processing. Overall, the survival-processing effect seems to occur for environmental sounds, but only when measured at the categorical level.

Keywords: Survival processing, auditory stimuli, environmental sounds, detail processing, schematic processing

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The Survival-processing Effect

Comprehending the systems underlying memory can be challenging and complicated. This is because there are so many diverse ways to understand memory structures. Because of its complexity, researchers are looking at the concept of memory from various perspectives. Nairne et al. (2007) examined the evolutionary perspective, finding that recall significantly improved when items were processed for their survival relevance—hereby naming this phenomenon "the survival-processing effect."

The survival-processing advantage is generally studied by having people imagine themselves trapped in a grassland with no food, water, or other resources critical for survival (Nairne et al., 2007). The participants then rate a series of words based on how relevant these would be to their survival in that hypothetical situation. In a control condition, one typically includes instances in which words are processed in a non-survival context, such as rating the words' perceived pleasantness or their relevance to an imagined scenario of relocating. When compared to these control conditions, the survival-processing task has been shown to increase the number of words retained.

Evolutionary Basis of The Survival-processing Effect

The significance of the survival-processing effect and the mnemonic advantages it confers are evident (Tay et al., 2019). But is it truly due to the existence of a fundamental survival mechanism that developed to assist our ancestors' survival? On the one hand, a number of studies have demonstrated that the survival-processing advantage is not solely attributable to the emphasis placed on survival in any survival scenario (Kang et al., 2008; Nairne & Pandeirada, 2010; Weinstein et al., 2008). These studies revealed that participants remembered objects better in a survival scenario featuring an ancestral grassland environment than in a survival scenario featuring a non-ancestral scenario, such as an urban setting. On the other hand, Soderstrom and McCabe (2011) discovered that a survival scenario involving a zombie attack led to better memory retention than both the ancestral grassland scenario and an urban survival scenario. This contradicts the evolutionary explanation for the survival-processing advantage, as zombies should not be ancestrally relevant to us. Despite the significance of the results on the survival-processing phenomenon, the evolutionary explanation for the survival-processing advantage seems to be less clear.

Encoding Theories

Another line of work has examined the possible proximate mechanisms behind the survival-processing advantage. Multiple encoding theories try to explain in their own way how items processed for their relevance in a survival context show superior memory encoding. One of these hypotheses is the richness-of-encoding hypothesis (Kroneisen & Erdfelder, 2011), which describes the proximate mechanism underlying the survival-processing effect by stating that rating the usefulness of an item in a survival scenario leads to a greater generation of ideas about that item's usefulness, which results in a deeper memory encoding and thus increases recall. The premise is that in fitness-relevant scenarios, such as the grassland scenario, it is naturally more necessary to consider the various uses of an item than in fitness-irrelevant ones, such as a moving scenario. The reason why deeper encoding is provided for items with several perceived uses is due to the amount of elaboration surrounding that item (Anderson & Reder, 1979). It is thought that deep processing of information results in more distinct memory traces and, therefore, more efficient retrieval. This is supported by Roër et al. (2013), who demonstrated that participants established more uses for words in the survival condition than in control conditions where fitness was negligible. Consequently, these participants demonstrated a greater recall of words of the survival condition, indicating a deeper encoding of these items.

The Current Study

The robustness of the survival-processing effect has been demonstrated through a variety of methodologies. Multiple studies comparing the survival condition to a control condition containing scenarios of comparable fitness demonstrated that the survival condition elicits better recall (Kang et al., 2008; Soderstrom & McCabe, 2011). It has been demonstrated that the survival-processing advantage is statistically significant in studies using both between and within-subject designs (Scofield et al., 2018). Significant survival-processing effects were found in studies that used both recall and recognition tests, illustrating the robustness of the effect (Tay et al., 2019).

To date, no research has been conducted to determine whether the survival-processing effect occurs for auditory stimuli, as only visual stimuli have been studied (Tay et al., 2019). A comprehensive meta-analysis conducted by Tay et al. (2019) reveals that only three of the 56 studies conducted prior to 2016 examined the survival-processing advantage using non-verbal stimuli (Clark & Bruno, 2016; Otgaar et al., 2014: Otgaar et al., 2010) whereas all others used words.

Notably, all experiments that used images as stimuli discovered a significant recall advantage for the survival condition, despite using a variety of stimuli types. Clark and Bruno (2016), for instance, observed a survival-processing effect of location memory using location-based image stimuli. Moreover, Otgaar et al. (2010) found a significant survival-processing effect by using images representing the same objects as the words presented in Nairne et al.'s (2007) original study. Consequently, these examples illustrate the robustness of the survival-processing effect for images.

The use of environmental sound stimuli can provide new views on the survival-processing effect in a variety of ways. First, the use of environmental sounds increases the ecological validity of the experiment since these "life-like" stimuli are more compatible with the simulated grassland scenario (Nairne et al., 2007) than words. Here, a clear theoretical differentiation may be formed regarding the type of environmental stimuli that enhances the experiment's ecological validity. Specifically, making a distinction between stimuli resembling man-made versus natural objects can be an insightful procedure for testing the evolutionary theory of the survival-processing effect. The evolutionary basis of the survival-processing effect can be supported by a clear memory advantage for stimuli that resemble natural objects, as the represented man-made objects were not prevalent in our ancestors' environment. Furthermore, it has also been shown that environmental sounds resemble visual objects in eliciting a "picture superiority effect". The picture superiority effect refers to the phenomenon that images of objects are more easily memorized than words that denote the same objects. Dual-coding theory provides a possible explanation for this advantage (Paivio & Csapo, 1973). It states that objects presented in the form of images have greater memory potential since they are encoded twice due to the visual and verbal properties of images. In contrast, objects presented as words are coded only once, according to their verbal properties. Crutcher and Beer (2011) investigated the extension of this effect to auditory stimuli and discovered that environmental sounds are, indeed, easier to memorize than spoken verbal labels. Assuming that environmental auditory stimuli are indeed more deeply processed than words, an interesting question is whether environmental sounds will also show a beneficial effect of deep encoding in the survival-processing paradigm.

Another reason why it is of interest to study whether the survival-processing advantage will occur with environmental sounds is that it is known that auditory memory differs from visual memory in various regards. When compared to visual stimuli, research has shown the recognition of auditory stimuli to be inferior (Bigelow & Poremba, 2014; Cohen et al., 2011; Cohen et al., 2009; Kassim et al., 2018). According to Cohen et al. (2011), even musicians who are experienced in auditory perception face this discrepancy. These disparities appear to hold even when using complex, naturalistic stimuli, demonstrating the extent of the difference between the two modalities (Bigelow & Poremba, 2014). However, as an exception, it has been shown that with repetition memory in both modalities, the differences seem to vanish (Parks & Werner, 2020). Despite these differences, auditory memory appears to be a viable means of assessing the survival-processing advantage for a variety of reasons. Auditory memory is suitable for studying such processing effect since Dyson and Ishfaq (2008) observed that similar to visual memory, auditory memory also organizes memories according to their object categories (e.g., the sound of a cat). Hence, there are fundamental parallels in the organization of memory across the two modalities. In light of these insights into the differences between the encoding of auditory and visual information, it becomes increasingly relevant to get an understanding of whether auditory stimuli will elicit a survival-processing advantage.

Outline of The Experiment

First, participants must assess the relevance of a sequence of environmental sound stimuli to a survival or control scenario. Two recognition tests will be administered to the participants following the implicit coding of these objects. One is a categorical-level recognition test that assesses the ability to recognize the correct categories of items (e.g., cat, thunder). The participants will next be given a more specific exemplar-level test, which measures the detail of encoding by giving two distinct sound stimuli of the same category, one of which has been heard before and the other which has not (e.g., two sounds of lions).

The Hypothesis

Our hypothesis states that we expect that a significant survival-processing effect will be found for environmental sounds, but only for categorical-level testing. This is based on the fact that the survival-processing effect is shown to be significant when images are used as stimuli (Clark & Bruno, 2016; Otgaar et al., 2014; Otgaar et al., 2010). This is relevant because it has been observed that visual stimuli can function similarly to auditory stimuli. The "picture superiority effect" demonstrates that pictures are processed more deeply than words (Paivio & Csapo, 1973), and similar effects have been observed for environmental versus verbal sounds (Crutcher & Beer, 2011). Therefore, it is reasonable to assume that the survival-processing effects of visual stimuli can be extended to environmental sounds. In conclusion, a significant survival-processing effect can be expected for environmental sounds due to similar effects found in visual stimuli.

Additionally, if we discover that the survival-processing effect does occur for environmental sounds, it is expected that a survival-processing effect would only be found for the categorical-level recognition test. This hypothesis is founded on the observation that schematic encoding elicited by survival processing compromises on the encoding of details (Otgaar et al., 2010). This is relevant because the categorical test evaluates survival processing of sounds at a schematic level, as opposed to the exemplar-level test, which evaluates survival processing at a more detailed level. This is further supported by Hou and Liu (2019), who showed that a survival-processing effect was found for the gist-level processing of overall facial recognition but did not seem to exist for the detail-level processing required for source memory of faces. Thus, in the survival condition, participants typically remembered the categorical labels of an image more clearly than its details. Expected is that the categorical-level test, which tests encoding of the gist, is likely to elicit a significant survival-processing effect as opposed to the exemplar-level test, where a non-significant effect is anticipated due to its detail-level assessment.

Methods

Participants

Fifty-two individuals were recruited through the website Prolific (www.prolific.co)[1]. Participants were incentivized to participate by receiving monetary compensation. For their participation, they received 8 pounds per hour. The participants ranged in age from 18 to 32 and were all native English speakers. The sample size was justified by using a power analysis done based on the effect size of the survival-processing advantage in studies with a within-subject design with words or pictured objects as stimuli (Scofield et al., 2018). According to this meta-analysis, a partial eta squared effect size of 0.15 was found for this effect. G-power (Faul et al., 2007) was used to do a power analysis for this effect size with correlations between repeated measures set between 0.1 and 0.8. These various analyses demonstrated that a sample of fifty-two participants would have a power of greater than 95%.

Materials

The software utilized to create the experiment was Opensesame (Mathôt et al., 2012). The experiment itself was hosted online via JATOS (Lange et al., 2015). Participants completed the experiment online, using their own laptops and desktops. The monitor resolution was set to 1366 x 768 pixels, and participants were asked to set their browser

[1] In our preregistration for the study, we aimed for a sample size of 40 participants. However, due to unevenness in the distribution of participants across the different versions of the experiment, we added 12 more participants to ensure complete counterbalancing of the order of conditions and the assignment of stimuli to conditions.

window to full screen and to use earbuds or a headphone, with the volume set to a clearly audible but comfortable level.

A total of 30 sound files were in the pleasantness and survival-rating tasks. These sound files were selected from Hocking et al. (2013)'s NESSTI audio file database (https://imaging.org.au/Nessti/Nessti) based on their identifiability percentage and similarity to the stimuli used in Nairne et al. (2007)'s study. This was achieved by selecting environmental sounds from a list whose identifiability was at least 50%. However, four sounds ("knife," "thunder," "throat-clearing," and "lighter") were selected despite failing to meet this criterion because they appeared to be identifiable at face value. These 30 sounds were assigned to the two scenario conditions. With 15 sounds included in the survival condition and 15 sounds in the pleasantness condition. Within the two scenario conditions, eight natural and seven man-made sounds were assigned to the survival condition, and eight man-made and seven natural sounds were assigned to the pleasantness condition.

An additional 34 sound files were obtained from epidemicsound.com for the forced two-choice alternative recognition test and practice trials for this task. Four of these sound files were used for practice trials. All the audio files were chosen based on their similarity to the selected NESSTI database audio clips (Hocking et al., 2013). Every audio file in this database had to be shortened to one second in order to be suitable for this experiment, just like the other stimuli.

Design

The study had a within-subject design consisting of two manipulated variables. The two factors included were rating condition (pleasantness ratings vs. survival-relevance ratings) and sound type (man-made vs. natural). The number of man-made and natural auditory stimuli was counterbalanced between the two rating conditions across participants. During the rating tasks, the stimuli were presented in random order.

In the second part of the experiment, the participant’s memory of the auditory stimuli was evaluated using a two-step recognition test. Participants first did a yes-no recognition test based on words (e.g., "drums" or "dog"). Half of the words corresponded to sounds that were heard during the rating tasks, and the other half comprised words denoting sounds that were not used in the rating task. After each word that was used in the rating task, an exemplar-level test required participants to determine which of two sounds of the same category (e.g., two audio clips of dogs) had been previously presented in the rating tasks.

Procedure

First, participants were provided with instruction texts similar to the ones in the original study by Nairne et al. (2007) but adapted for environmental sound stimuli. Participants were first asked, depending on the counterbalancing, to imagine themselves stranded on a foreign grassland without basic survival materials. Participants were exposed to four audio clips for practice. Subjects were then directed to determine if the objects and events denoted by the auditory stimuli were relevant in this scenario. In the pleasantness rating test, participants were instructed to assess whether the object or event denoted by the sound was perceived as pleasant or not. In the rating task, participants responded by rating the items on a 5-point scale, with 1 being totally irrelevant (or unpleasant) and 5 extremely relevant (or pleasant).

After completing the pleasantness and survival rating tasks, participants were introduced to the memory test. During the recognition test, participants first judged whether a word corresponded to a sound used in the rating task, using the left and right arrow keys. Old and new words were randomly intermixed. After responding to a word, the participants were notified whether their response was correct or incorrect. Regardless of whether the response was correct or incorrect, each old word was followed by an exemplar-level recognition test in which participants were consecutively presented two sounds of the same type and responded with which of the two they recognized from the rating task, again using the left and right arrow keys. The presentation of the old and new sounds was counterbalanced such that the first sound was an old sound in half of the trials. Following the recognition test, participants were debriefed.

Results

The standard level of significance $\alpha = .05$ was employed across all statistical analyses. First, for the categorical-level recognition test, individuals recognized significantly more sounds in the survival condition (*M* = .70, *SD* = .16) than in the pleasantness condition (*M* = 0.63, *SD* = .19), $t(51) = -2.49$, $p = .016$, $d = .422$. At the exemplar level, however, participants correctly selected the correct sounds significantly more often for the pleasantness condition (*M* = .82, *SD* = .14) compared to the survival condition (*M* = .77, *SD* = .14), $t(51) = 2.45$, $p = .019$, $d = .335$. These results demonstrate a significant recall advantage for environmental sounds processed in the survival condition, but only for recognition testing at the categorical level.

When comparing the false alarm and hit rates, it is evident that the participants did not perform at chance level, as false alarm rates (*M* = .23, *SD* = .12) were significantly lower than hit rates (*M* = .73, *SD* = .10), $t(51) = -16.45$, $p < .001$. For the rating tasks, participants in the survival condition rated item relevance with an average of 2.73 (*SD* = .61). In the pleasantness condition, participants judged the items' relevance with an average of 2.76 (*SD* = .44) which was statistically equivalent to the rating in the survival condition; $t(51) = .22$, $p = .825$.

For the exploratory analysis of the type of stimuli, a 2 (rating type) x 2 (sound type: man-made vs. natural) repeated measures ANOVA was conducted for both the categorical- and exemplar-level-recognition tests. Figure 1.1 displays an interaction effect between these variables for categorical recognition accuracy ($F[1,51] = 26.611$, $p < .001$, $\eta_p^2 = .343$), but not for exemplar-level recognition ($F[1,51] = 1.831$, $p = .182$, $\eta_p^2 = .035$; Figure 1.2). To investigate this effect further for the categorical-level test, it was statistically determined that the survival-processing effect was not present for man-made sounds ($t(51) = -.57$, $p = .570$, $d = .079$), whereas it was evidently present for natural sounds ($t(51) = 5.31$, $p < .001$, $d = .737$).

Figure 1.1

Descriptive plot of mean proportion corrects of categorical-level testing for each rating type

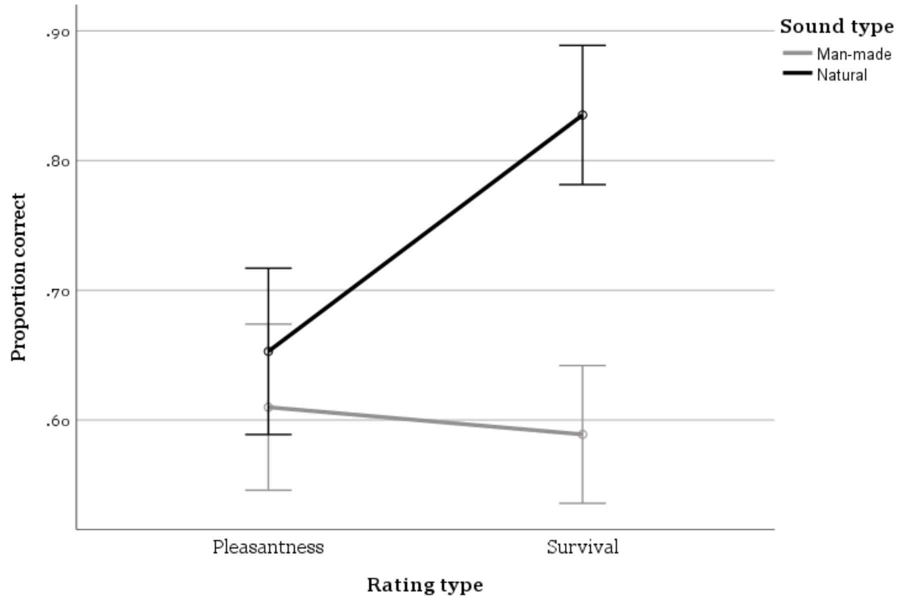
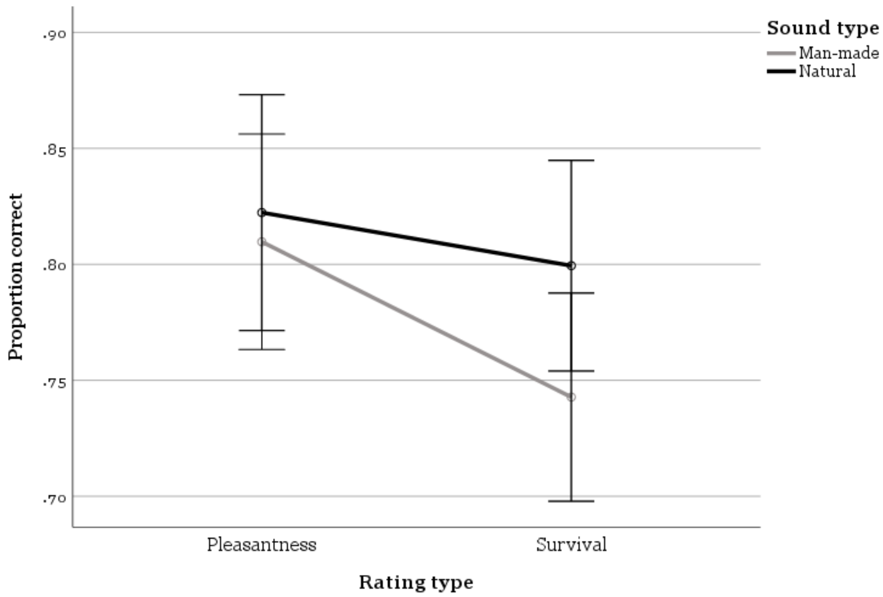


Figure 1.2

Descriptive plot of mean proportion corrects of exemplar-level testing for each rating type



Discussion

The purpose of this study was to see if there would be a significant memory advantage for environmental sounds rated for their relevance in a survival condition versus a pleasantness condition. We hypothesized that there would be a significant recall advantage for environmental sounds processed in the survival condition, but that this would only apply to the categorical-level test and not the exemplar-level test.

Findings

Consistent with our hypothesis, the findings show that a survival-processing effect does occur for environmental sounds, but only for categorical-level testing. Thus, significantly more environmental sounds were recalled at the categorical level in the survival condition than in the control condition. For the exemplar-level test, however, the opposite effect appeared to be observed, as more environmental sounds were recalled in the control condition. In the exploratory analysis, it was discovered that, for the categorical-level test, the survival-processing effect only persists for natural-environmental sounds as opposed to man-made ones.

Implications

These findings indicate that participants recalled environmental sounds significantly better when processed in a survival condition when compared to a control condition. This seems to be consistent with findings of Nairne et al.'s (2007) original study. Furthermore, it appears to support the literature on the robustness of the survival-processing effect (Scofield et al., 2018). Specifically, as hypothesized, our results appear to be consistent with significant findings from studies employing images to study the survival-processing effect (Clark & Bruno, 2016; Otgaar et al., 2014; Otgaar et al., 2010). Taking our current study into account, it has now been demonstrated that the survival-processing effect exists for visual and auditory stimuli. This indicates that the survival-processing mechanism appears to operate with both visual and auditory memory, adding to the literature on other similarities between the two memory systems (Crutcher & Beer, 2011).

Moreover, the literature suggests that a survival-processing effect only exists at the gist level rather than the detail level, which is consistent with our finding that a survival-processing effect was only found for categorical-level testing (Hou & Liu, 2019; Otgaar et al., 2010). Additionally, a significant recall advantage was observed for the pleasantness condition rather than the survival condition for exemplar-level testing. This could be explained by the fact that sounds processed in the pleasantness condition could not have been impacted by survival processing's distorted detail encoding, therefore showing its superior recall for exemplar-level testing. This is supported by Otgaar et al. (2010), who found that participants who processed images in a survival context presented more detail distortions than images processed in a control condition, despite still displaying greater recall.

Theoretically, these different outcomes of the two recognition tests may also be due to the fact that testing at the categorical level evaluates what sounds participants remember, whereas testing at the exemplar level asks participants to recall how it sounds. Asking how something sounds, in this case how pleasant it sounds, activates more detail-level processing, which can result in our established recall advantage seen in exemplar-level testing with sounds processed in the pleasantness condition. At the same time, perceptual details of a sound are encoded less in the survival condition because when participants are presented items in the survival condition, they first start to think about what they can do with them (Kroneisen et al., 2013). Consequently, the detailed exemplar-level testing showed a significantly lower recognition accuracy for sounds processed in the survival condition compared to the pleasantness condition.

We also found an interaction between natural and man-made items and rating task. The fact that the survival advantage only occurred for natural sounds and not for man-made sounds lends support for the evolutionary basis of the survival-processing theory. It supports the literature on the evolutionary basis of the survival-processing paradigm (Nairne & Pandeirada, 2016), as this memory advantage for natural sounds only holds in the survival condition as opposed to the control condition. According to the literature, this memory advantage may exist for natural stimuli because they are more closely related to our ancestors' environment, and this survival scenario triggers the evolutionary encoding of natural stimuli (Nairne & Pandeirada, 2010).

Limitations and future directions

Our research on the survival-processing effect and whether or not it occurs for environmental sounds contains several limitations providing a basis for future directions.

Due to the fact that the experiment was conducted online, environmental control was lacking. This primarily poses a problem for the experiment's overall standardization and more specifically for variations in participant's attention while engaging in the experiment. Yang et al. (2021) demonstrated that a survival-processing effect can only be observed when the participants’ full attention is guaranteed. Thus, variations in participants' engagement could lead to differences in survival-processing effects. In the future, the physical presence of participants in a laboratory setting could ensure a lack of environmental distractions and improve their overall concentration on the experiment.

There were also a number of limitations specifically related to the fact that at our study was the first to use auditory stimuli for the survival-processing effect. First, sound files were selected for the exemplar-level testing based on their similarity to the original sound pool that was used for rating tasks. This however leaves a great deal of room for variation between the old and new sounds, since some will sound more like the original pool than others. Given that the original sound files originated from a different source than the new sound files used for exemplar-level testing, it is reasonable to expect disparities between sound pools to vary widely. It would therefore be beneficial for future research to manually apply distinct acoustic differences to a sound pool, thereby managing disparities and creating equal differences between all auditory stimuli in the sound pool (e.g., high-pitched lion and low-pitched lion). In addition, using the existing sound file pools as the auditory stimuli for the exemplar-level assessment is flawed by the fact that the audio quality varies between the two, old and new, file groups within it. The original, old, group of audio files appeared to be of much lower quality than the comparison group used in the exemplar-level recognition test.

Theoretically, participants could distinguish between old and new audio files based solely on their audio quality. As previously mentioned, this can be avoided in the future by collecting all audio files from the same source.

Furthermore, it would be relevant to investigate any third variables that might have an influence on this discovered surviving-processing effect for environmental sounds. Since it has been demonstrated that auditory memory is inferior to visual memory (Cohen et al., 2009), it would be informative to determine whether this effect would change if participants with trained auditory memories, such as professional musicians (Cohen et al., 2011), participated in this study. Possibly observing a smaller effect as a result of this sample's increased detail-processing of auditory stimuli, thereby rendering the survival and control conditions more similar. Similar to what Otgaar et al. (2010) has shown with visual stimuli, it would be promising to examine the survival-processing paradigm using verbal sounds and environmental sounds to determine if they also reveal similar recall results.

The neural mechanisms underlying the difference in sound encoding between the survival and pleasantness conditions could be investigated in the future by using event-related potentials (ERPs). ERPs, which are measurements of brain activity obtained from electrodes mounted on the scalp, have been shown to be helpful for analysing cognitive processes (Garnsey, 1993). Measuring the amplitude of brain activity at various time intervals when a stimulus is presented can reveal the kind of cognitive process that has occurred. Therefore, unique ERP components consist of these distinct timestamps, revealing various cognitive processes. When analyzing ERPs, it would be valuable to determine if a sound processed in the survival condition and presented during the exemplar-level recognition task displays an increased amplitude at the N400 waveform associated with semantic processing of sounds (Dunn et al., 1998), indicating that it engaged in more gist-level processing. It would be intriguing to examine, for items processed under the pleasantness condition, whether the amplitude at P200, which is associated with more elaborate processing, increases (Dunn et al., 1998). These sorts of neurophysiological investigations will help researchers comprehend and identify the cognitive mechanisms underlying these variations in the survival-processing paradigm.

Conclusion

The survival-processing effect has been studied with a variety of stimulus types but never with auditory stimuli. Our findings demonstrate the existence of a survival-processing effect for auditory stimuli, specifically environmental sounds. This is important because it supports Nairne et al.'s (2007) original finding on survival processing and, consequently, the effect's already robust literature while employing a new type of stimulus. Our research also demonstrates that, in comparison to a control condition, the survival processing of sounds exhibits a reduction in the encoding of these sounds' details, supporting an analogous effect observed for images (Otgaar et al., 2010). Overall, the current study leads us to a better understanding of the survival-processing effect and, by offshoot, our memory systems as a whole.

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