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The Ravages of Absolute and Relative Amounts of Time on Memory

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Robert Crowder is one of those rare scientists who delights in clear evidence, perhaps more than in almost anything else. The first interchange between the present first author (NC) and Crowder occurred when NC submitted a paper to the Psychological Bulletin (Cowan, 1984) and Crowder was a reviewer (who always signed his reviews, being willing to be held accountable for his opinions). In the process of responding to one of the reviewers' concerns, NC asked Crowder for individual-subject data from a study carried out a few years earlier (Crowder, 1982) so that the results could be modeled. Crowder not only complied; he was delighted that he had been asked. He said that this was the first time than anyone had asked for his original data, and that he was proud to say he found it in good order in his filing cabinet. Many other researchers also would have complied with the request but ask yourself: How many would have seemed *delighted* at the request, as opposed to being a little apprehensive about how the evidence might be used? This is a strong indication of character in science. Also indicative of this is Crowder's striking intellectual honesty mixed with good humor; as, for example, in one paper (Crowder, 1983) in which he lamented that another investigator had used up a title that he otherwise would have liked to use for his own paper. In the present work, we will seek to emulate Robert Crowder in his courageous path in which he was among the first to repudiate his own earlier, well-received theory about sensory memory (e.g., Crowder & Morton, 1969) in light of evidence that he found contradictory (e.g., Crowder, 1989, 1993).

1. Immediate Memory and its Loss: Definition of the Problem

William James (1890) distinguished between one’s current thoughts, or primary memory, and one’s mental storehouse of knowledge, or secondary memory. A natural distinction that one can draw between these types of memory is that there is a limit in how long a particular thought can remain in primary memory. Many empirical studies have led to suggestions of an upper limit of about 30 s for primary memory information unless it is refreshed through rehearsal. As James noted, one also can observe a kind of memory mechanism that temporarily preserves the sensory information from all stimuli, even the ones that observers are ignoring but could turn attention to quickly. It has often been suggested that this kind of sensory memory, also, is limited to about 30 s or less. (For reviews of these literatures, see Cowan, 1988, 1995). One might define *immediate memory* as temporarily held information including both conscious primary memory and any other transient information source, such as sensory memory, available to primary memory.

The typical finding of a gradual decrease in average performance in immediate memory tasks as the retention interval increases, reaching an asymptote within about 30 s, can be termed memory decay. There have been some suggestions that the concept of memory decay is on a priori grounds unreasonable because time itself cannot cause a loss of information; processes taking place during that time must cause the loss and these processes can be altered. We would note that this type of objection has not stopped the concept of decay from being respectable in other areas of science. The prototypical case is radioactive decay. A radioactive material usually loses half of its radioactivity over a fixed time period X, which depends on the nature of the material. Even in the case of radioactivity, though, time itself is not an ultimate, unchanging causal factor. If a material is accelerated to nearly the speed of light, its rate of loss of radioactivity (and every other temporal process) slows down as measured by our stationary clocks. Thus, even in this case, one must specify the conditions before decay can be described. This situation seems similar to the use of the term decay to describe the loss of information from immediate memory at a certain rate under ordinary circumstances, though various factors can modify it. In both cases, the term decay can be used only with the conditions specified.

A more general question that can be investigated with less theoretical baggage is whether there is an effect of the *absolute duration of the retention interval* on memory or whether, instead, only relative amounts of time between stimuli make a difference. Several recent studies have discussed this issue explicitly (Cowan, Saults, & Nugent, 1997; Cowan, Wood, Nugent, & Treisman, 1997; Nairne, Neath, Serra, Byun, 1997) but it remains unresolved. On one hand, some classic results suggest that the relative distribution of time periods among the stimuli is so important that the absolute duration of the retention interval may not matter (e.g., Bjork & Whitten, 1974; Keppel & Underwood, 1962). On the other hand, one easily can imagine that there are some inevitable temporal limits to the ability of an active neural cell assembly (Hebb, 1949) to retain information, such as cellular fatigue or neural noise that eventually destroys the essential pattern carrying the information. The present paper focuses on the question of whether the absolute duration of the retention interval can be shown to be important for primary memory.

2. A "Brief History of Time" in Memory Research

The decay concept was a popular one early on in cognitive psychology (e.g., Brown, 1958, 1959; Broadbent, 1958; Glanzer & Cunitz, 1966; Peterson & Peterson, 1959) because of studies showing that memory was lost across a retention interval of some seconds filled with distracting information. The use of the concepts of decay and memory loss as a function of an absolute amount of time has continued into recent times in cognitive psychology, to account for apparently time-limited memory (e.g., Baddeley, 1986; Koppenaal & Glanzer, 1990; Towse, Hitch, & Hutton, 1998), and in cognitive neuroscience, to explain the loss of information about unattended stimuli automatically saved in the brain (Näätänen, 1992; Sams, Hari, Rif, & Knuutila, 1993).

Also for a very long time, there has been a reaction against these absolute time concepts. This reaction might be traced back to John McGeoch (1932) at the University of Missouri, as well as his successor, Art Melton (1963). Following Bjork and Whitten (1974) and Keppel and Underwood (1962), probably no one has argued against the decay principle as effectively as Robert Crowder (1989, 1993), who was a student of Art Melton. The persuasiveness of Crowder's arguments is evident in the fact that many of his students and close colleagues also have ended up arguing, in various ways, against the notion of decay. These include, among others, Art Glenberg (e.g., Glenberg & Swanson, 1986), Allison Marks (Marks & Crowder, 1997), Jim Nairne (e.g., Nairne et al., 1997), Ian Neath (e.g., Neath & Crowder, 1990; Neath & Nairne, 1995), Robert Greene (e.g., Greene, 1986; Thapar & Greene, 1993), and Henry Roediger (e.g., Roediger, Knight, & Kantowitz, 1977).

The difficulty in measuring effects of time per se on memory has always been that one must rule out effects of three sources of interference: retroactive (interference from subsequent items), concurrent (interference from concurrent items), and proactive (interference from previous items). Also, memory loss over time cannot be observed to its fullest extent unless covert rehearsal is blocked because rehearsal can refresh items in memory (Baddeley, 1986). However, most attempts to block rehearsal have used materials meant to serve as distracting tasks, and these, unfortunately, can impose retroactive interference. A few studies have blocked rehearsal in ways that may allow forgetting to be observed in the absence of important retroactive interference (Eriksen & Johnson, 1964; Cowan, Lichty, & Grove, 1990; Keller, Cowan, & Saults, 1995; Reitman, 1974; Watkins,

Watkins, Craik, & Mazuryk, 1973; Wingfield & Byrnes, 1972). Of course, concurrent interference is the easiest to avoid, simply by presenting only one stimulus at a time.

The most difficult type of interference to avoid is probably proactive interference. Although one can refrain from presenting items concurrent to a target item or during its retention interval, it is impossible to refrain from presenting items before a particular target item. One study has practically done so by presenting only one trial per subject (Baddeley & Scott, 1971), although one can question whether that study still imposed retroactive interference. The question, then, is typically how to *measure* proactive interference. The assumption of non-decay theorists has been that, if all types of interference could be taken into account, there would be no more variance left to be explained by decay. It is this issue that we will re-examine in the present paper.

3. Research Strategies for Assessing Decay

Given the strong bias that most of us have toward confirmation of our own theories, it makes a great deal of sense to try to counteract that bias by attempting to *disprove* one's working hypothesis (Platt, 1964). Robert Crowder previously adopted a viewpoint in which decay was important, inasmuch as he demonstrated aspects of forgetting in auditory memory that at first were explained according to a decaying auditory sensory memory trace (e.g., Crowder, 1982; Crowder & Morton, 1969). In this light, it has been deeply scientific of him and his colleagues to see whether they could account for all of the phenomena in the short-term memory literature without making use of the concept of decay, and to end up exploring and embracing concepts other than decay that could account for the data, thus attempting to disconfirm Crowder's own earlier conclusions.

Our laboratory more recently has operated from a framework in which decay (or, let us say, the absolute duration of the retention interval) has appeared to play a critical role. Several papers from our laboratory have provided evidence suggesting that decay could be an important principle despite the doubts that others have expressed (e.g., Cowan, Nugent, Elliott, & Geer, in press; Cowan, Wood, & Borne, 1994; Cowan, Wood et al., 1997; Cowan et al., 1992). Therefore, in emulation of Crowder's scientific approach, it behooves us to look hard for evidence *against* the principle of decay. It isn't very feasible to prove that something doesn't exist (in this case, that decay doesn't occur), but a way to go about this in practical terms would be to look hard for problems with the evidence that supposedly favors decay. That is the task that we take on in this chapter. It leads to somewhat different research than the tack of looking for evidence in favor of principles other than decay, and therefore complements the existing literature.

4. Decay or Proactive Interference?

New Evidence From a Two-Tone Comparison Task

Cowan, Saults, and Nugent (1997) presented pairs of 200-ms-long tones on every trial, wth a 1%, 2%, or 3% difference between the frequencies of the two tones. Twenty-eight subjects were tested and, on the basis of a pretest, each subject was assigned to the 1%, 2%, or 3% tone difference condition. This was done to achieve a relatively uniform, sensitive level of performance across subjects. The tone memory task was to decide whether the second tone was higher or lower in pitch than the first tone in a pair. Two time intervals were varied: the time between tones within a pair on a trial or inter-stimulus interval (ISI), which could be 1.5, 3, 6, or 12 s, and the time between pairs of tones or inter-pair interval (IPI), which could be 3, 6, 12, or 24 s. Each possible combination of these two intervals occurred equally often. Following pretest and practice trials, there were 256 tone comparison trials per subject. Each trial included the following phases: (a) a yellow background monitor display during which a silent distracting task was carried out (in which the left or right arrow keys were pressed in a non-repeating sequence to signify the directions of movement of a small icon on the screen), starting as soon as the response to the previous trial was completed and continuing for the duration of the IPI; (b) a blue background display with the word “listen” printed in a large font, beginning 250 ms before the first tone in a pair and continuing throughout the ISI and during the presentation of the second tone in the pair; and (c) a green background with a response display, during which the subject could use the arrow keys to indicate that the second tone was “higher” or “lower” in pitch than the first. This display ended when the response was made (with a 2-s limit for responses). Absence of a response within the time limit counted as incorrect. After the fixed, 2-s response period, the subject returned immediately to the silent task.

Performance was examined not only as a function of the ISI, but also as a function of the ratio between the immediately preceding IPI and the current ISI. The results are shown in Figure 1. Each data line reflects data from one particular IPI:ISI ratio. If one compares vertically the data points present at any one ISI, the effect of the IPI:ISI ratio can be seen in that points on different ratio lines differ from one another systematically. If one looks at the function across ISIs shown by any one ratio line, this indicates the effect of ISI with the IPI:ISI ratio held constant. In an ANOVA of the data with IPI and ISI as factors, both main effects were significant ($p < .02$ or smaller) but the interaction was not. In separate 1-way ANOVAs of the data restricted to a single IPI:ISI ratio per ANOVA, there were still significant effects of the ISI for the 2:1 ratio and the 1:1 ratio ($p < .04$ or better), the only two ratios that included at least three data means and included data at the 12-s ISI, where the strongest forgetting occurred. These results show that although there appear to be effects of distinctiveness (the IPI:ISI ratio effects), they cannot totally account for the effects of ISI, given that ISI effects are found even with the ratio held constant. This appeared to provide strong support for a theory that included memory decay across ISIs.

Gordon Brown (personal communication, November, 1998) emphasized to us something that we had vaguely thought, but had not previously been sufficiently motivated to pursue: That the ratio we measured captured only part of the distinctiveness mechanism. In order to capture the entire mechanism, we would have to measure back in time at least to the beginning of the experiment, to find out how distinct an item was from all previous items in the experiment. We did not track the stimulus lags back that far because there would be no clear way to analyze the information. However, we did what we could. We had recorded not only the IPI preceding a stimulus, but also the ISI within the previous tone pair and the IPI preceding that. In other words, for a particular Trial n, we knew an IPI(n-1) / ISI(n-1) / IPI(n) / ISI(n) timing sequence. To clarify this notation, ISI(n-1) is the time between tones in the previous trial and ISI(n) is the time between tones in the current trial. IPI(n-1) and IPI(n) are the periods preceding these two trials, respectively. This elaborate categorization of trials results in 256 possible sequences, with an occurrence randomly determined rather than counterbalanced. On the average, each of these 256 possible sequences occurred in only one trial per subject, and some subjects had no data for some of these sequences.

We nevertheless found the data, pooled across subjects, to be interesting. Out of 256 trial types contributing to 64 forgetting functions, we narrowed our approach by asking the following question. If we look at the trials in which the distinctiveness of the current trial's tones was as high as possible, based on the IPI(n-1), ISI(n-1), and IPI(n) intervals, would we still find forgetting as a function of the ISI(n) interval? Before this question can be addressed, we must reach an operational definition of "distinctiveness."

Two different distinctiveness theories seemed plausible. In a *pair distinctiveness* theory, what is important is how tones are grouped. For example, if the first tone in Trial n is closer in time to the second tone in the previous trial (Trial n-1) than it is to the second tone in the current trial (Trial n), then perceptual grouping may lead to the wrong comparison. According to this theory, the best distinctiveness and least forgetting across ISI(n) should occur when both IPIs are long but when the preceding ISI, namely ISI(n-1), is short. Under that circumstance, it is least likely that the tones from Trial n-1 will be incorrectly separated from one another in the perceptual grouping process and the second one incorrectly grouped with the tones of the current trial, Trial n.

In a *tone distinctiveness* theory, the grouping of tones is not considered. It is simply assumed that it is the previous tones, and not their grouping, that interfere with memory for the tones of the current trial. According to this theory, the best distinctiveness and least forgetting across ISI(n) should occur when IPI(n-1), ISI(n-1), and IPI(n) all are long, so that the tones of previous trials are as far from the tones of the current trial as possible.

These theories can be shown graphically as follows. Consider three trials in a row with tones A1 and A2 on Trial A, B1 and B2 on Trial B, and C1 and C2 on trial C. Then the distinctiveness of the tones on Trial C can be classified as follows with respect to the prior intervals, with more rapid forgetting across the C1 - C2 interval when distinctiveness is low. High distinctiveness on Trial C occurs, according to the pair distinctiveness theory, when tones from a trial are grouped together well, as illustrated below:

...A2.................B1..B2.................C1..., etc.

Low distinctiveness on Trial C occurs, according to the pair distinctiveness theory, when the tones are temporally grouped across trials, not within a trial:

...A2..B1.................B2..C1..., etc.

High distinctiveness on Trial C occurs, according to the tone distinctiveness theory, when prior tones are maximally far from C1 in time, as follows:

...A2.................B1.................B2.................C1..., etc.

Finally, low distinctiveness on Trial C occurs, according to the tone distinctiveness theory, when prior tones are temporally close to C1:

...A2..B1..B2..C1..., etc.

Some relevant results can be seen in Figures 2 - 4. The top panel of Figure 2 shows data for trials with the highest level of distinctiveness according to the pair distinctiveness theory. The error bars show standard errors of the mean; no ordinary inferential statistics can be run given that pooled data were used and the contribution of particular subjects differed across ISIs. There appears to have been forgetting across ISIs even under these high distinctiveness conditions. However, it was not a gradual, regular sort of forgetting. Instead, memory was maintained across the first three ISIs and apparently plummeted in the longest ISI. This is not what would be expected according to a decay principle and instead could reflect a higher-level type of distinctiveness that we haven't been able to define (perhaps related to attentional vigilance given the length of this longest ISI). The bottom panel of Figure 2 serves as a manipulation check, showing that there was memory loss in the trials in which distinctiveness was as low as possible according to this theory.

One way to quantify memory loss is to accept the shortest available ISI as a pre-loss baseline and to express the amount of loss as a percentage of the possible amount of loss between the shortest ISI and the longest. For the top panel of Figure 2, the loss across retention intervals was .88 - .66 = .28. Because chance level is .50 in this task, the possible loss was .88 - .50 = .38 and the percentage of the possible was 100 x (.28 / .38) = 74%. In the bottom panel of the figure, forgetting was 50% of the possible amount.

The top panel of Figure 3 shows the data for the highest level of distinctiveness according to the tone distinctiveness theory. Here there is no tangible evidence of decay (0% of possible). The bottom panel of the figure shows the lowest level of distinctiveness, in which observable memory loss (56% of possible) is again evident.

The top panel of Figure 3 suggests that there may be no memory loss when the tones of the current trial are as distinct from previous tones as possible. However, we also found that even a small departure from the maximal distinctiveness conditions already allowed observable forgetting. Two examples of this appear in Figure 4. For the top panel of Figure 4, we attempted to obtain more stable means by collapsing data across levels of IPI(n-1) in order to produce 16 forgetting functions rather than 64. It was possible to get means for these 16 forgetting functions on an individual-subject basis and then average across these means. The top panel of Figure 4 shows the forgetting curve, out of 16, with the highest distinctiveness according to the tone distinctiveness theory. One can see that there was observable forgetting (31% of possible). We saw forgetting in all but 2 of the 16 functions, and we cannot find a principled way to account for the two that showed no forgetting: trials with ISI(n-1) = 1.5 s and IPI(n) = 6 s; and trials with ISI(n-1) = 6 s and IPI(n) = 12 s.

The bottom panel of Figure 4 returns to the more detailed data set involving 64 forgetting functions and shows the ones in which just one interval was one value removed from what would be needed for maximal distinctiveness as shown in the top panel of Figure 3. This bottom panel of Figure 4 shows once more that, when the amount of distinctiveness is just a little bit lower than our maximum, there is forgetting (14%, 42%, and 34% of the possible forgetting for the top, middle, and bottom lines on the legend).

There are at least two possible interpretations of all of these results. (1) The data may suggest that a variety of conditions can cause the tones that are to be compared to lose distinctiveness, but that conditions have to be just right (as in the top panel of Figure 3) in order to provide sufficient distinctiveness to prevent forgetting across the ISIs between the tones to be compared. Alternatively, (2) the absence of observable forgetting in the top panel of Figure 3 may reflect testing error given the random way in which these trials were distributed across subjects. Either way, the present data provide no clear evidence for the importance of the absolute amount of time in recall; that is, for decay. All of the forgetting that we see could have to do with the loss of distinctiveness. This is true also of the vast two-stimulus comparison literature, which basically has ignored distinctiveness issues. This preliminary investigation should be taken as an impetus for more systematic studies of forgetting with proactive, concurrent, and retroactive interference all minimized.

5. Concluding Observations

We have failed to find clear evidence of decay in a situation that has often been viewed as one of the simplest paradigm cases for decay, namely in two-tone comparisons (Cowan, 1984). Nevertheless, one caution is in order. It is possible that all of the studies that have examined factors of distinctiveness, including this one, have allowed some rehearsal of the stimuli. Some studies of memory for unattended stimuli have attempted to eliminate retroactive interference (e.g., Cowan et al., 1990; Eriksen & Johnson, 1964) but have not manipulated factors that affect distinctiveness. Possibly, those studies will show forgetting that will not go away no matter how distinct the stimuli are. Thus, we have not yet ruled out decay as a memory mechanism, but have not found clear evidence for it, either.

The fact that this difficulty has remained unnoticed until now in such a vast literature can be taken as a caution for other procedures, also. In particular, one must look very carefully to make sure that *retroactive* interference does not sneak in where it is thought not to be. One illustration of this concern occurs in the findings of Cowan, Kanevsky, Nugent, Saults and Hismjatullina (in preparation). They attempted to study the effects of response delay on performance in a situation in which rehearsal would be blocked without extra interference being introduced. Subjects saw lists of seven digits at irregular intervals. The first three inter-digit intervals could be either 0.5 s or 2.0 s, as could the second three inter-digit intervals. This resulted in lists with four varieties of stimulus timing: short-short, short-long, long-short, and long-long (though there were other, filler trials that were not analyzed). Half of the subjects were simply to recall the digits in each list aloud, at any pace that was preferred; whereas the remaining subjects were to recall the list aloud using the same timing that was present in the stimulus list. We hoped that subjects who were to repeat the timing would not be able to rehearse (at least when the timing was irregular) because rehearsal would interfere with memory of the timing. We expected that, in the absence of rehearsal for subjects in this group, a long lag between digits in the spoken response would allow more forgetting of the remaining digits.

Initially, we were delighted because the results were as predicted. For the subjects who were to recall the list at any speed that they wished, there was little difference between the presentation timing conditions. In contrast, for the subjects who were to recall the list in the presented timing, performance for the long-short trials was markedly inferior to performance in the other three timing conditions. We supposed that memory for not-yet-recalled digits was lost during long inter-digit intervals early in the response. Our opinion changed, however, after we conducted a detailed analysis of the timing of responses. Although the onset-to-onset intervals in the responses were exactly as we had expected, subjects did not produce long intervals totally by interleaving silent periods between words as we had hoped. The silent periods did vary as was hoped but there also were significant differences in the durations of *digits* in the responses for different timing conditions. When a subject was supposed to produce a word followed by a long delay, the mean duration of the word itself within the response was longer than when a subject was supposed to produce a word followed by a short delay. Moreover, a regression analysis indicated that the duration of words in the responses accounted for performance levels better than the duration of silent periods in the responses. (This, by the way, is different from our studies of individual differences in list recall, in which it has been the silent periods between words rather than the words themselves that correlate best with recall; see for example Cowan et al., 1998; Hulme, Newton, Cowan, Stuart, & Brown, 1999). Retroactive interference rather than decay could account for these new results.

Memory decay could be viewed as a hypothesis that is vague because it fails to state the actual cause of forgetting. Cowan, Saults, and Nugent (1997) articulated four slightly different possible definitions of memory decay. However, the issue that is most basic is whether the absolute amount of time, and not just the relative timing of stimuli, is relevant for recall. We suggest that it is now important to search for possible effects of the absolute amount of time on forgetting of unattended as well as attended stimuli. In the realm of attended stimuli, no clear evidence of decay has emerged in, lo, these many years.

6. Epilogue: A Decadent Song

As a light-hearted tribute to Robert Crowder's theoretical interests, N. Cowan approximated the singing of the following song at Crowder's Festschrift, just before the introduction of the final conference speaker, Robert Bjork.

To the tune of "New York, New York":

I'm tracking my lags / I'm leaving Decay / I want to be a part of it -- / New Bjork* New Bjork! / If I can't find Decay here / I can't find it anywhere! / It's up to you / New Bjork, New Bjork!

* See Bjork & Whitten (1974).

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Author Notes

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Figure Captions

Figure 1. After Cowan, Saults, and Nugent (1997). Proportion correct tone comparisons as a function of the interstimulus interval (ISI) between tones in a pair (x axis) and the ratio between the inter-pair interval (IPI) and ISI (graph parameter).

Figure 2. Proportion correct from the data set reported by Cowan, Saults, and Nugent (1997), shown here for trials in which the conditions for tone memory were best (top panel) or worst (bottom panel) according to the *pair distinctiveness theory*. Data are pooled across individuals. Error bars reflect the standard error of the mean.

Figure 3. Proportion correct from the data set reported by Cowan Saults, and Nugent (1997), shown here for trials in which the conditions for tone memory were best (top panel) or worst (bottom panel) according to the *tone distinctiveness theory*. Data are pooled across individuals. Error bars reflect the standard error of the mean.

Figure 4. Proportion correct from the data set reported by Cowan Saults, and Nugent (1997), shown here for trials in which the conditions for tone memory were relatively good, but not best, according to the tone distinctiveness theory. *Top panel*: Grand means based on means from each subject, collapsed across the preceding trial's IPI, for the longest possible values of the preceding trial's ISI and the current trial's IPI. *Bottom panel*: trials in which one of three preceding intervals (preceding trial's IPI, preceding trial's ISI, and current trial's IPI) is the second-longest possible and the other two intervals are as long as possible according to the experimental design. Error bars reflect the standard error of the mean.

Figure 1

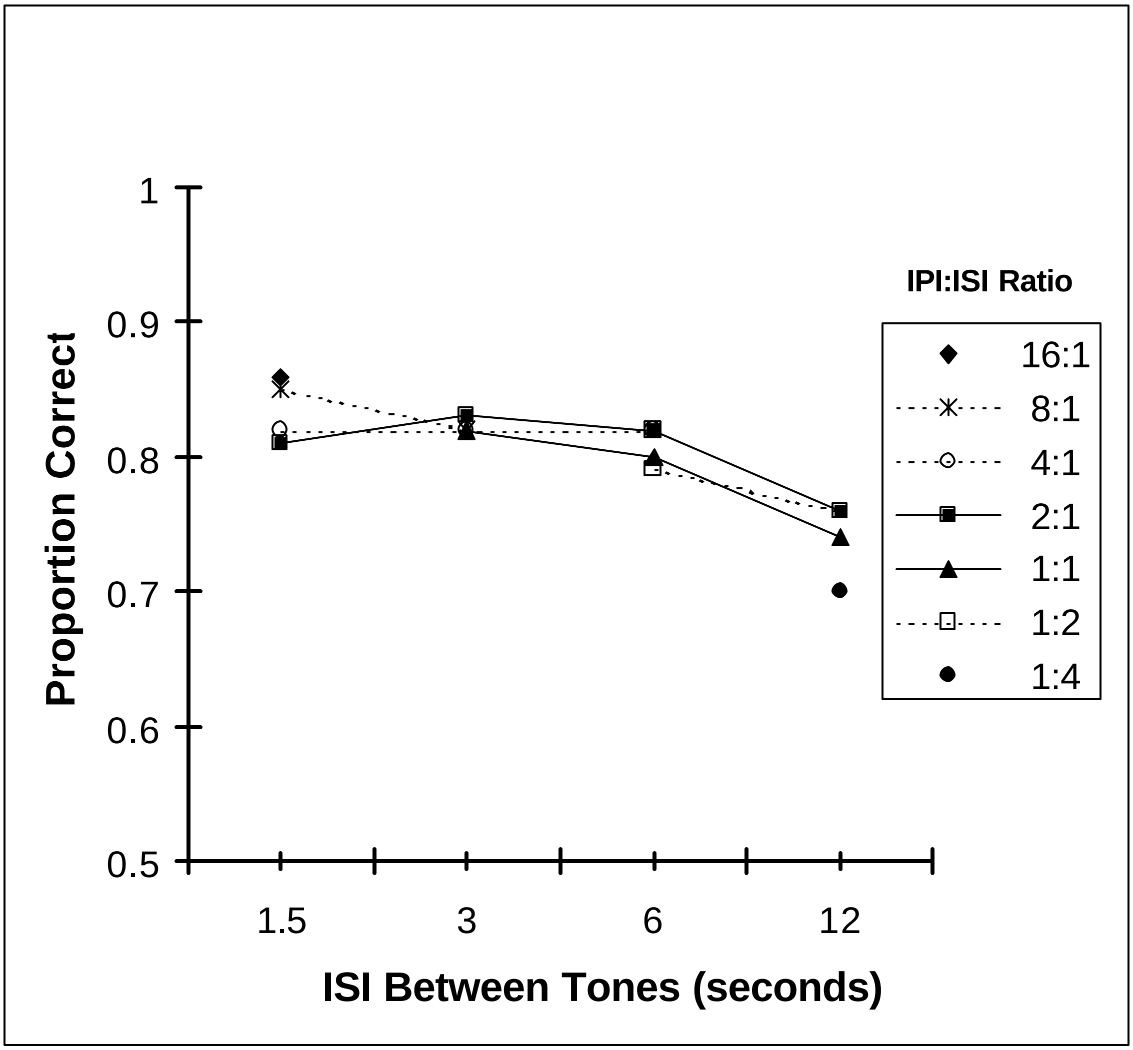
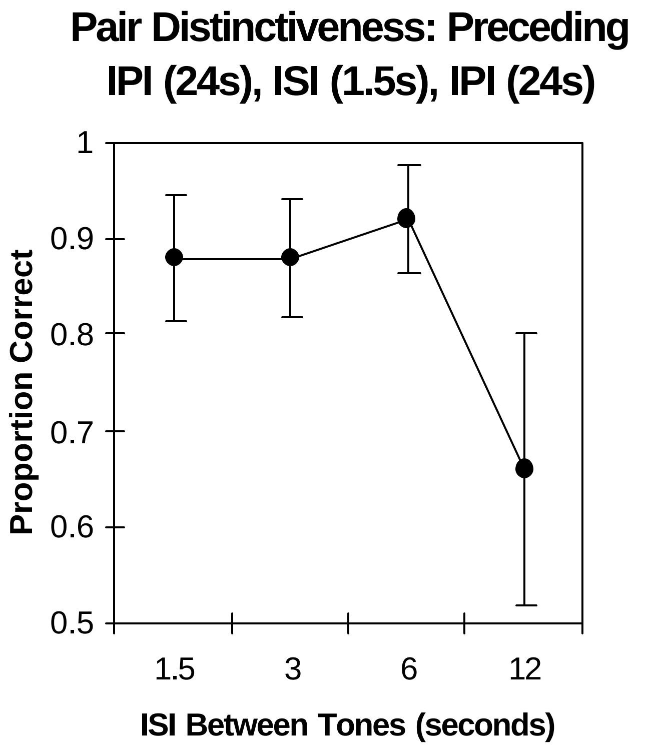

1
0.9
0.8
0.7
0.6
0.5
Proportion Correct
1.5
3
6
12
ISI Between Tones (seconds)
IPI:ISI Ratio
16:1
8:1
4:1
2:1
1:1
1:2
1:4

Figure 2


Pair Distinctiveness: Preceding
IPI (24s), ISI (1.5s), IPI (24s)
Proportion Correct
1
0.9
0.8
0.7
0.6
0.5
1.5
3
6
12
ISI Between Tones (seconds)

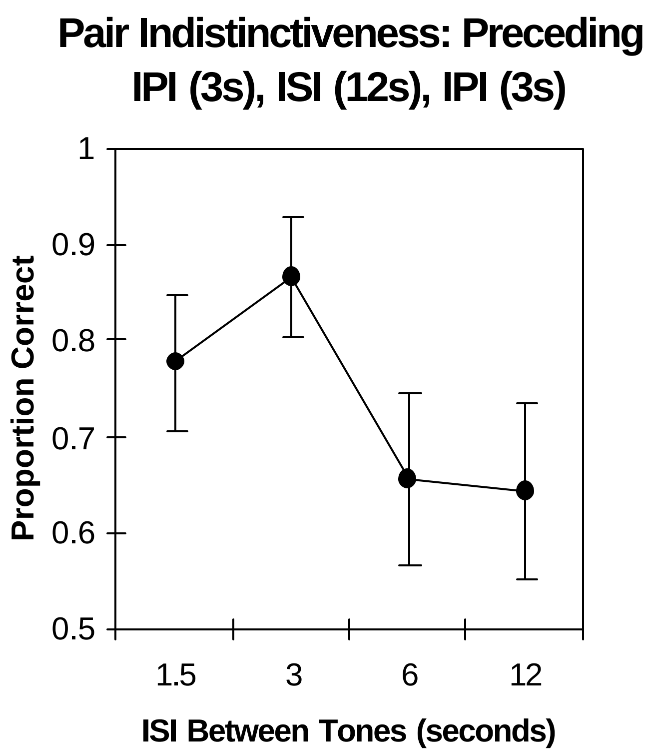
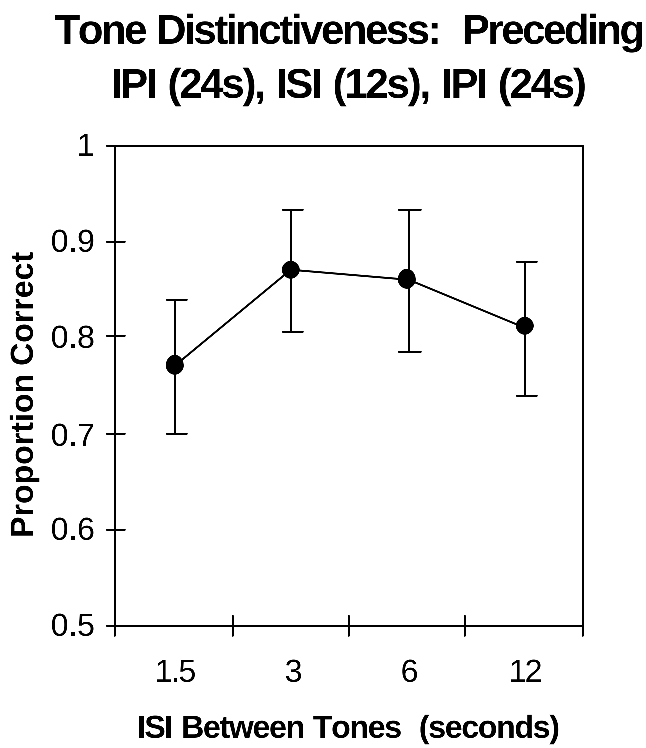

Pair Indistinctiveness: Preceding
IPI (3s), ISI (12s), IPI (3s)
Proportion Correct
1
0.9
0.8
0.7
0.6
0.5
1.5
3
6
12
ISI Between Tones (seconds)

Figure 3


Tone Distinctiveness: Preceding
IPI (24s), ISI (12s), IPI (24s)
1
0.9
0.8
0.7
0.6
0.5
Proportion Correct
1.5
3
6
12
ISI Between Tones (seconds)

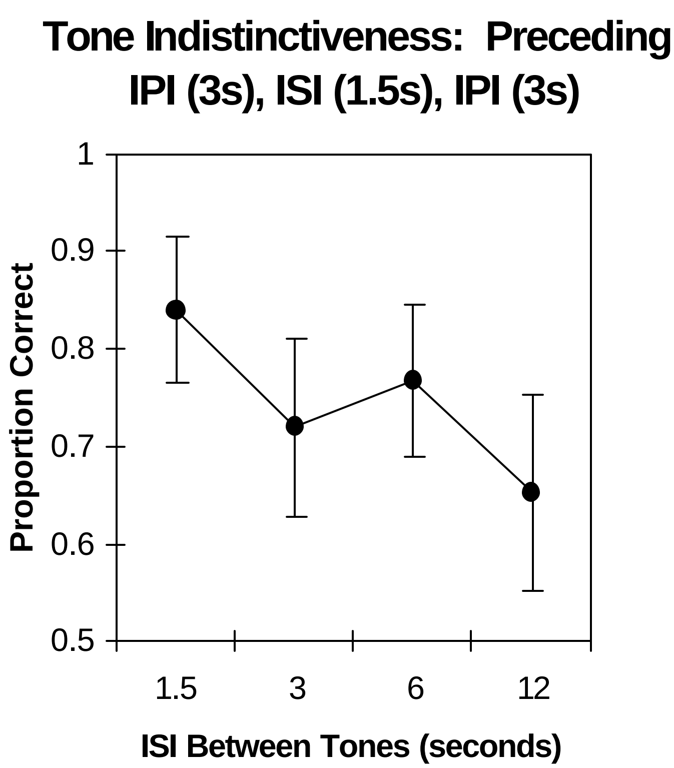
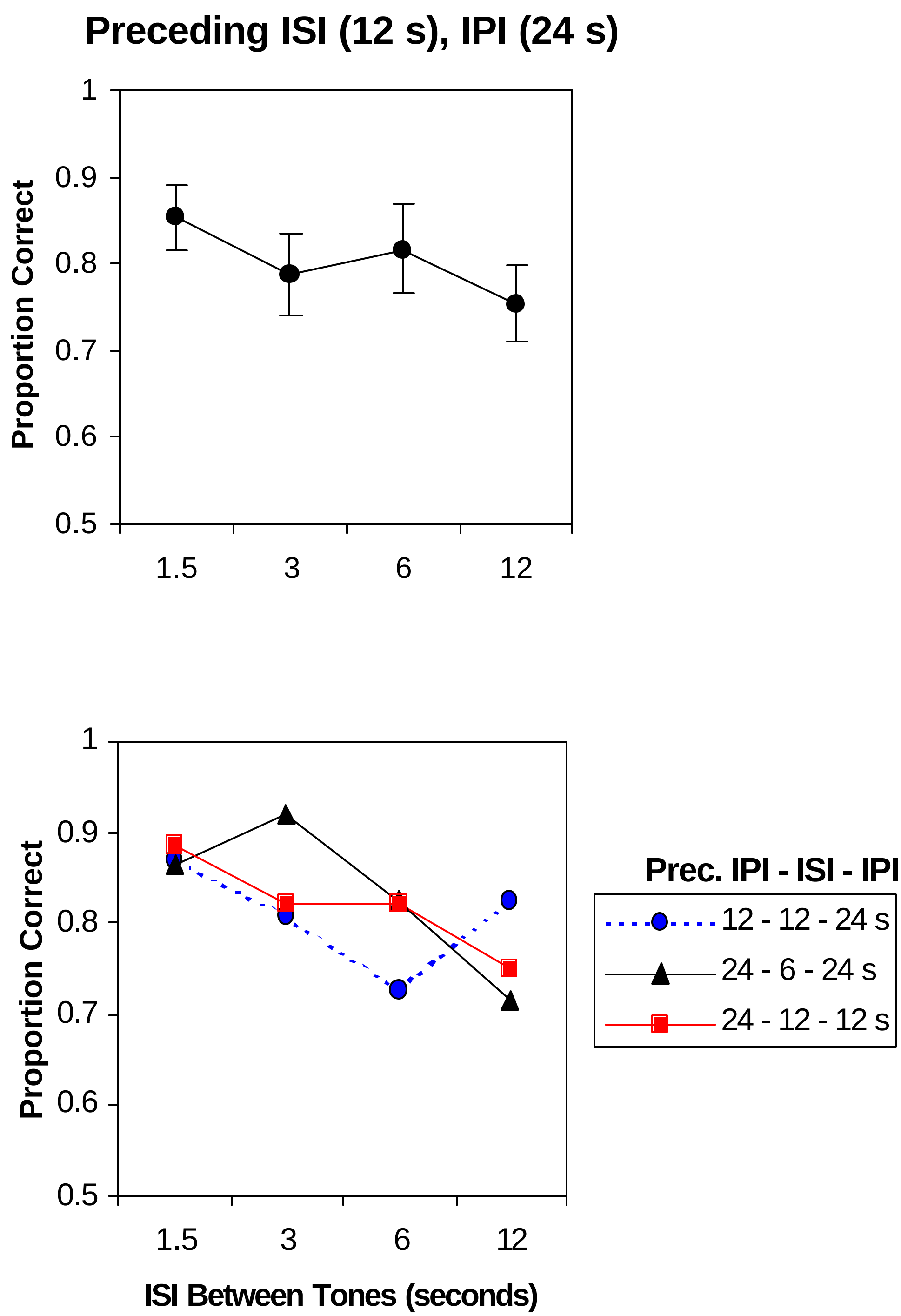

Tone Indistinctiveness: Preceding
IPI (3s), ISI (1.5s), IPI (3s)
1
0.9
0.8
0.7
0.6
0.5
Proportion Correct
1.5
3
6
12
ISI Between Tones (seconds)

Figure 4



Preceding ISI (12 s), IPI (24 s)
Proportion Correct
1
0.9
0.8
0.7
0.6
0.5
1.5
3
6
12
Prec. IPI - ISI - IPI
12 - 12 - 24 s
24 - 6 - 24 s
24 - 12 - 12 s
ISI Between Tones (seconds)