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Pictures versus digits in the irrelevant sound effect

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Abstract

Colle and Welsh (1976) discovered that irrelevant sounds cause detrimental performance on serial recall tasks. This effect has been dubbed the irrelevant-sound effect (ISE), and is important to discovering why people get distracted by outside influences. The present study attempts to determine why Elliott (2002) and Klatte et al. (2010) had different results regarding the magnitude of the ISE in children. The present study tested the methodological differences between the two previous studies. Elliott (2002) used serial recall of digits while Klatte et al. (2010) used reconstruction of order of images; thus, the present study examined differences in the magnitude of the ISE due to those methodological differences. We found no significant difference in the magnitude of the ISE between digit recall and image reconstruction of order conditions, suggesting that methodological differences were not the determining factor in the previous conflicting results.

Pictures versus digits in the irrelevant sound effect

Colle and Welsh (1976) discovered that when performing a serial recall task with visual stimuli, speech irrelevant to the task at hand impaired performance on the task. Jones and Macken (1993) dubbed the effect the irrelevant-sound effect (ISE) after finding that sound in general, not just speech, was detrimental to performance. For example, when remembering a list of digits for a short period of time, performance is worsened by outside sound, be it speech or simply tones.

Jones, Macken, and Murray’s (1993) research led to the emergence of the object-oriented episodic record model (O-OER) of the ISE. The O-OER assumes two central hypotheses to explain the ISE, the changing-state hypothesis and the equipotentiality hypothesis. The changing state hypothesis assumes that auditory distractors that change over time in some way cause worse performance than if the distractor stays the same. The equipotentiality hypothesis assumes that speech and nonspeech disruptors are functionally equivalent (meaning that speech is not “special” in its disruptive ability when compared to sounds that are not speech).

An alternative theoretical model for the ISE is that it is caused by attentional recruitment away from the relevant information, and involves the attentional orienting response (Cowan, 1995). This theory asserts that the ISE is inherent upon the idea that an irrelevant sound recruits attention away from the relevant tasks or stimuli. Habituation could also be the cause this of selective attention deficit (Cowan, 1995). Changing state sounds (ex. “Q-B-T-Y-F-Z”) cause a greater ISE because steady state sounds (ex. “Q-Q-Q-Q-Q”) are easier to ignore, due to smaller degrees of change between items, and thus have a lessened attention orienting response. This approach to the ISE can be applied to developmental investigations more readily than the O-OER. Because children do not have the same level of attentional resources available to ignore

irrelevant sounds that adults do, Cowan's theoretical explanation for the ISE would seem to indicate they would be more susceptible than adults and the effect would be greater in children than adults.

However, conflict between separate sets of serial order cues causes the ISE according to the O-OER model (Jones, 1999; Jones, Beaman, & Macken, 1996). Irrelevant sounds with different auditory elements (changing state sound), like tones or syllables, are represented in short-term memory as objects joined together by linkages. The irrelevant sounds cause the linkages (or associations) between items adjacent to each other in a list to become weaker. Thus changing state sounds affect the ability to rehearse because they have conflicting order information inherent in the changes in the sound. Worsened rehearsal can negatively affect performance on serial recall tasks. However, a irrelevant sound that remains consistent over time (steady state sound) impairs performance because it is still taking up space in our limited working memory, but performance is not as severely impaired. The lack of order cues stemming from steady state irrelevant sound means that it does not interfere with the order cues we use to remember the stimuli to be recalled.

Elliott (2002) argued that the O-OER model would indicate children should be less affected by the ISE because they do not utilize rehearsal like adults, as rehearsal is a skill that is developed over time. The intermixed cues between the ignored and to-be-remembered items do not cause as much of an effect if children do not practice the order. Ultimately, the O-OER emphasizes rehearsal as critical to ISE.

Elliott (2002) found children to be significantly more vulnerable to the ISE, as compared to adults. She also found that as children become older the magnitude of the ISE is lessened. The ISE was worse in younger children no matter what kind of irrelevant sound was used (Elliott,

2002). Elliott (2002) concluded that, because the ISE in children was significantly larger than the ISE in adults, an attentional orienting response or some form of attentional resource deficit must be responsible for the ISE. Children have not developed the skills to minimize the response so they are less able to focus on the relevant items, while ignoring the irrelevant items, when tested.

However, Klatte, Lachmann, Schlittmeier, and Hellbrück (2010) attempted to recreate Elliott (2002) and found what they deemed conflicting evidence. Klatte et al. (2010) found that the ISE was independent of age of the participant; overall, both children and adults were equally affected by irrelevant speech. Furthermore, it was demonstrated that first grade children were negatively affected by irrelevant classroom noise when the length of the recall task was fixed at four for each participant. However, when the children were second to third grade children neither they nor adults suffered significantly from classroom noise, compared to a silent control condition. Additionally, in this second experiment, the length of the task was individually adjusted to fit the participant’s abilities, similar to the design of Elliott (2002). Klatte et al. (2010) claimed their findings supported the O-OER model for the ISE because children and adults were both affected by the irrelevant speech but neither were affected by the classroom noise condition. It is assumed this is because irrelevant classroom noise has unique sounds in no particular order, thus the noises are perceived as an unconnected string of sounds, not an ordered sequence. In the O-OER model these sounds would not cause an ISE because the lack of time codes minimizes interference with relevant information. According to Klatte et al. (2010), the attentional orienting response hypothesis indicates that change in acoustic tones in classroom noise should draw the participant’s attention similarly to changing tone sounds in Elliott (2002), which were significantly disruptive to recall performance.

As mentioned above, Elliott (2002) and Klatte et al. (2010) had conflicting results. Elliott (2002) found children to be considerably more affected by the ISE than adults. Klatte et al. (2010) found that children were not more affected by the ISE than adults. However there were many differences in the way the two experiments were run that could account for this difference in the developmental aspect of the results (See Table 1). The present study focused solely on differences in stimulus type and recall methods associated with those stimuli.

Elliott (2002) used digits as the critical stimuli in a serial recall task that required participants to recreate the list of digits in order, by typing out their responses. Klatte et al. (2010) used pictures and words instead of digits. Adults were shown images in a particular order and then given an answer sheet with seven images and blanks next to them for the participant to write “1st” through “7th” to indicate the order it was originally presented (children used a smaller list length). These presentation and recall mode differences were the key differences focused on in the present study.

The goal of the present study was to determine whether these two key differences might have caused a difference in the magnitude of the ISE in an adult sample. If effects of the type of stimulus and recall mode are found, these findings may explain why children showed a larger ISE comparatively in Elliott (2002) than Klatte et al. (2010). The difference in pictures as stimuli, as opposed to digits, could account for some of the discrepancies. For example, Craik and Tulving (1975) found that when there is a deeper level of processing, recall of the stimuli is greater. The hypothesis relies on the assumption that a deeper level of processing brings to mind more than just the superficial information regarding the stimuli, but something more. Paivio (1991) proposed that the pictorial superiority effect works in a similar manner. According to Paivio (1991), images are routinely found to be more easily recalled than other stimuli,

supposedly due to the pictorial dual coding theory. Just as Craik and Tulving (1975) found a deeper level of processing improves recall, Paivio (1991) suggested the dual coding improves recall because images increase the encoded information into memory. The theory explains image recall as superior to just words because the image is encoded through two different processes. Words are encoded into memory using verbal memory pathways, but an image is encoded in not only a visual pathway but also the verbal pathway. This is because when seeing an image people internally verbalize a label for the image to go along with the encoded picture. Tests of the pictorial superiority effect are often done by forcing the participants away from short-term memory by using a delay between the study period and the recall period. In contrast, serial order recall tasks used to study the ISE are preformed almost immediately after the study period. We believed it was possible that the pictorial superiority effect could carry over into serial order recall, thus resulting in Elliott (2002) and Klatte et al. (2010) differing because each used different stimuli. In Elliott (2002) participants had to recall the target digits and their order entirely on their own, while Klatte et al. (2010) required participants to reconstruct the order of the images as they were given the stimuli to put in order themselves (i.e. they used a reconstruction of order manipulation at recall).

We predicted that there would be a significant main effect of sound conditions, and irrelevant sound would impair performance when compared to silent conditions. A main effect of recall mode was predicted, such that reconstruction of order would lead to significantly better performance than serial order recall. The last predicted significant main effect was stimulus type. We believed that the pictorial superiority effect would carry over into serial order recall tasks and that pictures would be significantly easier to recall than digits. We predicted an interaction between recall mode and stimulus type and a three way interaction between all three variables.

We believed that the pictorial superiority effect would interact with irrelevant sound such that irrelevant sound would have a lessened effect in image reconstruction conditions. It was hypothesized that the image reconstruction conditions both with and without irrelevant sound would be significantly higher in the proportion of correct recall than all other groups in both silent and irrelevant speech conditions. Essentially, images would facilitate serial order recall in line with the pictorial superiority effect, and this facilitation would minimize the magnitude of the ISE.

Methods

Participants

Undergraduates from the Louisiana State University Department of Psychology's participant pool participated in the experiment for either course credit or extra credit in undergraduate psychology courses. However, five participants experienced computer errors during the experiment. Additionally, participants who were non-native English speakers, reported hearing loss, or uncorrected vision problems were not retained in the final data analysis. One participant was excluded for hearing loss and another for being a non-native English speaker, creating a final sample of fifty (thirty-nine females, *M* (age) = 20.10) participants.

Design

A two (stimulus mode) x two (response mode) x two (auditory condition) within-subjects design was utilized.

Stimuli

Participants had to complete a short-term memory task involving a set of nine pictures (bone, drum, leaf, fish, tent, nail, pear, kite, and rope – see Figure 1) and nine digits (1-9). The nine images all had one alternate response provided during the International Picture-Naming

Project (Szekely et al., 2004). This meant that during the course of the experiment participants only provided one other response than the desired name for the target image. For example, for the picture of "tent", if one or more people provided a response for the name of the image as "teepee", one alternative response would be recorded. If someone else responded with "camper" that would be a total of two alternate responses. The number of responses was considered independently of the number of people who provided the same alternate responses.

Stimuli were then presented on a computer screen one at a time, and remained on screen for one second each before automatically moving to the next stimulus. Seven stimuli were presented for each trial from the original set of nine, with no repeated stimuli within a trial. After all seven stimuli were shown an answer screen appeared, but the answer screen differed depending on what kind of recall method they were to perform (See Figures 2-5 for an example of each possible answer screen).

The two recall methods were chosen to recreate the two separate recall methods used in the two experiments being investigated within the current study. The first was serial order recall as used in Elliot (2002). In this situation participants typed the numbers or the names of the images in order on the computer keyboard. The participant was told that these trials would be called recall. The second method of recall came from the methods used in Klatte et al. (2010) and was reconstruction of order. In the reconstruction mode the participants were shown the pictures or digits on the screen and asked to click on the images in the order in which they originally appeared. Participants were told these trials would simply be called reconstruction.

To introduce distracting irrelevant speech we used a digitized recording of a foreign language narrative played over headphones set at a controlled volume. The story we used was a German story titled *Die Leiden des Jungen Werther* read by a native German speaker. We chose

to use a foreign language narrative because Klatte et al. (2010) used a Danish newspaper article as irrelevant sound, which was not the native language of participants. We did not use an irrelevant sound in the same language as the participant's native language in the current study to balance the number of variables chosen from each of the designs of Elliott (2002) and Klatte et al. (2010; see Table 1). The audio was trimmed to thirty-second intervals and played from the time the first visual stimuli were presented until the participant finished providing their answer. Participants did not report having the sound stop before finishing their answer.

The irrelevant speech was played over headphones at each workstation for each participant timed with their experiment. All headphone volumes were set to the same level and were subjectively the same. The volume was checked at each computer before each trial. However it has been shown that the volume level does not have an effect on the size of the ISE (Tremblay & Jones, 1999).

Procedure

Groups of participants from three to six people entered the room and were instructed where to sit by the experimenter. Then, they were asked for their signed consent to participate in the experiment. Once all participants had arrived they were instructed that nothing they heard throughout the experiment would be later tested and they need not pay attention to any sounds. Then participants were instructed to start the program.

Participants were initially asked to provide demographic information, along with information regarding their native language and hearing loss. Then the participants were provided instructions on how to complete the trials and what types of stimuli they would see. They were shown all the possible images along with the name of the object to ensure participants

knew the intended labels for the objects. After an explanation of the two recall methods, practice trials began.

The practice trials consisted of two blocks of four trials. The first block of practice trials began with digit recall, then proceeded with digit reconstruction, image recall and image reconstruction in that order. Then the participants were prompted that at times they may hear sounds over the headphones, but that they should ignore the sounds as best they can. After explaining that they should ignore any sounds they hear, the second practice trial block began. These trials proceeded in the same order as the first four trials, only this time the German narrative played over the headphones. After the end of all four trials participants were told that the practice trials were through and that the critical trials were about to begin. This was because in other studies of the ISE, participants are only asked to perform one type of trial so they were always aware beforehand of what type of stimulus they would see and how they would be asked to recreate the list. In the present study we felt providing the trial type before each trial would minimize any confusion stemming from the participant not being aware ahead of time of what to be prepared for.

The critical trials were separated into four blocks of eight trials for a total of thirty-two trials. Each block of trials had the same eight types of trials. There were silent and irrelevant sound trials for each of the four types of stimuli and recall method combinations: digit recall, digit reconstruction, image recall, and image reconstruction. The eight trials were randomly ordered within each critical block ensuring that all eight trials would be tested before repeating trials. The order of the critical blocks was also randomized. After completing the critical trials participants remained seated until the rest of the participants in the group were also finished. Once everyone had completed their tasks, the experimenter announced that everyone had

finished and that they were free to leave. The subjects were told that they were being tested on their ability to recall certain stimuli while distracted by irrelevant sound, and instructed that if they had any questions the experimenter would be available to answer them.

Results

The dependent variable was the percent of items reported in the correct order. Strict serial position scoring determined correctness of an item, so that only items correctly placed in order were considered correct. These items were averaged to create an average serial position score, for example, if 5 of the 7 items from the trial were reported in the correct position it would be scored as 71% (or 0.71).

Data were collected at two time points, the end of one semester (N = 35) and the beginning of the next (N = 15). To determine if there was an effect of when the data were collected, we included a between-subjects factor of semester in the analysis. We found no significant main effect or interactions with the factor of semester, so the condition was collapsed thereafter.

We then performed a three-factor within-subjects analysis of variance (ANOVA) with sound (silence vs. foreign language narrative), the recall method (serial order recall vs. reconstruction of order), and the stimulus type (images vs. digits; see Figure 6). We found a significant main effect of sound condition, $F(1,49) = 96.53$, $MSE = 1.45$, $p < 0.01$ partial $\eta^2 = 0.66$, indicating the irrelevant sound effect was present and detrimental to participants' ability to recall the presented stimuli. Performance in silence was higher than in the presence of irrelevant speech ($M = 0.69$, 0.56, respectively). We also found a main effect of recall method, $F(1,49) = 102.12$, $MSE = .92$, $p < 0.01$ partial $\eta^2 = 0.68$, which indicated that it was harder to recall the stimuli when participants had to recall the list entirely from memory ($M = 0.58$) as opposed to

when reconstruction of order was used (*M* = 0.67). Lastly a main effect of stimulus type was found, $F(1,49) = 278.49$, $MSE = 7.06$, $p < 0.01$ partial $\eta^2 = 0.85$, indicating that pictures (*M* = 0.49) were harder to recall than digits (*M* = 0.76). However, the main effects were qualified by interactions. A two-way interaction was found between recall method and stimulus type, $F(1,49) = 10.80$, $MSE = 0.18$, $p < 0.01$ partial $\eta^2 = 0.18$; however, the other two-way interactions were not significant.

Finally, there was a significant three-way interaction, $F(1,49) = 13.30$, $MSE = 0.152$, $p < 0.01$ partial $\eta^2 = 0.214$. To determine how recall method and stimulus type affected the magnitude of the ISE, we collapsed the silent and irrelevant sound conditions by creating difference scores. We subtracted performance in the irrelevant sound condition from the silent condition for the stimulus/recall pairings of digit recall, image recall, digit reconstruction, and image reconstruction. These difference scores allowed us to analyze the detrimental effect of irrelevant sound on performance by providing a measure of its effect. We performed a two-way within-subjects ANOVA on these difference scores. We found no significant main effect of either recall method or stimuli type, however, the interaction was significant, $F(1,49) = 10.80$, $MSE = 0.18$, $p < 0.01$ partial $\eta^2 = 0.18$.

To understand the two-way interaction, we performed two paired samples *t*-tests using the Bonferroni correction. The first *t*-test was between digit recall (*M* = 0.16) and image recall (*M* = 0.12) conditions and found no significant difference, revealing that despite poor overall performance on image recall tasks, the ISE was of similar magnitude for both conditions. The second paired samples *t*-test was between digit reconstruction (*M* = 0.05) and image reconstruction (*M* = 0.16), and resulted in a significant difference, $t(49) = -3.81$, $p < 0.01$. This finding is important because it indicates that digit reconstruction causes a significantly lowered

ISE from image reconstruction, meaning that digit reconstruction tasks may not be a good test of the ISE due to its lowered effect on performance.

Finally, we performed a dependent *t*-test on the digit reconstruction silent and digit reconstruction irrelevant sound conditions to verify that they were significantly different, $t(49) = 2.30$, $p < 0.05$. The existence of an ISE suggests that despite the difference score for digit reconstruction being lower than the others, irrelevant sound still significantly worsened performance on serial order recall tasks.

Discussion

Some of our original hypotheses were found to be correct, such as the existence of three main effects in the three-way ANOVA. The main effects of sound condition and recall mode were just as expected, but images were found to be significantly harder to recall than digits which was not expected. Furthermore while both the predicted two-way (stimulus type and recall method) and three-way interactions were significant, both were driven by high and similar performance in digit reconstruction conditions with and without sound, not by the hypothesized image reconstruction predictions. Neither stimulus type nor recall method interacted with the sound condition.

Our findings indicated that the magnitude of the ISE was essentially the same for digit recall and image reconstruction of order tasks. These were the conditions used in Elliott (2002; digit serial order recall) and in Klatte et al. (2010; image reconstruction of order). Thus, the contradictory results in the two previous experiments are likely not attributable to the type of stimulus or the recall method. However, since the conflicting results were found while studying the size of the ISE in children as compared to adults, recreating the experiment with children will generalize the validity of our results. However, one interesting difference between our results

and the results of Klatte et al. (2010) was the effect of irrelevant sound on the image reconstruction conditions. In the current experiment, irrelevant sound caused a 16 percent decrease in performance on serial recall tasks, relative to silence. However, Klatte et al. (2010) found only a 6 percent difference in irrelevant sound conditions as compared to silence. The difference in the results is a slight cause for concern that lacks an explanation, other than the locational differences between the studies. One possible explanation of these conflicting results is that the present study simply did not have enough repetition of trials for participants to truly get accustomed to each trial type. In Klatte et al. (2010) participants had either sixteen or thirty trials, and the stimulus type and recall mode did not change. While the present study did have 32 trials, only 8 trials of each stimulus type and recall mode were performed by each participant.

Images were significantly harder to recall than digits and the trend was consistent across both the recall method conditions and both sound conditions. On the surface, this seems to refute the pictorial superiority effect (Paivio, 1991) but it may be due to a number of different factors. It is possible that the same factors that cause the pictorial superiority effect in longer-term memory are detrimental to recall in working memory.

In studies showing the presence of a pictorial superiority effect participants were forced away from using working memory. Kee (1981) used a 120 second delay between initial presentation of the stimuli and the testing period. Whitehouse, Maybery, and Durkin (2006) used a similar approach with the use of a 120 second delay and a filler task between study and testing periods. Both methods were used to force encoding of stimuli into memory for it to be recalled later, not continually rehearsing the stimuli until the testing period. However, the present study along with Elliott (2002) and Klatte et al. (2010) was more similar to Dark and Benbow (1991). Each study used serial order recall tasks, in which stimuli are presented one at a time to the

participant(s), and after presentation participants recreate the list of stimuli. These force participants to use working memory and rehearsal to recall the stimuli in the short-term, instead of encoding them for the longer-term into their memory. Dark and Benbow (1991) found digit span to be significantly higher than word span in working memory. Dark and Benbow's (1991) results mirror the results of the present study in that the increased information that comes from words or images decreases ability to recall in serial order recall tasks.

Craik and Tulving (1975) asserted that, normally, more information allows for an improved ability to recall, and the dual coding theory (Paivio, 1991) proposes that images provide not only the visual information from seeing the image but also all the verbal information from the name of the image. However, it is possible that in serial order recall tasks the increased information could interfere with recall abilities. According to the O-OER model of the irrelevant sound effect the ISE is caused by increased order cues coming from the irrelevant sound conflicting with the participants' ability to recall the order of critical stimuli (Jones et al., 1996). Since images are being processed through two pathways (Paivio, 1991) subjects receive order information from not only the visual information but also the internalized verbal. Thus, serial recall is more difficult with images; especially in the image recall condition when participants must convert the image into its verbal counterpart to recall the image. The increased information from images that improves memory in delayed memory tests (Whitehouse et al., 2006; Kee, 1981), has the opposite effect in immediate memory tests like the present study.

To test this hypothesis we can test if children show the same level of determent in serial recall tests when tested with images compared to digits. Kee (1981) showed that children also show the ability to dual code images because the pictorial superiority effect was shown to exist in children too. However, Whitehouse et al. (2006) found that while the pictorial superiority

effect does exist in children it is a developed skill. Younger students were shown to have a lessened pictorial superiority effect. The steady increase means that dual coding images in memory is not an inherent ability and is developed through experience. Thus younger participants are receiving less information from the same stimuli. Assuming that the dual coding is what causes worsened image recall in serial order tasks, suggests that children would show a lessened detrimental effect from image recall compared to other single coded information.

One of the more interesting results of the present study was that in the digit reconstruction condition, irrelevant sound had a minimal effect on performance. In digit reconstruction the irrelevant sound condition hindered performance by only 5 percent when compared to silence, but in the three other conditions performance in irrelevant sound conditions was twelve to sixteen percent worse than for silent conditions. All four conditions produced an ISE, however, the diminished effect of the ISE in the digit recall condition suggests that there is something that limits the ISE when the conditions interact. There is no current literature on why this may affect the magnitude of the ISE but presents a promising area for future research.

Reconstruction of order being significantly easier than serial recall was an expected result. However, excluding the digit reconstruction condition, the magnitude of the ISE was similar in the other three conditions despite the recall method. Neath, Farley, and Surprenant (2003) found a significant effect of irrelevant sound using reconstruction of order with letters as stimuli. Reconstruction of order may be significantly easier, but it is unlikely to affect the ISE in most conditions. For example, only the correct answers are given as possible responses in reconstruction conditions, so the participant cannot provide a response that was not listed during the trial. Participants can only make an error in the way they order the stimuli in reconstruction of order tasks, but in serial order recall a participant can provide any answer from the set of

digits, and are not limited to the stimuli presented on any given list. The digit recall essentially comes from a larger response set than the order reconstruction, and this fact could account for the difference in the main effect of recall mode.

In conclusion, the magnitude of the ISE was largely unaffected by using either digits or images as stimuli and the recall method associated with the respective stimulus types. This indicates that the conflicting results in Elliott (2002) and Klatte et al. (2010) were not caused by methodological differences from the stimulus and recall types. However, there are a multitude of differences between the two studies that need to be examined before the results of the two can be scrutinized and explained (See Table 1). It is important to discover the cause of the conflicting results to better understand how irrelevant sound effects serial order recall.

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Table 1. Methodological Comparison of Three Studies

Method	Elliott (2002)	Klatte et al. (2010)	Present Study
Stimulus Type	digits	images	both
Recall Mode	serial order recall	reconstruction of order	both
Irrelvant Sound	native language speech and tones	foreign language speech and classroom noise	foreign language speech
Sound Presentation	headphones	speakers	headphones
Pacing	individually	group	individually
Answers on	computer	paper	computer
List Length	personal span	personal span and set length	set length
Knowledge of Irrelevant Sound Before Trial	No	Yes	No
Age of Children	second grade, third and fourth grade, and fifth and sixth grade	first grade, and second and third grade	None

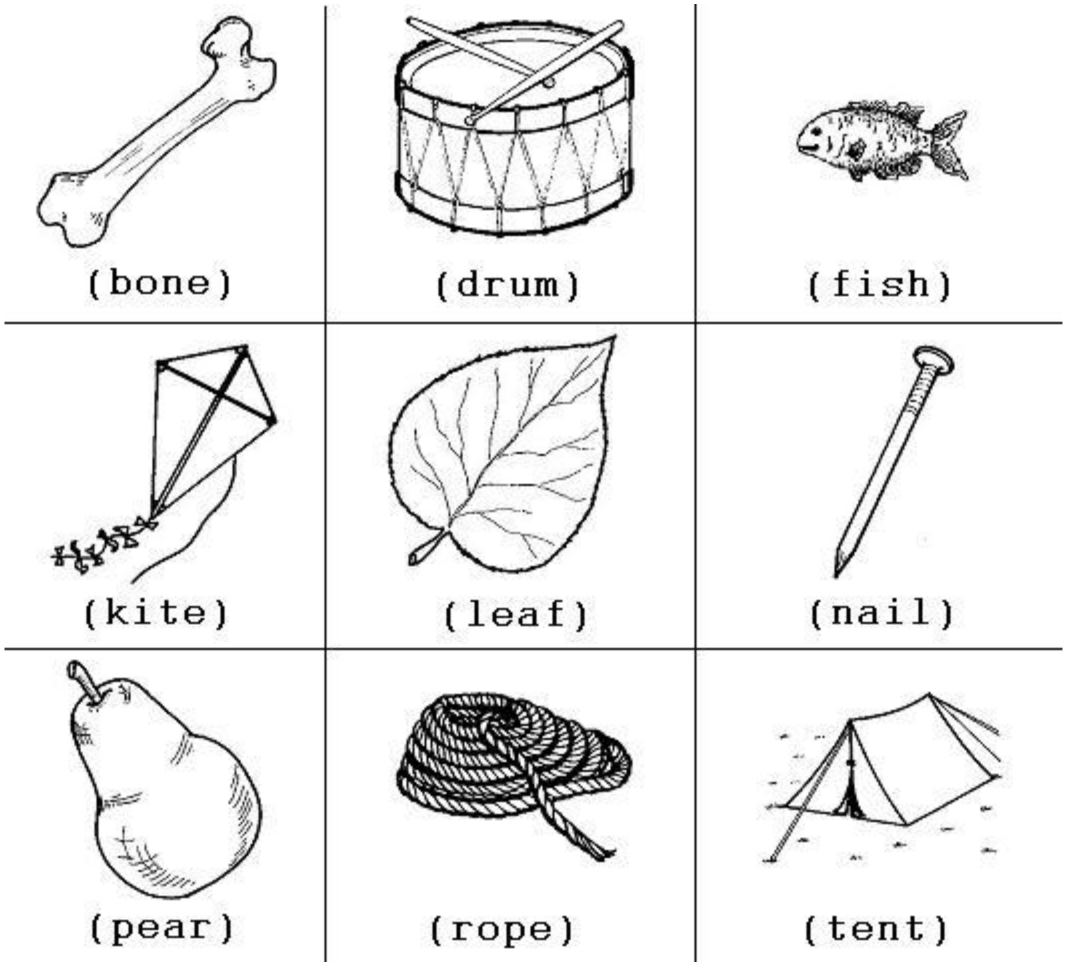

Figure 1. The pictures (and their names) used in the image stimulus condition.

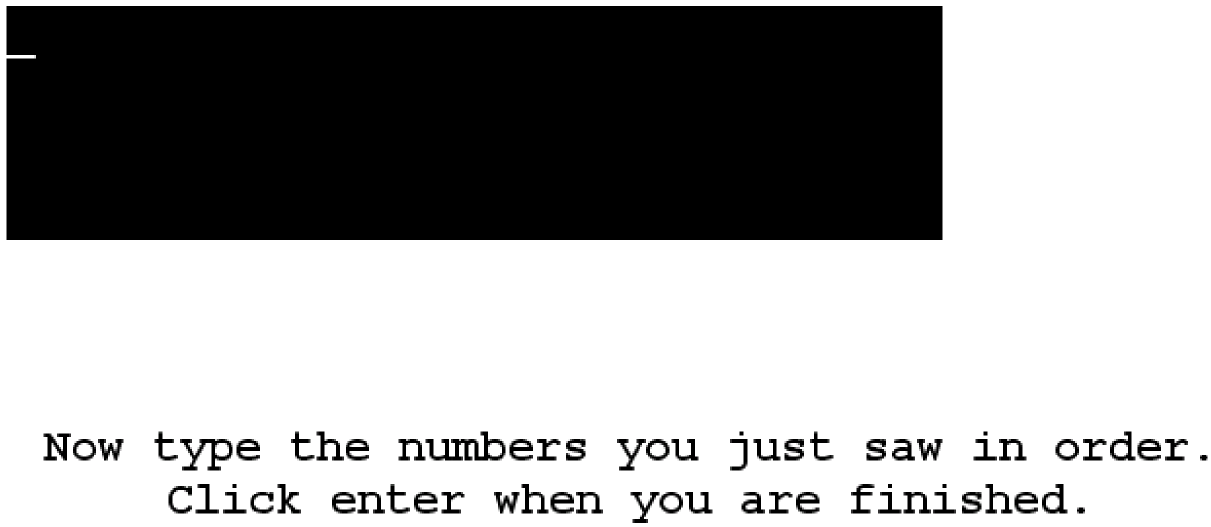

Figure 2. Sample answer screen for digit recall conditions.

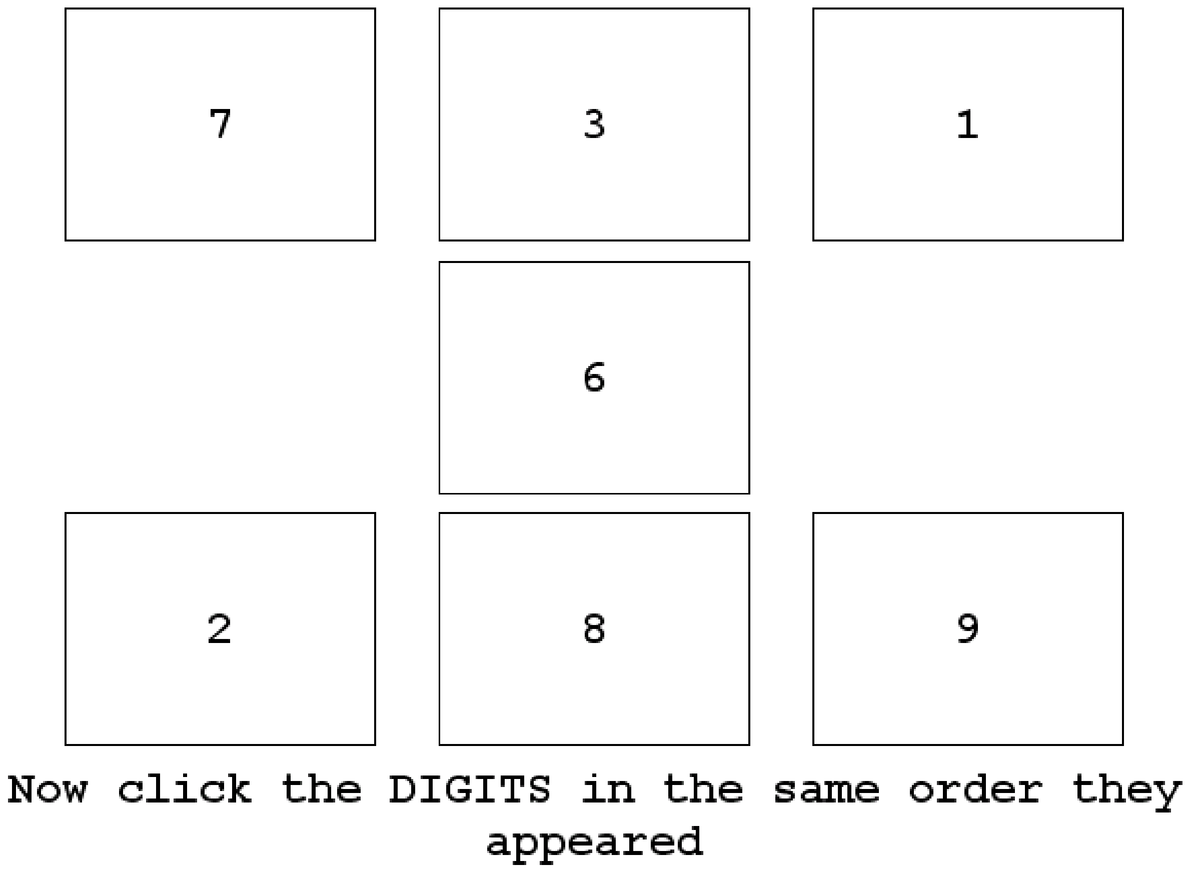

Figure 3. Sample answer screen for digit reconstruction conditions.

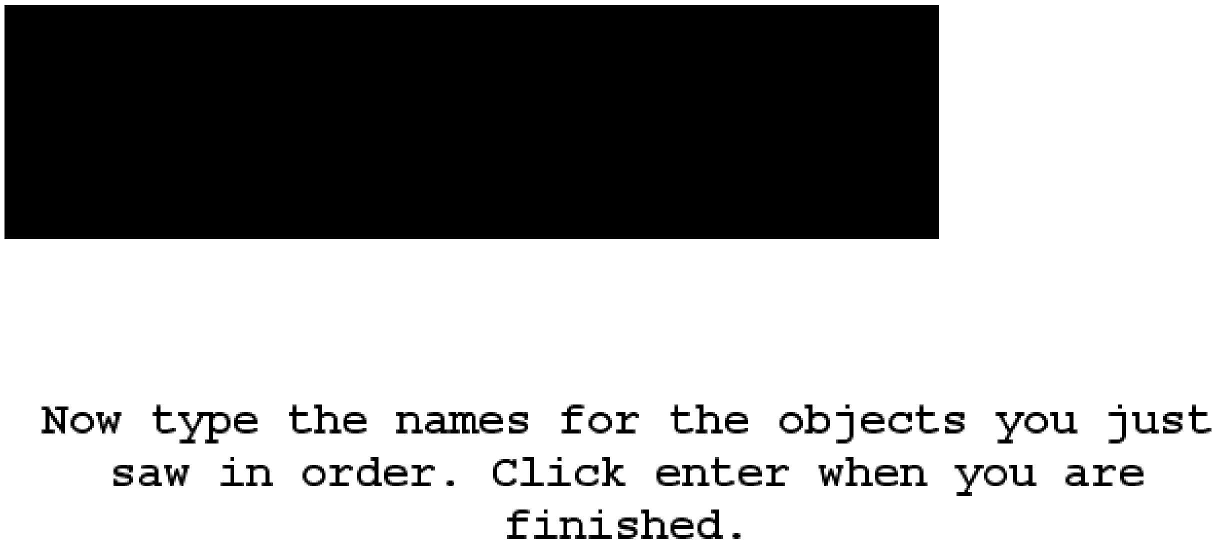

Figure 4. Sample answer screen for image recall conditions.

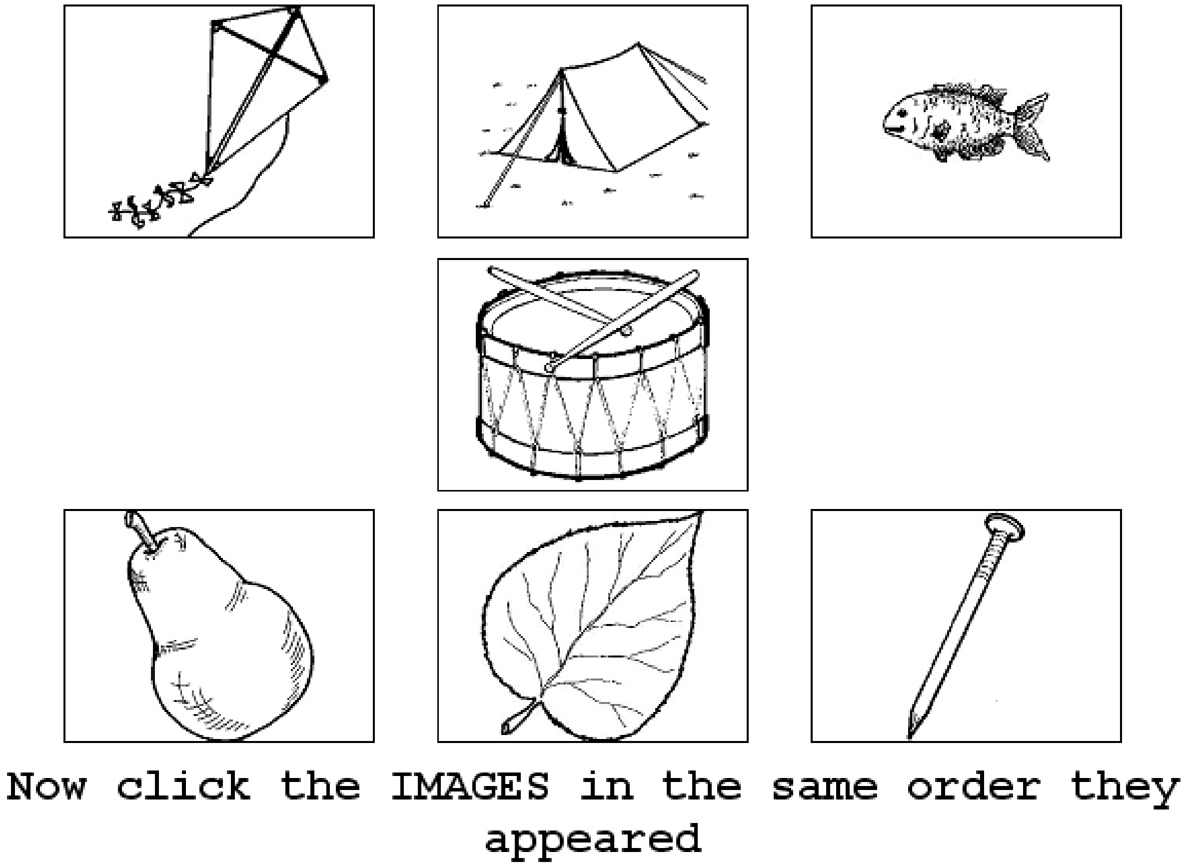

Figure 5. Sample answer screen for image reconstruction conditions.

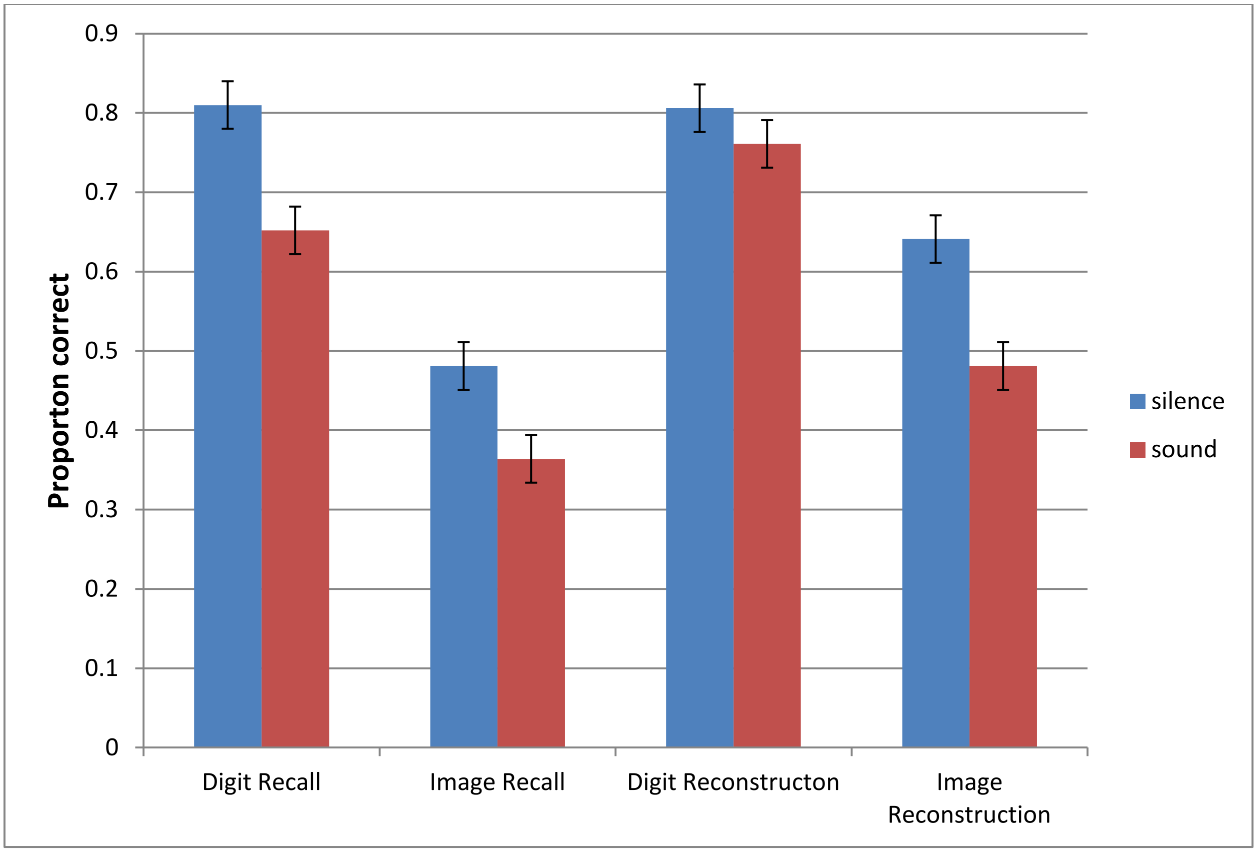

Figure 6. Proportion correctly recalled by stimulus type, recall mode, and sound.