The Effects of Semantic Relationships on the Irrelevant Sound Effect

This study investigated whether the degree of semantic relationship between audible distracter words and visually displayed to-be-remembered words impact short-term memory recall. Semantic relationship was defined as the level of synonymity between the two categories of words. Participants were divided into a control group receiving no distracters, a group in which distracter words and to-be-remembered words were closely synonymous, and a group in which distracter words and to-be-remembered words were loosely synonymous. The results indicate that semantic relationships have no impact on the number of words correctly recalled. However, closely synonymous relationships caused more replacement errors than silence or loosely synonymous relationships. One possible explanation is that auditory stimuli are more readily perceived than visual stimuli when synonymity is high.

Several types of distracters can inhibit the formation or recall of memories. While there is more time for interference to occur with long-term memories than short-term memories, short-term memory (STM) can still be disrupted. One type of distracter is external auditory stimuli. Sounds not associated with a task involving short-term memory negatively affect recall. This effect is termed the irrelevant sound effect (ISE; Colle & Welsh, 1976).

It is uncertain which features of auditory stimuli cause the greatest impact on the level of disruption in the ISE. Some studies indicate that acoustic properties are the key features of the ISE (Salamé & Baddeley, 1982; Tremblay, Macken, & Jones, 2000). Acoustic properties, such as the complexity and non-continuity of sounds, cause significant disturbance, with non-continuous and more complex sounds being more disturbing (Jones, Macken, & Murray, 1993). For instance, a continuous tone (such as a siren) would be less disturbing than a pulsating alarm. Also, a complex multi-toned siren would be more distracting than a siren with only a single tone. However, auditory stimuli experienced during memory recall include more than tones, music, and noise. More specific than the acoustic properties of general sounds are the acoustic properties of human speech. The acoustic properties within human speech are referred to as phonological properties. LeCompte and Shaibe (1997) reported that there was no phonological effect, meaning that acoustic properties within irrelevant speech do not affect recall. These studies suggest that human speech is not a significant cause of disruption (Buchner, Irmin, & Erdfelder, 1996).

While the previously cited studies indicate that the acoustic properties of speech do not impact STM recall, some research posits that semantic properties of the irrelevant sound are significant in the ISE (Neely & LeCompte, 1999). Semantic properties are those properties associated with a word’s meaning. Tests originally claiming that semantics had no effect lacked statistical power because of low subject counts (Buchner, Irmin, & Erdfelder, 1996). Buchner, Irmin, and Erdfelder (1996) conceptually replicated Salamé and Baddeley’s (1982) study while including more
subjects. They also concluded that semantics had no effect. However, these tests were designed to measure the semantic effects of digits, not words. In experiments testing the effects of words with more semantic meaning than digits, results indicated that the semantic relatedness of distracter words to the to-be-remembered (TBR) words was a significant factor in disruption of STM (Neely & LeCompte, 1999; Oswald, Tremblay, & Jones, 2000). There is a difference between how the sounds involved within human speech distract and how the meanings involved with those sounds distract.

Only a few studies have investigated in any depth the significance of semantics involved with the ISE. Neely and LeCompte (1999) used distracter words that had related meaning to the TBR words. During trials where the distracter words were related to the TBR words, both sets of words came from the same general category of word types (e.g., all words were types of fruits; Neely & LeCompte, 1999). Other research reports that the valency of distracter words has a negative effect on recall, particularly negatively valenced words (Buchner, 2005). It has also been found that the frequency of repeated words within a sentence proportionally increases the effect of the ISE (Buchner, 2005). These findings provide insight into how the semantic aspects of words actually impact recall. However, much is still to be learned about how related words impact recall.

Studies based on Buchner’s (2005) work involving valence and word frequency and modeled after Neely and LeCompte’s work (1999) might further the understanding of semantic elements in the ISE. Neely and LeCompte’s results indicate that words within the same category negatively affect recall more than distracter words from different categories. There is much more to semantics than nouns within the same category. Elements of speech that are more abstract, such as the synonymous conceptual meanings of words, may also negatively affect recall in a similar manner to Neely and LeCompte’s word groupings.

Much research has been done to establish whether or not semantics affect recall ability. What remains is the need to understand how and to what degree the effect occurs. Many aspects of semantics may impact recall. Our study examined the impact of words with similar meanings. Previous research identified a difference in recall when distracter words were in the same word grouping as the TBR words (Neely & LeCompte, 1999), but all of the words were distinct in meaning. Our study extends Neely’s work to examine differences in meaning within word groups. Specifically, we examined the effect of distracter words that were synonyms of the TBR words.

It was hypothesized that irrelevant sounds will generally inhibit recall of visually presented TBR words. Furthermore, auditory distracter words that are close synonyms of visually displayed words will produce fewer correctly recalled words than auditory distracter words that are loose synonyms of visually presented words.

**Method**

**Participants**

Sixty-seven college students participated in the study. These students were recruited from psychology classes at Brigham Young University and were all fluent in English. In most situations the students received extra credit for their participation. Researchers went to introductory psychology classrooms and asked for volunteers to participate in a memory test scheduled for a classroom location on campus at various times.

Participants were randomly assigned without replacement to three groups by asking them to choose a coin out of a sack. The year on each coin determined the groups: 2001 for group 1, 2002 for group 2, or 2003 for group 3.

**Materials**

The experiment used an Apple PowerBook G4 (model 6, 4) laptop computer, Sony MDR-V600
headphones, a pen, and 3" x 5" cards. Microsoft PowerPoint 2004 for Macintosh was used to flash words on the computer screen, and Garage Band v 1.1.0126 was used to paste in the auditory background words. A one-second time delay was used in PowerPoint to flash the words on the screen one at a time (see Table 1).

**Design and Procedure**

Participants were asked to sit down at the computer, which was placed on a desk at the front of a classroom. They were given a 3" x 5" card and a pen and were told to put the headphones on. They were instructed by a researcher to push the space bar when they were ready to start and that the computer would instruct them on the rest of the procedure. The researchers made sure not to stare or look at participants while they were taking the test. After the participants completed their tests, one of the researchers asked them if they had any questions. If they did, their questions were answered as their card was collected. The participants were debriefed, receiving a description of the nature and purpose of the experiment. Participants were told that their performance appeared to be normal and that they had adequately performed the task. They were thanked for their participation and excused.

**Recall Test**

The timing, words used, instructions, order of the slides, and the presence or absence of sounds are summarized below.

Slide #1: A blank screen displays until participant presses the space bar.

Slide #2: Slide displays: “Listen to the instructions. Press space bar when you’re ready.”

Participant hears: “Thank you for your participation in this study. This is not a test of skill or intelligence, so please make yourselves comfortable and relax.

“A list of 10 words will be presented to you. Each word will be displayed for approximately one second. Please memorize each word as it is displayed, ignore any word or sounds you hear, and only pay attention to the words on the screen. Once all the words have been displayed, 10 seconds will elapse before you are prompted to record what words you can remember in any order on the note card provided. You will be given 30 seconds to record. We will begin now.”

(Participant presses the space bar to start the word list.)

Slides #3–#12: (Each visual word is displayed for 1 second for all groups. Auditory words are heard simultaneously with the visual words displayed except for in group 1, which is the control group. Close synonyms are heard in group 2 and loose synonyms in group 3. See Table 1 for the word lists.)

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| Visual words (same for all groups): |
| house | engine | book | human | student |
| country | wish | parent | field | school |

| Auditory distracter words in group 2 (closely related): |
| home | motor | text | person | learner |
| nation | hope | father | pasture | college |

| Auditory distracter words in group 3 (loosely related): |
| abode | machine | tome | creature | novice |
| terrain | fancy | author | patch | system |

Slide #13: A blank slide appears for 10 seconds before participants are prompted to record words.
Data Analysis

The number of words correctly recalled and written down by subjects in each of the three groups was recorded. A one-way ANOVA was run on these results. In examining the 3” x 5” cards we discovered that many participants in group 2 (close synonyms) and only one in group 3 (loose synonyms) recorded distracter words. The distracter words were also analyzed. A one-way ANOVA in a secondary analysis compared the number of distracter words that replaced TBR words.

Results

The number of correctly recalled words from the three groups was recorded, as was the number of distracter words written down in each of the three groups. A one-way ANOVA was used to determine whether the differences were statistically significant. SPSS was used for all the statistical analyses.

Analysis of Correctly Recalled and Recorded Words

When correctly recalled words (see Table 2) were compared across the three groups, it was found that the differences were statistically significant $F(2, 64) = 8.95$ ($p < .0001$). A Tukey post-hoc test revealed that the mean differences were significant ($p < .05$) between groups 1 and 2 and between groups 1 and 3, but not groups 2 and 3 ($M = 6.33$, $M = 4.8$, and $M = 5.35$ for groups 1, 2, and 3 respectively).

Analysis of Replacement of TBR Words with Auditory Distracter Words during Recall

Group 1 replaced none of the TBR words with the auditory distracter words during recall, while...
group 2 had a mean of 0.36 words per participant and group 3 had a mean of 0.05 words per participant (see Table 3). An F-test showed that there were statistically significant differences \((p < .05)\) between groups 2 and 3 in the number of words replaced (see Table 3). Tukey post-hoc tests revealed mean differences between group 1 and 3, and 2 and 3. This indicates that the synonyms had a small but significant effect on the replacement of TBR words with distracter words.

**Discussion**

Our first hypothesis was that any auditory distracter words would be more disruptive than silence. Our second hypothesis was that distracter words that are more synonymous with TBR words would be more disruptive of recall than words that are less synonymous. That is, fewer words would be recalled correctly when the semantic relationship between words was closer. The finding that groups 2 and 3 recalled fewer words correctly than group 1 did support our first hypothesis. Using only the number of correctly remembered words, the difference between the two groups who heard different distracter words was not significant. Thus, the results do not support the second hypothesis.

In a secondary analysis, we found that the differences between replacement error rates between groups were significant. A replacement error was defined as the recall of a distracter word in place of the recall of a visually presented word. Following a one-way ANOVA, a Tukey post-hoc test indicated that the differences between groups 2 and 1 and between groups 2 and 3 were significant, with group 2 having the most replacement errors. The difference between group 3 with loosely synonymous distracter words and the control group 1 with no irrelevant speech distracters was not significant.

These findings from the secondary analysis indicate that, when replacements of words occur, closely synonymous relationships impact replacement errors more heavily. Loosely synonymous relationships have no more bearing on replacement errors than silence does. The results of the secondary analysis extend beyond our original second hypothesis. Specifically, the second hypothesis was that fewer words would be recalled when there was a closer relationship between words. However, in a more general form, the second hypothesis was that closer synonymous relationships between distracter and TBR words would be more disruptive of memory recall.

The ISE not only is impacted by semantics but is impacted in a subtler manner than previously indicated. Taken together, the results indicate that varying the levels of semantic relationship between visually presented words and auditorily presented words has no impact on correct recall of the visually displayed words. However, the recall errors when the visually presented and audibly presented words were more closely related were more frequent than when the relationship was looser. Participants were less likely to distinguish between what was seen and what was heard when the two words were more closely related. This difference supports the general hypothesis put forth by Buchner (2005) and Neely and LeCompte (1999), who posited that semantics impact recall. The present study extended Neely and LeCompte's (1999) test beyond using only words from the same semantic family during each trial to include words from a variety of families within one trial. Also, the distracter words were related to the visually displayed words in a conceptual manner rather than having direct item-family relationships as in Neely and LeCompte's (1999) test, where words were related in that they were, for example, all fruits. Both the increased complexity of the word list and the looser word associations between visually and auditorily presented words aided in uncovering these subtle influences in distraction that had not been previously expected.

No studies within the literature have addressed the issue of replacement by the distracter word in the ISE. This may be due to the testing design used thus far in studies attempting to identify the
role of semantics in the ISE. Buchner (1996, 2005) used serial recall in his tests. Neely and LeCompte (1999) also used serial recall but were not studying degrees of relatedness. Serial recall tests may not lend themselves to the detection of replacement words. However, free recall tests allow this. The current study showed that closely synonymous relationships between distracter words and TBR words increased the likelihood of the distracter words to be recalled. Free recall tests may make it easier for such replacements to be measured, but whether they will help to parse the differential effects of different levels of semantic relationships on word replacement remains to be determined. To further this study, the reliability of free recall versus serial recall versus multiple-choice tests in detecting these differences should be better established.

One explanation for the replacement in recall is that two semantically related words may tap into a schema in which both words are present. Whichever word is more salient or more highly prioritized within the individual’s schema will be recalled. Each schema and prioritization order would differ subjectively. This also assumes an equal-priority balance between modes of perception. That is to say, this explanation assumes that neither the auditory nor visual pathways should have greater access to the schema than the other. Attention to stimuli from both auditory and visual sources being equal, they should receive equal priority in accessing the schematic information. Thus, whichever word of the two presented to the subject is more highly prioritized within the schema at any point in time will be recalled more readily, regardless of which channel the recalled word was presented in.

This putative explanation is unlikely for at least two reasons. As the participants were specifically told to pay no attention to audio stimuli, words stored in memory that matched what had been visually presented should have had greater priority. Also, while personally relevant words may cause attention to be shifted to otherwise irrelevant speech (Buchner, Irmen, & Erdfelder, 1996), the personally neutral words in the present study should not have caused the participants to attend to them when they were instructed to ignore them. These two reasons could be assured by better controlling for the neutrality of the distracter words and determining the extent to which instructions to ignore auditory words were obeyed.

Another possible explanation for the results we have termed the “aural-trust” phenomenon. It is possible that when disparity between related words is low, the brain is more likely to perceive what was heard rather than what was seen. Therefore, when there is a closely synonymous relationship between the words, the auditory presentations are perceived ahead of the visually presented words. Such a mechanism may explain the pattern of replacement that was observed.

In addition, there were four internal limitations within the current study. The first involved the control of semantic influence. In hindsight, more information about the effects of semantic influence on the ISE may have been obtained with a fourth group included in the research design. This fourth group that had received irrelevant speech distracter words with no semantic relationship to the visually presented TBR words would have acted as a secondary control for the effect of semantic relationship on recall; that is, they would have provided a baseline for no semantic relationships.

Another limitation was the word list construction. Synonyms are difficult to rank by order of similarity, especially while simultaneously controlling for word length and phoneme-matching between word pairs. Subjective differences in how synonyms are related to an individual may vary, as already noted in the previous discussion of schemas, causing differences in the words that are close enough in meaning to be replaced during recall. The disparity in word meaning that was a prospective cause of replacement may have varied from person to person. The disparity may also have varied in degree within some word lists, with some pairs in a group being more closely related than other pairs. Perhaps one way to control for a
subjective difference in the perceived synonymity of word pairs would be to ask participants to rate word pairs according to synonymity after the recall task. This rating, if factored into the participant’s results, may provide for better control of synonymity differences when examining replacement errors.

The third limitation was that the subjects were not isolated during the tests, allowing for distraction beyond that which was purposely included in the design. While this was controlled for as much as possible, the nature of room scheduling inherent in using the campus made it impossible to isolate each student in order to be undistracted by anything other than distracter words. Participants may have been distracted by background noise other than what the study controlled for. Several participants were observed to look about the room at other participants and researchers during the course of the session. Occasionally external sounds (such as the door being closed loudly or other persons speaking loudly) disrupted an otherwise silent testing environment.

The fourth limitation in the study was that some of the words in the auditory portion of the slideshow were not completely audible due to recording difficulties. Some of the words ended slightly prematurely, causing a minor abnormality in their sound. Three of the words had this defect. This irregular sound of the words may have confounded the semantic effects.

While it is possible that word replacement is the only effect of the ISE connected with semantics, the extent of semantic effects should be more thoroughly probed. Although the present study narrowed the effect of semantics on the ISE more than previous research, it was nevertheless still a broad approach. More detailed analysis of the impact of synonyms must be done by eliminating potential confounds. As our hypothesis was not focused on the replacement of target words by distracter words, research pointed at this issue should employ similar word lists while using free recall tests specifically aimed at discovering how and why words are replaced. This could be done by varying the disparity between synonymous word groups to better describe the continuum of effect. The number of target words used in the test should be examined as well. In this experiment the word list included only 10 words. Most people can remember only seven items, plus or minus two, without any distractions. A longer list may cause the retention of words to drop at different rates depending upon a given distraction. The order in which the words are administered should be analyzed to determine if these two effects override any ISE. Research should also investigate whether there is a threshold for the sound levels at which the ISE occurs.

References


