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ABSTRACT

The effect of presentation modality and stimulus type on memory for frequency was examined. In Experiment 1, forty undergraduate students viewed or handled 21 three-dimensional items. Items were either (a) geometric shapes, (b) nonsense objects, or (c) familiar items and occurred either 2, 4, or 6 times, creating a randomly ordered list of 72 items. Subjects were tested in the same modality on their memory for frequency of those items. Subjects were able to distinguish between items which occurred less frequently versus those which occurred more often. The average frequency estimates for nonsense and familiar items were closest to the actual average. In Experiment 2, subjects initially viewed or handled the items and were tested in the opposite modality. Subjects were again sensitive to frequency although the pattern of frequency estimates for geometric items differed significantly. It appears subjects may have been deprived of too many haptic cues to distinctly identify each geometric shape. Results support a central frequency processing mechanism hypothesis.

INTRODUCTION

People have the ability to retain an accurate count of the frequency of occurrence of events around them (Hasher & Zacks, 1984). This ability has been well documented in instances involving the visual system, such as memory for frequency of words (Beins, Lindner, & Lepsch, 1991) and for single letter occurrences (Attneave, 1953, cited in Hasher & Zacks, 1984). However, evidence suggesting its existence in other modalities, in particular the tactile modality, is lacking.

Hasher and Zacks (1984) described the process as automatic; one only need experience an event and it will be registered in memory as having occurred. As such, whether one intended to process such information would play no role in the processing of the event. Jonides and Naveh-Benjamin (1987), however, propose a multi-mechanism model of frequency encoding that consists of a direct and an indirect coding mechanism. The direct coding mechanism codes events using an active process, such as counting, which registers the frequency of that event as a separate attribute of the event. The indirect coding mechanism encodes the frequency information of that particular event. Jonides and Naveh-Benjamin (1987) suggest these two mechanisms together contribute to the frequency storage process.

In our first study, subjects will be presented either visually or tactually with nonsense objects (i.e., items which, when presented both visually and tactually, are difficult to identify); three-dimensional geometric figures; and familiar items, chosen from a list composed by Klatzky, Lederman, & Metzger (1985). Subjects will then be tested for their memory for frequency of these items in the same modality.

Klatzky et al. (1985) asserted that the haptic system is inadequate in object identification, especially when compared with the visual system. Research comparing the visual system to the haptic system using two-dimensional nonsense shapes (e.g., Bryant & Raz, 1975; Cashdan, 1968; Rock & Victor, 1964, cited in Klatzky et al., 1985) and research conducted using tangible graphics displays, such as maps or graphs (e.g., Lederman & Campbell, 1982; Klatzky & Barber, 1985; Magee & Kennedy, 1980, cited in Klatzky et al., 1985) have provided empirical evidence for this conclusion. However, it may be the absence of important cues in these stimuli which lead to the resulting differences between the modalities and the ultimate assessment of the haptic system as being inadequate.

To assess the possibility that reduced cues make the haptic system seem impoverished, Klatzky et al. (1985)

blindfolded subjects and allowed them to feel familiar objects. Subjects were instructed to name the objects as quickly as possible and were asked to tell how they arrived at their conclusions. Results indicated subjects were able to identify a wide range of objects quickly and accurately. In addition, subjects reported using global shape (e.g., of a comb), global texture, the presence of a distinct component (e.g., a pen cap or a tea bag string), component texture, global size, and component shape most often when making identification decisions using only haptic information.

Of particular interest in our study is the effect of the modality on memory for frequency. Kazen-Saad (1986) presented one group of subjects with patterns made of wire, allowing them to touch each while blindfolded. The second group constructed the patterns in their mind while listening to verbal descriptions of the patterns. After each pattern was completed, subjects in each group were told to indicate orally the target pattern from a recognition sheet containing the target amidst distracters. Kazen-Saad concluded that information taken in by the two different sensory pathways was in turn processed differently, allowing for better performance in the verbal (aural) condition. Will such a difference between modalities be demonstrated when testing memory for frequency or is this information processed in the same way, regardless of modality?

Of further interest in our study is the effect, if any, of the stimulus type on memory for frequency. Perhaps the familiarity of the items plays a role in frequency recall ability. Bower, Karlin, and Dueck (1975), for instance, presented subjects with a series of nonsense pictures. One group was given an interpretation of the drawings during the presentation while another was not. All subjects were asked to recreate the gist of the drawings they could remember immediately following all presentations. Subjects in the interpretation group recalled significantly more pictures than those subjects receiving no interpretation. Bower et al. suggest that if a picture may be related to a schema and thus understood, it will be remembered much better than pictures for which no understanding is generated. Perhaps the interpretation effect will be observed as subjects try to estimate frequency of occurrence of nonsense objects, which are characterized by their ambiguity and lack of identification. If subjects have difficulty interpreting the nonsense items because of lack of familiarity or cue deprivation, subjects' performance would be worst for the nonsense objects. Furthermore, if the ability to tally items is modality dependent, one would expect that subjects' performance might change across modalities.

EXPERIMENT 1

METHOD

Subjects

Forty undergraduate students participated in the study, some of whom received extra credit. None of the participants were paid. All were treated in accordance with the "Ethical Principles of Psychologists" (American Psychological Association, 1981).

Materials

The stimuli consisted of familiar objects taken from a list published by Klatzky et al. (1985), geometric objects, and nonsense stimuli. The geometric objects were hollow plastic shapes, including those found in the infant's toy *L'il Hands Shape Sorter Bucket*, by Unimax Toys. The nonsense objects were gathered and chosen based on whether or not the experimenters could recognize them as familiar or determine their purpose. Those that failed to spark recognition or an idea of purpose were deemed suitable for use in our study.

All of the stimuli were kept in a box, out of view of the subjects. For those subjects in the tactile condition, a blindfold was also used.

Procedure

Subjects were told they would be presented with a series of objects either visually or tactually and would later be tested for their memory for these items. The specific nature of the memory test was left unspecified.

In the tactile acquisition condition, subjects were blindfolded and presented with each stimulus individually. They were allowed to hold each object with both hands for a period of five seconds at which point the experimenter tapped the table, signaling the subject to release the stimulus. In the visual acquisition condition, subjects were permitted to view the same individual stimulus for five seconds. The 18 stimuli used in acquisition, six from each category (familiar, non-familiar, geometric), were randomly ordered and occurred either 2, 4, or 6 times. This resulted in a list containing 72 items: six items occurring 2 times, six items occurring 4 times, and six items occurring 6 times.

During testing, six more items (two of each category) were added which had not occurred during the acquisition portion. These are referred to as zero frequency items. During the test, subjects in the tactile condition were presented with the 24 stimuli one by one, randomly ordered, while still blindfolded. Subjects in the visual condition viewed the 24 items in the same random order as for tactile subjects. Subjects in both conditions were asked to report aloud how many times they thought each item had occurred during acquisition. Subjects' responses were recorded for each of the 24 items.

RESULTS AND DISCUSSION

A significant effect for frequency resulted, $\underline{F}(3, 114) = 72.92$, $\underline{p} = .000$. The average estimate for items occurring 0 times, 2 times, 4 times, and 6 times were .17, 2.66, 4.51, and 5.83 respectively. On the average, subjects were very good at estimating frequency; as the frequency of occurrence of each item increased, so did the subjects' estimates. Subjects were able to differentiate between those items which occurred only a few times from those items which occurred more often.

A significant effect for stimulus type also appeared, $\underline{F}(2, 76) = 4.54$, $\underline{p} = .014$. The average estimate for familiar items was reported to be 3.36 times, 3.07 times for nonsense items, and 3.30 times for geometric items.

It is interesting to note that the average estimate for nonsense items is closest to the actual occurrence. Although the exact reasons for this observation are not known, the following explanations are offered. First of all, it is helpful to utilize Hintzman's theory (1976, cited in Hasher & Zacks, 1984) that our memory system works in such a way that a separate trace is established for each occurrence of an event (i.e., item). With this in mind, it is possible that traces established in this experiment were confused with traces previously established due to prior exposure to those items. In other words, the familiar and geometric items have, presumably, been encountered before in everyday life. Traces made by those encounters may be confused with traces established during the experiment. The nonsense items presumably have not been encountered nearly as often, if at all, prior to this experiment and therefore the trace record for these items is not as extensive. As a result, subjects are less likely to confuse these traces and estimates of the frequency of occurrence of nonsense items turns out to be closer to the actual occurrence.

A second explanation deals with the observation that many subjects tended to explore the nonsense items more extensively than they did any of the other items. Subjects appeared to lose interest in the familiar and geometric stimuli upon repeated presentations but were consistently attentive when presented with the nonsense items. Taking into consideration the direct coding mechanism involved in the processing of frequency information (Jonides et al., 1987), it is possible that the unfamiliarity of such items caused subjects to pay more attention during the presentation, thus resulting in recall that was closer to the actual occurrence. Furthermore, because subjects tended to lose interest when presented with the other item types, estimates were not as close to the actual occurrence.

A significant interaction between frequency and stimulus type was also observed, $\underline{F}(6, 228) = 264.68$, $\underline{p} = .000$. The average frequency estimates obtained

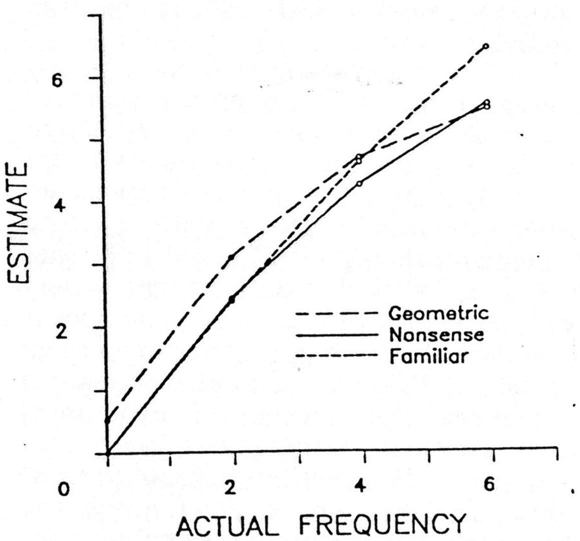

Figure 1. Average estimates of the frequency of occurence of familiar, nonsense, and geometric items versus the actual occurence of each item in Experiment 1.

in figure 1. While the general trend of the curves representing the familiar and nonsense items appears to be similar, the different trend of the curve representing the geometric items becomes evident. We are not sure why this difference exists. It is interesting to note, however, that the average incremental increase in estimates between each frequency interval (i.e., 0, 2, 4, and 6) for familiar items was 2.15, .15 above the actual increase of 2, and 1.85 for nonsense items, .15 below the actual increase. It is possible that subjects reported lower estimates of the nonsense items because the item identities were not clear cut. Instead, the traces created for these items may have been clustered together, resulting in estimates which, on the average, increased slightly less than the actual increase in frequency. Average estimates of the frequency of occurrence of the familiar items may have been larger because subjects confused previously established traces with those established in the experiment, as was discussed earlier. In either case, as the frequency of occurrence of each item increases from zero to six presentations, the average estimate increases as well, never straying more than .15 from the actual value.

No significant difference was observed between the performance of the visual group, M = 3.383, versus the tactual group, M = 3.205, $\underline{F} < 1$. An interaction between groups and frequency was not observed, $\underline{F} < 1$, nor was there an interaction between group type and stimulus type, $\underline{F} < 1$. In general, if the performance on the frequency task in one modality is known, performance on the same task in the other modality will be about the same, regardless of the frequency interval or stimulus type. The three-way interaction between group, frequency, and stimulus type was also not significant $\underline{F}(6, 228) = 1.68$, $\underline{p} = .127$.

As expected, our results demonstrated people's ability to maintain an accurate account of the frequency of occurrence of events around them. These results also support our hypothesis that stimulus type (i.e., geometric, nonsense, or familiar items) affects memory for frequency recall; however, the results also demonstrate an effect we had not expected: average estimates (across modalities and frequency intervals) were closest to actual occurrence for nonsense items, not for familiar items, as we had hypothesized. However, when the significant interaction between stimulus type and frequency is taken into consideration, it becomes clear that the average estimates increased close to the actual increase for both familiar and nonsense items. Lastly, although we had suggested that differences in performance in memory for frequency might emerge for different modalities, our results did not support this conclusion. This may indicate that a single mechanism is involved in the processing of frequency information. Experiment 2 assesses this hypothesis.

EXPERIMENT 2

METHOD

Subjects

Fifty undergraduate students participated in the study, some of whom received extra credit. None of the participants were paid. All were treated in accordance with the "Ethical Principles of Psychologists" (American Psychological Association, 1981).

Materials

The stimuli were the same as those presented in Experiment 1. The randomized lists used in acquisition and testing were also identical to those used in the first experiment.

Procedure

Subjects heard the same instructions used in Experiment 1. Again, the nature of the memory test was left unspecified.

During the acquisition phase, subjects in the visual-tactile condition (VT) were shown individually each of the 72 stimuli, randomly ordered as in Experiment 1. Subjects in the tactile-visual condition (TV) were blindfolded and permitted to handle the same 72 stimuli, randomly ordered. Both groups were allowed five seconds to study each object.

Modality was switched during the testing phase. That is, those subjects in the VT condition were asked to blindfold themselves for the testing phase and those in the TV condition were permitted to remove their blindfolds. The 24 items, randomly ordered, were presented to each subject. TV subjects were only allowed to view the objects during testing while VT subjects were permitted to feel the objects. U;con presentation, subjects in both groups were asked to report aloud how many times they had encountered the item prior to the current presentation.

RESULTS AND DISCUSSION

A significant effect for frequency resulted, $\underline{F}(3, 144) = 62.14$, $\underline{p}=.000$. Average estimates for items occurring 0 times, 2 times, 4 times, and 6 times were .42, 2.99, 4.59, 5.63 respectively. Again, as the actual frequency of items increased, subjects' estimates of the frequency of these items also increased. An interaction between frequency and stimulus type also occurred, $\underline{F}(6. 288)$. 2.32, $\underline{p}= .03$. The average frequency estimates obtained for the three stimulus types are represented in Figure 2. As in Experiment 1, a similar trend may be observed between the frequency estimates of familiar items and nonsense items. The average incremental increase in estimates between each frequency interval (i.e., 0, 2, 4, and 6) for familiar items was 2.01 and 1.88 for nonsense items.

Geometric items, on the other hand, once again followed a different frequency trend. Aside from recognizing that some geometric shapes were novel in testing, subjects were largely unable to differentiate the frequency of occurrence of items appearing two, four, or six times. Klatzky et al. (1985) reported that subjects used particular cues when identifying items haptically. The cues used most often include global shape, global textures, and the presence of a distinct component while component texture, global size, and component shape were utilized less often. When modalities were different in acquisition and testing, these haptic cues were not available for subjects to use to make distinctions between the geometric items. For example, subjects in the visual-tactile group may have used color as a cue to recognize the different geometric stimuli. When modality was switched in testing, this cue was not available. Instead, the haptic system had only the number of sides of the objects to differentiate between the stimuli.

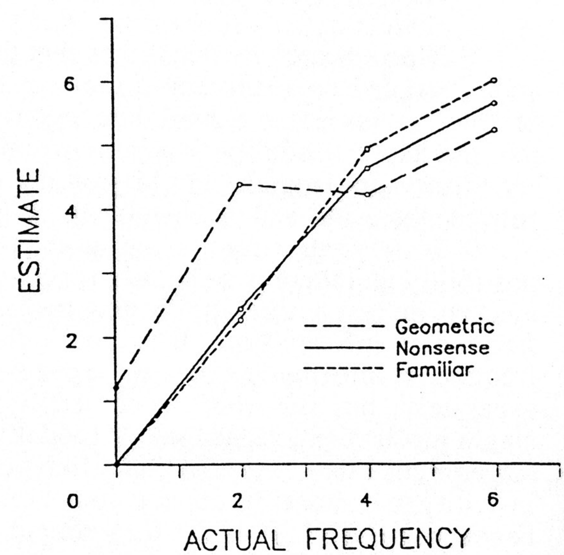

Figure 2. Average estimates of the frequency of occurence off familiar, nonsense, and geometric items versus the actual occurence of each item in Experiment 2.

The average frequency estimate for the tactile-visual (TV) condition was 3.27 and 3.54 for the visual-tactile (VT) condition, $F<1$. Performance was comparable in both conditions.

The fact that no significant difference resulted between the conditions suggests that frequency information is processed similarly in both the visual and haptic modalities. The lack of difference supports the hypothesis that there is a central frequency processing mechanism, responsible for keeping track of the number of times events occur around us, regardless of modality.

Average estimates for familiar, nonsense, and geometric items were 3.30, 3.18, and 3.75 respectively, and did not differ significantly, $F(2, 96) = 1.51$, $p=.226$. An interaction between condition and stimulus type was not evident, $F< 1$, nor was there an interaction between condition and frequency, $F< 1$, or between condition, frequency, and stimulus type, $F(6, 288) =1.41$, $p= .209$. Again, if subjects' performance in one condition is known, performance on the same task in the other condition will be about the same, regardless of stimulus type and frequency interval.

GENERAL DISCUSSION

This research demonstrates that the ability people have to remember the number of times events occur around them extends into the haptic modality. Furthermore, the sensitivity to frequency did not differ between the visual and tactile modalities.

Both experiments support the possibility that there is a central processing mechanism responsible for keeping track of frequency information. It appears that frequency information is not registered separately, but is rather processed by a single mechanism, regardless of modality. Experiment 1 demonstrated that differences in ability to estimate frequency do not exist between the modalities. In Experiment 2, results indicated that frequency information experienced and processed by one modality could be retrieved by cues given to another modality, providing the strongest support for our central processing hypotheses.

Another aspect of the studies included the stimulus type used in the tasks. Originally, it was hypothesized that the familiarity of the stimuli might affect the frequency estimates. In Experiment 1, results indicated a significant effect for stimulus type. The average estimates for non-familiar items were closest to the actual frequency of occurrence, M = 3.07 times, while estimates for familiar items tended to be higher than the actual occurrence, M =3.36. In Experiment 2, however, a significant effect of stimulus type did not appear. Average estimates were 3.30, 3.18, and 3.75 for familiar, nonsense, and geometric items respectively. The error variability was larger in the second experiment, indicating the difference in averages may not be only due to the stimulus type itself, but may also be due to unknown factors.

In examining the results of the geometric items, it becomes evident that perhaps it is not helpful to look at the stimuli on a continuum of familiarity. Rather it may be more useful to look at the stimuli in terms of how many cues are available for the modalities to process. The familiar items were rich in haptic cues (e.g., presence of a distinct component such as the pen cap or tea bag string) and visual cues (e.g., color). The same holds true for the non-familiar items (e.g., haptic cues include the wire component of the incense burner and visual cues include color). For the geometric items, the haptic system had to rely on the cue of the number of sides of an object to differentiate between one geometric item and the next. The visual system, on the other hand, could use this cue as well as the color of the items. In Experiment 1, these cues could be relied upon to distinguish between the stimuli in both acquisition and testing. However, in Experiment 2, color cannot be detected by the haptic system and only the number of sides remains as a cue between the modalities. In both cases, however, only a small number of cues exist, thus subjects had difficulty distinguishing among geometric items.

In conclusion, memory for frequency information may very well be processed in one, central location. In addition, whereas the ability to remember the number of times events occur around us in not affected by presentation modality, the number of stimulus cues available does affect the ability to process frequency information.

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