# Auditory target identification in a visual search task

by

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I hereby declare that I am the sole author of this thesis. This is a true copy of the thesis, including any required final revisions, as accepted by my examiners.

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# Abstract

Previous research has shown that simultaneous auditory identification of the target in a visual search task can lead to more efficient (i.e. 'flatter') search functions (Spivey et al., 2001). Experiment 1 replicates the paradigm of Spivey et al., providing subjects with auditory identification of the search target either before (*Consecutive* condition) or simultaneously with (*Concurrent* condition) the onset of the search task. RT x Set Size slopes in the *Concurrent* condition are approximately 1/2 as steep as those in the *Consecutive* condition. Experiment 2 employs a distractor ratio manipulation to test the notion that subjects are using the simultaneous auditory target identification to 'parse' the search set by colour, thus reducing the search set by 1/2. The results of Experiment 2 do not support the notion that subjects are parsing the search set by colour. Experiment 3 addresses the same question as Experiment 2, but obtains the desired distractor ratios by holding the amount of relevantly-coloured items constant while letting overall set size vary. Unlike Experiment 2, Experiment 3 supports the interpretation that subjects are using the auditory target identification to parse the search set.

# Acknowledgements

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## Introduction

Over the past three decades a great volume of work has been published, sketching various theoretical accounts of the human visual system. Essentially, our task has been to elucidate the process by which patterns of gradient light hitting the retina are transformed into conscious percepts, creating a solid visual world. "Bottom-up" properties of the external world are combined with "top-down" processes originating in our cognitive machinery, and the result is our visual reality. The bulk of research in this area focuses, not surprisingly, on various manipulations of visual input. Yet, vision does not exist in a void. Quite the opposite; vision is just one element in a complex array of inputs that we use to understand the world around us. While the traditional practice of treating vision as a modular aspect of attention (i.e. functionally independent from other senses, like hearing) is still in fashion, an increasingly large body of evidence against this modular view is accumulating. The very nature of top-down processes demands that they are high-level, integrative, associative operations; as such, it is not surprising that they are shared across input modalities, and that information in one modality can constrain that in another.

A number of studies supporting this integrative view are present in the literature. For example, visual information regarding mouth shape can affect auditory speech perception (Massaro, 1997; McGurk & MacDonald, 1976). In contrast, Spivey, Tyler, Eberhard & Tannenhaus (2001) used a visual search task to demonstrate a case in which 7auditory information constrained visual behaviour. In the standard visual search paradigm, participants look through a set of distractors (e.g. red-vertical and green-horizontal bars) in search of a specific target (e.g. a red-vertical bar). Response times to locate the target (in milliseconds) generally demonstrate a positive linear function as the number of distracting items increases. Because half of the distractors share one feature with the target (e.g. colour) and the rest share another feature (e.g. orientation), this is termed a *conjunction search*.

Importantly, if the distractors differ from the target on only one dimension (e.g. a red vertical bar amongst a number of green vertical bars) the pattern is different. Here, response times are generally much less affected by increases in the number of distracting items. Because the target differs from the distractors on only one dimension, this is termed a *feature search*. Spivey et al. (2001) demonstrated that, when presented simultaneously with a standard conjunction search task and an auditory stimulus that identifies the search target (e.g. "Is there a red vertical?"), subjects showed a different response pattern than when the target was specified prior to the search. Specifically, in the simultaneous-onset condition participants showed a smaller RT increase as search set size increased. The slope of the search function in the simultaneous-onset condition was approximately half that of an equivalent standard visual search (i.e. sequential onset of target identification and search task). The authors concluded that subjects in the simultaneous-onset condition may use the auditory target identification to 'parse' the search set, ignoring distractors which are not relevant to the task (i.e. searching only the 'red' items to find the 'red vertical' one), thus producing feature-search-like results. Because the efficiency advantage is obtained when the Auditory Target Identification is presented concurrently with the search display, we will refer to this as the *Concurrency Effect.*

The notion that efficiency in a visual search task can be experimentally manipulated has support in the literature. Watson and Humphreys (1997) demonstrated what they call the "Gap Effect". The "Gap" manipulation is basically a conjunction search in which one half of the distractor set, comprising half of the conjunction (e.g. all of the blue 'H's, where the total distractor set includes blue 'H's and yellow 'O's) was presented before the other. When this gap was present, participants were more efficient at reporting the presence or absence of the target. Given this equal (50/50) split in the distractor set, the slopes in the Gap condition were approximately 1/2 those in the control condition. The authors concluded that the temporal offset of the distractors allowed the participant to ignore the irrelevant items through a process of 'visual marking'. This allowed the participant to perform a search that was, in effect, a feature search. By this interpretation, the Gap manipulation is functionally equivalent to the auditory target identification used in Spivey et al. (2001).

The goal of the present studies is to further investigate the effect of simultaneous auditory target identification on visual search efficiency. Specifically, I investigate the claim that subjects are able to use the auditory information to parse the search set, thus searching through only the relevant half of the distractor set. The first step is to replicate Spivey et al.'s original findings.

## Experiment 1

Method

*Participants.* Twelve undergraduate students from the cognition pool at the University of Waterloo participated for pay ($6 CDN). All participants reported normal or corrected-to-normal visual acuity, and normal colour vision.

*Stimuli and stimulus presentation.* Participants were presented with randomly arranged arrays of red and green, vertical and horizontal bars. Each bar subtended approximately 3 by .5 degrees visual angle. The coloured bars were equiluminant. Auditory target identification was provided using *.wav* format voice files (e.g. "Is there a RED VERTICAL?") played through the computer speakers. All stimuli were presented on a 17-inch CRT computer monitor, controlled by an IBM PC-compatible computer using a standard VGA graphics card. Stimuli presentation was controlled by the Micro Experimental Laboratory (MEL) software (Schneider, 1988). An example of the stimulus display is given in Figure 1.

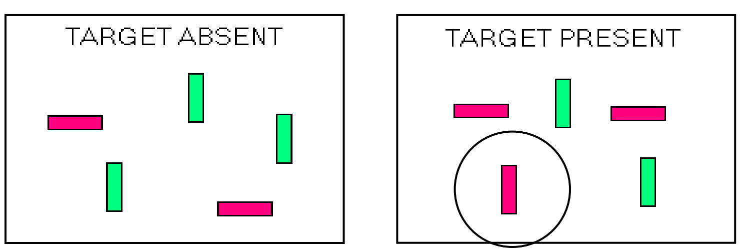


**Figure 1:** Target Present and Target Absent displays

*Design and Procedure:* Experiment 1 had three main manipulations: Set Size, Target Presence/Absence, and Onset Type. For each trial, the Set Size was 5, 10, 15 or

20 items. For half of the trials the target was present; for the other half, absent. The third experimental manipulation, Onset Type, was either Consecutive or Concurrent. On Consecutive trials, participants received the complete target identification information before the search commenced (see the left panel of Figure 2). For Concurrent trials, the onset of the search grid coincided exactly with the verbal target identification (see the right panel of Figure 2). All manipulations were within-subject. Onset-type was blocked, with order counterbalanced across participants; all other variables were randomized. Each participant completed 280 trials, which took approximately 25 minutes.

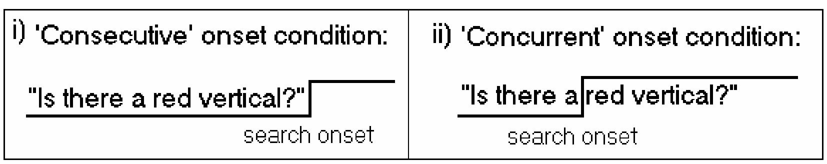


**Figure 2:** Consecutive and Concurrent onset conditions

Each trial began with a fixation cross. After 500ms, this was replaced by the search grid, which stayed on until either the participant responded, or 2 seconds elapsed. On half of the trials, the auditory target identification occurred simultaneously with the onset of the search grid (Concurrent condition). On the other half of the trials, the search display was not shown until the auditory target identification was given (Consecutive condition). Subjects were asked to indicate whether the target was present or absent using the [Z] and [?] keys (counterbalanced across subjects) on the computer keyboard. Response time and accuracy data were collected, with RT beginning from the onset of the search grid. After the participant responded an ITI of 500 ms elapsed, after which the next trial commenced with a fixation cross.

Results:

RT analyses were performed for trials in which subjects responded correctly. 2.3% of correct RTs were considered to be outliers, based on a recursive trimming procedure in which outliers were identified within each cell for each subject, by reference to the sample size in that cell (Van Selst & Jolicoeur, 1994). The remaining RT data were subjected to a 2 x 2 x 4 (Onset Type x Target Present / Absent x Set Size) Repeated Measures ANOVA. A parallel analysis was conducted on the error data. Figure 3 plots the RT x Set-Size functions for Target Present and Target Absent trials for each level of Onset Type (Concurrent vs. Consecutive).

When the target was absent, subjects were slower to respond than when the target was present, $F(1,11) = 19.23$, $MS_e = 39{,}345.69$, $p = .001$. Likewise, as Set Size increased from 5 to 20 items, subjects took longer to respond, $F(3,33) = 59.32$, $MS_e = 9861.73$, $p = .000$. The analysis also revealed a significant Target Presence / Absence x Set Size interaction, $F(3,33) = 6.24$, $MS_e = 9659.16$, $p = .002$, indicating that response times were more affected by increasing Set Size when the target was absent than when it was present.

A significant main effect of Onset Type was found, $F(1,11) = 44.28$, $MS_e = 164{,}664.36$, $p = .000$, indicating that responses in the Concurrent condition were slower than those in the Consecutive condition. We attribute this to the fact that, in the Concurrent condition, the RT clock begins at the onset of the auditory target identification, before the subject has received the entire identification phrase (e.g. "is there a RED VERTICAL?"). Thus, the subject cannot respond with full confidence until the auditory target identification phrase is complete. The central question here is whether there was a significant interaction between the effects of Onset Type and Set Size; that is, whether the subjects' search functions were less affected by increases in set size in the Concurrent Onset condition than in the Consecutive Onset condition. This predicted interaction was significant at $F(3,33) = 2.85$, $MS_e = 15{,}910.54$, $p = .052$. Performing an Onset Type x Set Size linear contrast, this interaction was significant at $F(1,11) = 7.18$, $MS_e = 17{,}165.63$, $p = .021$, indicating that the effect is highly linear.

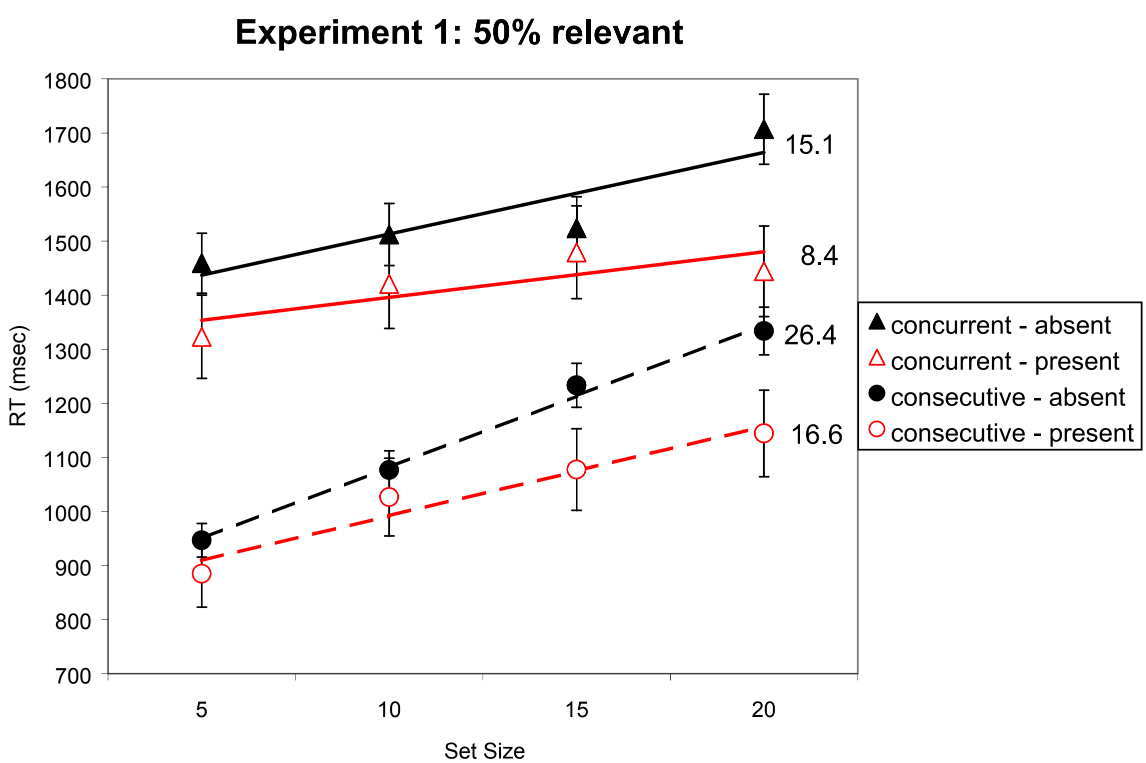


**Figure 3**:
Experiment 1: mean correct RT x Set Size search slopes as a function of Onset Type (Consecutive vs Concurrent) and Target Presence / Absence.

Error Analysis

The top of Table 1 presents the proportion of incorrect responses in Experiment 1. Whereas the proportion of incorrect responses did not differ across levels of Onset Type, $F < 1$, or Set Size, $F < 1$, the proportion of incorrect responses was significantly greater for Target Present trials than for Target Absent trials, $F(1,11) = 5.27$, $MS_e = 2.00$, $p = .042$. This pattern, combined with the above finding that Target Absent trials were significantly slower than Target Present trials, suggests a speed/accuracy trade off between Target Present and Target Absent trials. Because the critical Onset Type x Set Size interaction reported above is not contingent on the difference between target present and target absent trials, the possibility of a speed/accuracy trade-off is not a factor in our interpretation of the results.

The error data also showed a significant 3-way interaction between Target Present / Absent x Onset Type x Set Size, $F(3,33) = 2.98$, $MS_e = .55$, $p = .045$, in which the error differences across Target Present / Absent were modulated by both Set Size and Onset Type. Specifically, whereas the larger Set Sizes (i.e. 15, 20) demonstrated equivalent error rates across Onset Type for Target Present trials, for Target Absent trials the high Set Size values were different, with more errors in the Consecutive condition. Finally, there was a marginally significant Target Present / Absent x Set Size interaction, $F(3,33) = 2.76$, $MS_e = .53$, $p = .058$, in which the number of incorrect trials across levels of Set Size was greater when the target was present than when the target was absent. There were no other significant effects in the error data.

**Table 1**: Error rates across Onset Type and Set Size for Experiment 1, and Onset Type, Ratio Type, and Set Size for Experiments 2 and 3.

**Experiment 1**

| Onset Type | Target | Set Size 5 | 10 | 15 | 20 |
|---|---|---|---|---|---|
| Consecutive | Present | 0.06 | 0.07 | 0.07 | 0.09 |
| | Absent | 0.03 | 0.02 | 0.04 | 0.04 |
| Concurrent | Present | 0.05 | 0.04 | 0.05 | 0.09 |
| | Absent | 0.02 | 0.07 | 0.04 | 0.02 |

**Experiment 2**

| Ratio | Onset Type | Target | Set Size 6 | 12 | 18 | 24 |
|---|---|---|---|---|---|---|
| 33 | Consecutive | Absent | 0.05 | 0.07 | 0.08 | 0.14 |
| | | Present | 0.09 | 0.06 | 0.04 | 0.03 |
| | Concurrent | Absent | 0.05 | 0.03 | 0.07 | 0.08 |
| | | Present | 0.05 | 0.06 | 0.03 | 0.03 |
| 66 | Consecutive | Absent | 0.07 | 0.12 | 0.08 | 0.09 |
| | | Present | 0.02 | 0.03 | 0.01 | 0.03 |
| | Concurrent | Absent | 0.05 | 0.07 | 0.14 | 0.13 |
| | | Present | 0.04 | 0.02 | 0.03 | 0.01 |

**Experiment 3**

| Ratio | Onset Type | Target | Set Size 9 | 18 | 27 | 36 |
|---|---|---|---|---|---|---|
| 33 | Consecutive | Present | 0.05 | 0.07 | 0.10 | 0.16 |
| | | Absent | 0.05 | 0.04 | 0.01 | 0.02 |
| | Concurrent | Present | 0.04 | 0.08 | 0.02 | 0.12 |
| | | Absent | 0.03 | 0.04 | 0.03 | 0.01 |
| | | | Set Size 4.5 | 9 | 13.5 | 19 |
| 66 | Consecutive | Present | 0.02 | 0.06 | 0.10 | 0.08 |
| | | Absent | 0.02 | 0.02 | 0.03 | 0.03 |
| | Concurrent | Present | 0.01 | 0.01 | 0.07 | 0.06 |
| | | Absent | 0.01 | 0.02 | 0.02 | 0.03 |

Discussion

Experiment 1 provided a successful replication of the Concurrency effect reported by Spivey et al. (2001). As display sizes in the Consecutive condition increased from 5 to 20 items, RTs increased at a rate of 16.6 ms per item for Target Present trials, and 26.4

ms per item for Target Absent trials. In contrast, RTs in the Concurrent condition increased at a rate of 8.4 ms per item and 15.1 ms per item for Target Present and Target Absent conditions, respectively. To determine the efficiency advantage achieved in the Concurrent condition, we divided the slopes in the Concurrent condition by those in the Consecutive condition. This gives us 8.4 / 16.6 = 50.6% for target present trials and 15.1 / 26.4 = 57% for target absent trials, indicating that slopes in the Concurrent condition are 50.6% and 57% as steep as those in the Consecutive condition, for target present and target absent trials, respectively. In comparison, the data of Spivey et al. (2001) show that Concurrent slopes are 7.7 / 19.8 = 39% (target present) and 22.7 / 31.4 = 72% (target absent) as steep as slopes in the Consecutive condition. Our data confirm that, with an evenly split distractor set, the simultaneous onset of visual and auditory information (Concurrent onset) does indeed produce search slopes that are approximately half as steep as those in the consecutive onset condition.

One possible explanation for this finding, offered by Spivey et al. (2001), is that the appearance of a colour (e.g. red) in the search grid, simultaneously with the auditory identification of the search target ("RED VERTICAL") allows the observer to selectively attend to those items that possess the relevant characteristic; in this case, the colour red. By this interpretation, the fact that the slopes in the concurrent condition are half as steep as those in the consecutive condition is directly linked to the fact that the relevantly-coloured distracting items make up exactly half of the display. The ability to 'parse out' the irrelevant items leaves the participant with a search display that is effectively half of the size. Consequently, search *rate* per item has not changed; just the number of items searched.

## Experiment 2

### The Distractor-Ratio Manipulation

One way to test the interpretation that participants are ignoring the irrelevantly-coloured items is to vary the ratio of relevant to irrelevant items, with the prediction that the efficiency advantage in the Concurrent condition should vary directly with the ratio of relevant to irrelevant distractors. That is, when there are proportionally fewer items in the relevantly-coloured portion of the distractor set, we would expect the efficiency advantage gained in the concurrent condition to be somewhat greater, as there are fewer items to search through. Likewise, when there are proportionally more items in the relevant search set, we would expect the efficiency advantage to be somewhat smaller. To this end, Experiment 2 included a Distractor-Ratio manipulation in which the ratio of relevant (same colour as target) to irrelevant (different colour than target) items was either 2:1 (66.6% to 33.3%), or inversely, 1:2 (33.3% to 66.6%). Hereafter, these conditions will be referred to as 66%-relevant and 33%-relevant, respectively.

### Method

*Participants.* Sixteen undergraduate students from the cognition subject pool at the University of Waterloo participated for pay ($6 CDN). All participants reported normal or corrected-to-normal visual acuity, and normal colour vision. None of the participants in this experiment had participated in Experiment 1.

*Design and Procedure.* Experiment 2 was similar to Experiment 1 in design, the main difference being the inclusion of the distractor-ratio manipulation described above. In Experiment 2 there were four manipulations: Set Size, Target Presence/Absence, Onset Type, and Distractor Ratio. In order to incorporate the Distractor Ratio manipulation described above, the set sizes were changed from 5, 10, 15 and 20 in Experiment 1, to 6, 12, 18 and 24 in Experiment 2, thus allowing for the 33/66 ratio split. See Table 2 for the distractor ratios & set sizes for Experiments 1, 2, and 3. The Target Present / Absent and the Onset Type variables were identical to those in Experiment 1. For the distractor ratio manipulation, in half of the trials the distracting items consisted of 33% relevant (i.e. same colour as target) items and 66% irrelevant (i.e. different colour than target) items. In the other half of the trials, the ratio was reversed, with 66% of the distracting items being the same colour as the target (e.g. red), and 33% of items being a different colour (e.g. green). All manipulations were within-subject, with onset-type blocked and order counterbalanced across participants. Each participant completed 320 trials, which took approximately 28 minutes. The procedure in Experiment 2 was identical to that in Experiment 1.

**Table 2:** Relevant to irrelevant distractor ratios: Experiments 1, 2, and 3

| **Experiment 1: 50 / 50** | | **Experiment 2: 66 / 33** | | | | **Experiment 3: 66 / 33** | | | |
|---|---|---|---|---|---|---|---|---|---|
| 50% relevant | | 66% relevant | | 33% relevant | | 66% relevant | | 33% relevant | |
| total | split | total | split | total | split | total | split | total | split |
| 5 | 2.5 / 2.5 | 6 | 4 / 2 | 6 | 2 / 4 | 4.5 | 3 / 1.5 | 12 | 3 / 9 |
| 10 | 5 / 5 | 12 | 8 / 4 | 12 | 4 / 8 | 9 | 6 / 3.0 | 18 | 6 / 12 |
| 15 | 7.5 / 7.5 | 18 | 12 / 6 | 18 | 6 / 12 | 13.5 | 9 / 4.5 | 27 | 9 / 18 |
| 20 | 10 / 10 | 24 | 16 / 8 | 24 | 8 / 16 | 18 | 12 / 6.0 | 36 | 12 / 24 |

Note: Set sizes with decimal places (e.g. 2.5) were implemented by presenting an equal number of larger and smaller trials (e.g. 2, 3), thus obtaining the desired average.

Results

RT analyses were performed for trials in which subjects correctly determined whether the target was present or absent. A recursive outlier analysis using the same procedure as in Experiment 1 removed 1.6% of the trials. The remaining RT data were subjected to a 2 x 2 x 2 x 4 (Onset Type x Ratio Type x Target Present / Absent x Set Size) Repeated Measures ANOVA. A parallel analysis was conducted on the error data. Figure 4 plots the Response-Time x Set-Size functions for Target Present and Target Absent trials across Onset Type (Concurrent vs. Consecutive) and Distractor Ratio (66% vs 33% relevant).

Target Absent responses were significantly slower than Target Present responses, $F(1,15) = 15.10$, $MS_e = 253{,}597.74$, $p = .001$. Likewise, as set sizes increased from 6 to 24, response times became slower, $F(3,45) = 49.25$, $MS_e = 41{,}786.88$, $p = .000$. There was a significant main effect of Onset Type, $F(1,15) = 54.54$, $MS_e = 203{,}478.12$, $p = .000$, indicating that response times in the Concurrent condition were slower than those in the Consecutive condition. Additionally, Experiment 2 produced a significant main effect of Ratio Type, in which response times in the 66%-relevant condition were significantly slower than those in the 33% relevant condition, $F(1,15) = 19.62$, $MS_e = 28{,}799.28$, $p = .000$. Ratio Type interacted with Target Present / Absent at $F(1,15) = 25.99$, $MS_e = 17{,}502.14$, $p = .000$, and with Onset Type, $F(1,15) = 12.60$, $MS_e = 7241.42$, $p = .003$. When auditory identification of the target was given simultaneously with the onset of the search grid (Concurrent Onset), subjects' response times were less affected by increases in set size than when auditory identification of the target was given prior to the onset of the search grid (Consecutive Onset), $F(3,45) = 4.23$, $MS_e = 24{,}830.81$, $p = .01$. Performing an Onset Type x Set Size linear contrast, this effect was significant at

$F(1,15) = 9.87$, $MS_e = 31{,}520.12$, $p = .007$. The 3-way Onset Type x Ratio Type x Set Size interaction was not significant, $F < 1$.

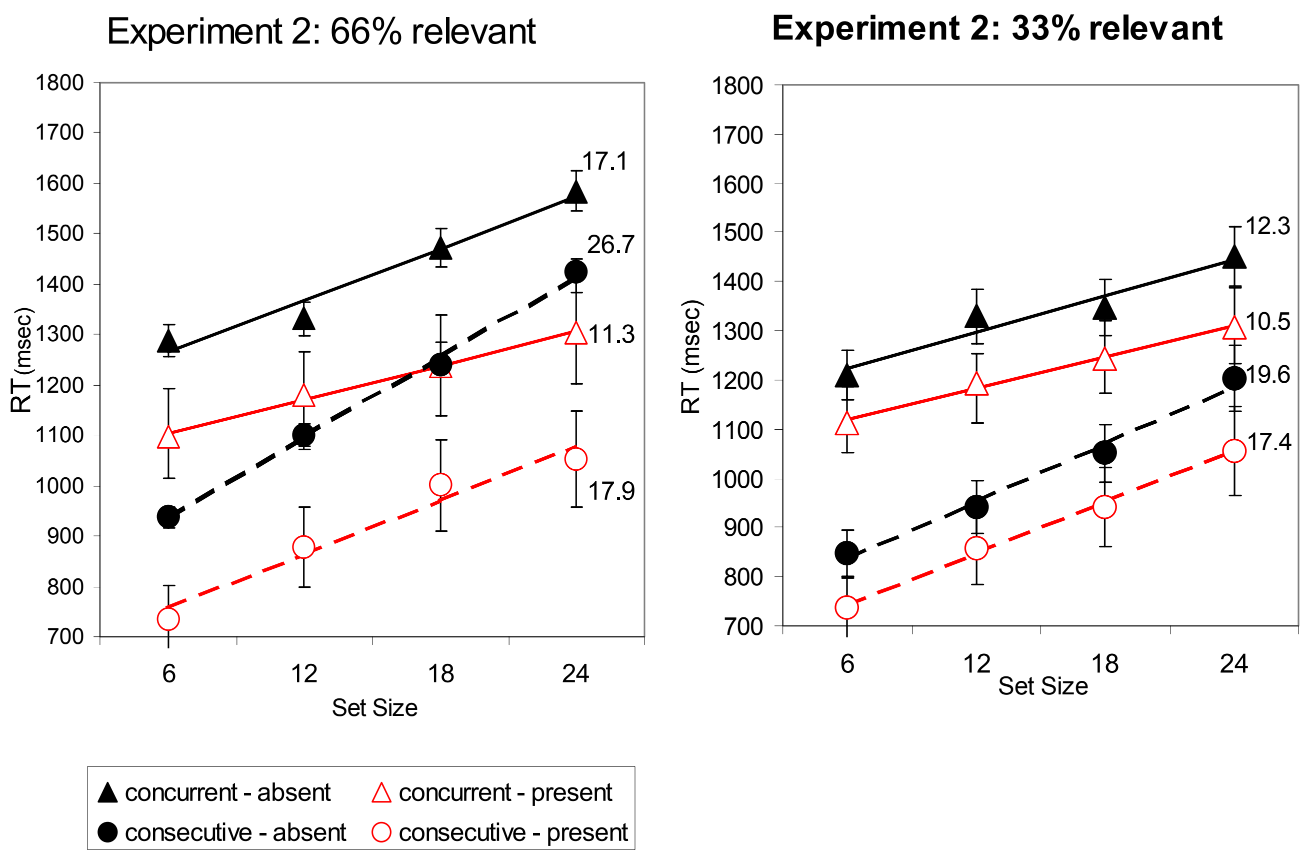


**Figure 4:**
Experiment 2: mean correct RT x Set Size search slopes as a function of Onset Type (Consecutive vs. Concurrent), Target Presence / Absence, and Distractor Ratio (66 vs. 33) across panels *a* and *b*.

Error Analysis

The proportion of incorrect responses did not differ across levels of Onset Type, $F < 1$, Set Size, $F(3,45) = 1.36$, $MS_e = .50$, $p = .268$, or Ratio Type, $F < 1$, but the proportion of incorrect responses was significantly greater for Target Present trials than for Target Absent trials, $F(1,15) = 22.25$, $MS_e = 1.18$, $p = .000$. This pattern, combined with the above finding that Target Absent trials were significantly slower than Target Present trials, again suggests a speed/accuracy trade off between Target Present and Target Absent trials. As in Experiment 1, because the critical Onset Type x Set Size interaction reported above is not contingent on the difference between target present and target absent trials, the possibility of a speed/accuracy trade-off is not a factor in our interpretation of the results.

The error data also showed a significant Target Present / Absent x Ratio Type interaction, $F(1,15) = 18.86$, $MS_e = .37$, $p = .001$, with greater error in the 33% relevant condition for Target Present trials, greater error in the 66% relevant condition for Target Absent trials, and greater error for Target Absent trials overall. Finally, there was a Target Present / Absent x Set Size interaction, in which the number of incorrect trials across levels of Set Size was greater when the target was present than when the target was absent, $F(3,45) = 5.91$, $MS_e = .69$, $p = .002$. There were no other significant effects in the error data.

## Discussion

Experiment 2 provided another replication of the concurrency effect on search slopes: When auditory identification of the target was given simultaneously with the onset of the search grid, subjects' response times were less affected by increases in set size for both Target Present and Target Absent conditions. In addition, Experiment 2 demonstrated an effect of the distractor-ratio manipulation. When 66% of the distractors were the same colour as the target, the participants, as expected, demonstrated numerically less of an efficiency advantage in the concurrent condition relative to the consecutive condition (11.3 / 17.9 = 63%) when compared to the 50% advantage found in

Experiment 1. However, when the numbers were reversed, and only 33% of the distracting items were the same colour as the target, the pattern did not reverse itself. As shown in Figure 4, when only 33% of the items were relevantly coloured, subjects in the concurrent condition still demonstrated less of an advantage over the consecutive condition (10.5 / 17.4 = 60%) when compared to the 50% advantage found in Experiment 1.

Based on the logic that subjects are 'parsing out' the irrelevantly-coloured portion of the distractors, we predicted that 1) the 66% relevant condition would produce less of an efficiency advantage than the 50% baseline, and that 2) the 33% relevant condition would produce more of an efficiency advantage than the 50% baseline. Experiment 2 showed that instead, both the 66% and 33% relevant conditions produce the same trend: somewhat less of an efficiency advantage than is found in the 50% baseline of Experiment 1. This being the case, the results of Experiment 2 seem to contradict the notion that subjects are ignoring the irrelevantly-coloured distractors. Because the 66%-relevant and 33%-relevant conditions both produced a similar efficiency advantage, it is possible that the demonstrated Concurrency Effect (i.e. more efficient search slopes in the Concurrent Onset condition) is not due to a parsing of the search set by relevant colour, as hypothesized by Spivey et al. (2001). An alternative explanation is considered in the General Discussion.

## Experiment 3

Relevant Search Set Manipulation:

In Experiment 2 we manipulated the ratio of relevant to irrelevant distractors in the colour dimension (i.e. red to green, when the target is red) by varying their relative proportions (33% or 66%) within a set number of items (6, 12, 18 or 24). Another way in which our desired proportions of 66% and 33% can be obtained is to hold the relevant set (red, when the target is red) constant, while letting total set size vary. This method has the advantage of keeping the number of relevantly-coloured items consistent across distractor-ratio conditions, while still obtaining the desired 33% and 66% distractor ratios. This manipulation was implemented in Experiment 3, which was otherwise identical to Experiment 2. For the complete distribution of trials, see Table 1. The 'Relevant Search Set' manipulation allowed us to address the same question in a slightly different way. In Experiment 3, the relevant search set was equivalent across conditions, and the desired ratios emerged solely from the variation in the irrelevantly coloured items.

Method

*Participants*: Ten undergraduate students from the cognition subject pool at the University of Waterloo participated for pay ($6 CDN). All participants reported normal or corrected-to-normal visual acuity, and normal colour vision. None of the participants in Experiment 3 had participated in previous experiments.

*Design and Procedure:* The design and procedure of Experiment 3 were identical to those of Experiment 2, with the exception of the Relevant Search Set manipulation described above. Again, subjects were presented with search grids that contained either 66% or 33% relevantly-coloured distractors, with the remainder of distractors being irrelevantly-coloured. Subjects were asked to report whether the target was present or absent; RT and accuracy data were collected.

Results

RT analyses were performed for trials in which subjects correctly determined whether the target was present or absent. Recursive outlier analysis using the same procedure as in Experiments 1 and 2 removed 2.23% of the trials. The remaining RT data were subjected to a 2 x 2 x 2 x 4 (Onset Type x Ratio Type x Target Present / Absent x Set Size) Repeated Measures ANOVA. Figure 5 plots the Response-Time x Set-Size functions for Target Present and Target Absent trials at each level of Onset Type (Concurrent vs. Consecutive) and Distractor Ratio (66% vs. 33% relevant).

When the target was absent, responses were significantly slower than when the target was present, $F(1,9) = 22.97$, $MS_e = 67{,}272.51$, $p = .001$. As set sizes increased, response times became slower, $F(3,27) = 23.42$, $MS_e = 39{,}338.64$, $p = .000$. As in Experiments 1 and 2, there was a significant main effect of Onset Type, $F(1,9) = 29.34$, $MS_e = 288{,}509.01$, $p = .000$, with mean RT slower in the Concurrent Onset condition. As well, Experiment 3 produced a significant main effect of Ratio Type, in which RTs in the 66% relevant condition were significantly slower than those in the 33% relevant condition, $F(1,9) = 21.27$, $MS_e = 14{,}388.83$, $p = .001$, and a Target Present / Absent x Set Size interaction, $F(3,27) = 7.94$, $MS_e = 18{,}072.32$, $p = .001$. Finally, Experiment 3 again replicated the overall concurrency advantage present in previous experiments; slopes in the concurrent condition were flatter (more efficient) on average than those in the consecutive condition, as indicated by an Onset Type x Set Size interaction, $F(3,27) = 2.43$, $MS_e = 20,326.02$, $p = .087$. Considering that this effect has been found consistently across experiments, and that the Onset Type x Set Size linear contrast is significant at $F(1,9) = 5.40$, $MS_e = 18,855.09$, $p = .05$, we interpret this as a statistically significant finding.

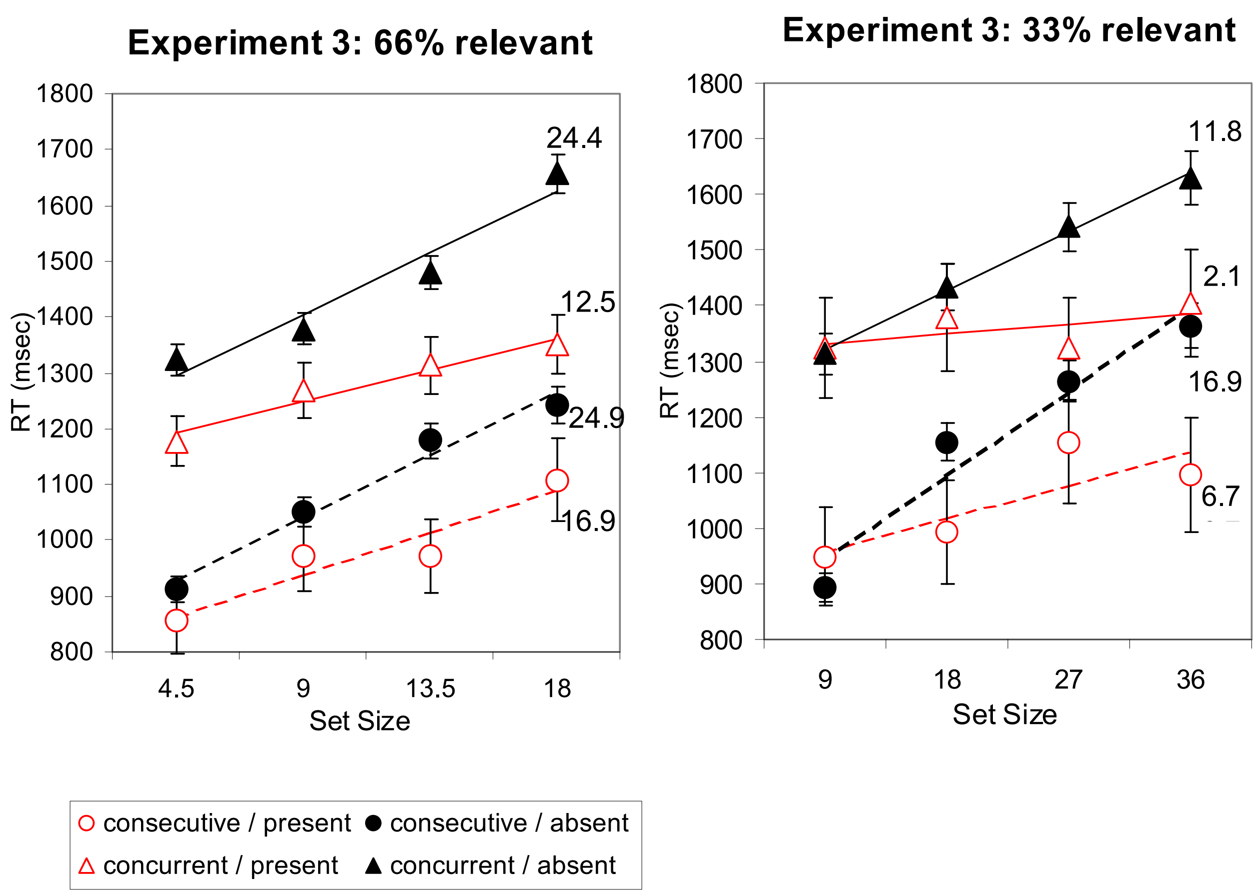


**Figure 5:**
Experiment 3: mean correct RT x Set Size search slopes as a function of Onset Type (Consecutive vs. Concurrent), Target Presence / Absence, and Distractor Ratio (66 vs. 33) across panels *a* and *b*.

Error Analysis

A Repeated Measures ANOVA was performed, comparing the proportion of incorrect trials across conditions. As in Experiments 1 and 2, the proportion of incorrect trials was greater for Target Present trials than for Target Absent trials, $F(1,9) = 31.14$, $MS_e = .41$, $p = .000$. However, Experiment 3 also produced asymmetrical error data across levels of Ratio Type, $F(1,9) = 6.31$, $MS_e = .34$, $p = .033$, with greater error in the 33%-relevant condition, and Set Size, $F(3,27) = 3.53$, $MS_e = .47$, $p = .028$, with a linear increase in error as set sizes increased (see Table 2). The most obvious explanation for this difference in error data across experiments is the way in which the Set Sizes were established (i.e. the "Relevant Search Set" manipulation described above) in Experiment 3. That is, because set sizes in the 33%-relevant condition (12, 18, 27, 36) were quantitatively different than set sizes in the 66%-relevant condition (4.5, 9, 13.5, 18), a difference in the number of incorrect responses being made across Ratio Type conditions is not surprising.

In Experiment 3 the possibility of speed-accuracy trade-offs again arises. Though response times for Target Present trials were faster than those for Target Absent trials, this was offset by a greater number of errors on Target Present trials. This, however, does not impact the interpretability of the results of the current experiment, as the difference between Target Absent and Target present trials is not critical to the reported Onset Type x Set Size interaction. The pattern of error data across levels of Ratio Type and Set Size did not suggest any speed-accuracy trade-offs. The error data also showed a significant Target Present / Absent x Ratio Type interaction, $F(1,9) = 14.88$, $MS_e = .07$, p = .004, with a greater difference in error across levels of Ratio Type for Target Present trials than for Target Absent trials, and greater error in Target Present trials, overall.

Finally, there was a significant Target Present / Absent x Set Size interaction, in which the number of incorrect trials across levels of Set Size was greater when the target was present than when the target was absent, $F(3,27) = 5.85$, $MS_e = .36$, $p = .003$. There were no other significant effects in the error data.

Discussion

Experiment 3 again demonstrated the overall concurrency advantage present in the earlier experiments; slopes in the concurrent condition were significantly flatter (more efficient) on average than those in the consecutive condition. The 66% relevant condition produced the same pattern observed in Experiment 2: Participants demonstrated numerically less of an efficiency advantage in the concurrent condition relative to the consecutive condition (12.5 / 16.9 = 74%) when compared to the 50% advantage found in Experiment 1. However, in the 33% relevant condition, participants, on average, demonstrated a numerically greater than 50% efficiency advantage in the concurrent condition over the consecutive condition (2.06 / 6.66 = 31%) when compared to the 50% advantage found in Experiment 1. Unlike the results of Experiment 2, this pattern is consistent with the interpretation that subjects are ignoring the irrelevantly-coloured items, and searching only through those that are the same colour as the target.

## General Discussion

In Experiment 1 we set out to replicate the results of previous research (Spivey et al., 2001) demonstrating that, when auditory target identification is given simultaneously with the onset of the search display, subjects are more efficient at locating the target in a standard visual search task, than when auditory identification of the target is given prior to the onset of the search grid. In Experiment 2 we tested whether this advantage was the result of the subjects' ability to parse the search set based on the auditory information. This was done by varying the ratio of relevant (same colour as target) to irrelevant (different colour from target) items in the distractor set. In Experiment 3 we investigated this question from a slightly different angle, using distractor sets that held the number of relevantly coloured items constant across the two distractor-ratio conditions (33%- and 66%-relevant).

Experiment 1 provided a successful replication of the efficiency advantage in the simultaneous-onset condition. Experiment 2 also showed a replication of this efficiency advantage (i.e. the *Concurrency Effect*), but produced data that were inconsistent with the notion that subjects were ignoring the irrelevantly coloured portion of distractors. If subjects were ignoring the irrelevantly-coloured distractors and, instead, were searching through only those that were the same colour as the target, we would have expected a larger efficiency advantage when there were fewer items to search through, and a smaller efficiency advantage when there were more items to search through. Instead, both the 33%- and 66%-relevant conditions produced somewhat less of an efficiency advantage than was found in Experiment 1. Experiment 3, in contrast, produced results that were consistent with the notion that subjects' were ignoring the irrelevantly coloured distractors. That is, in the 66% relevant condition we found an efficiency advantage that was somewhat smaller than that found in Experiment 1, whereas in the 33% relevant condition we found an efficiency advantage that was somewhat larger than that found in Experiment 1. The main difference between Experiments 2 and 3 – the way in which the desired distractor ratios were obtained – is argued to be responsible for this key difference.

For insight as to why the distractor ratio manipulation in Experiment 2 did not produce the expected reversal across distractor ratio conditions, we note the study by Zohary and Hochstein (1989), which examined the effects of a similar distractor ratio manipulation. These authors presented subjects with a 64-item grid of red and green, horizontal and vertical bars. The SOA (Stimulus Onset Asynchrony) between stimulus and mask was manipulated, and the dependent variable was the SOA required to reach a criterion of 70% correct. Across trials the ratio of red to green items varied from 0:64 to 64:0, thus providing data on the full range of distractor ratios. Interestingly, the experiment produced data that described a quadratic, rather than a linear, function. That is, as the ratio moved towards the halfway point (32:32) SOA required to reach criterion increased. After the halfway point, SOA again began to decrease. The resulting parabola was skewed in favour of the colour dimension, indicating that colour was more salient than orientation. Still, the quadratic nature of the data is striking. The authors hypothesize that subjects in this experiment were changing strategies on either side of the 50% mark, searching through whichever dimension (red/green vs. horizontal/vertical) was smaller and/or more salient.

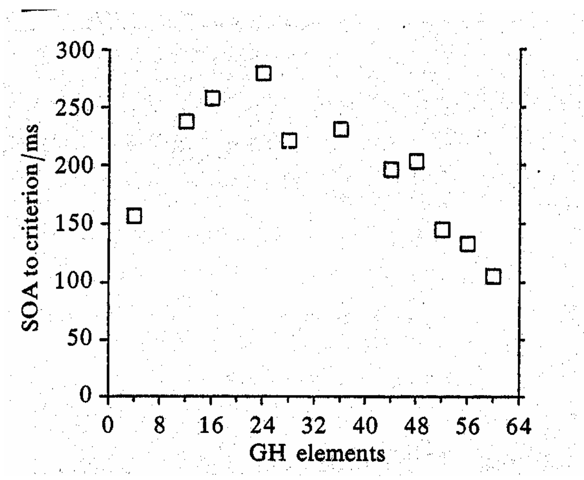


**Figure 6:**
Quadratic effects of a distractor ratio manipulation – reproduced from Zohary and Hochstein (1989). "GH elements" on the X axis refers to the number of Green Horizontal elements in the display, which is inversely proportional to the number of Red Vertical elements in the display.

The results of the Zohary and Hochstein study offer a possible explanation for why, in Experiment 2, we did not find a reversal across distractor ratio conditions. Zohary and Hochstein demonstrated that as distractor ratios moved away from the 50% mark, SOA to criterion decreased. This was true regardless of which dimension (colour vs. orientation) was larger, though the colour dimension did appear to be somewhat more salient (that is, the resulting parabola was skewed in the direction of the colour dimension). Our interpretation for Experiment 2, then, is that in the 33% relevant condition (i.e. 33% of the items were the same *colour* as the target), subjects searched through the colour dimension, and in the 66% relevant (i.e. 66% of the items were the same colour as the target, but 33% were the same *orientation*) subjects switched and searched through the orientation dimension to find the odd one out. Thus, the Target Present data were identical across distractor-ratio conditions because the subjects were performing searches on sets that were functionally identical in size. The distractor ratio manipulation, then, had no effect on search efficiency across distractor-ratio conditions.

There are a few potential problems with this interpretation. First, whereas the concurrency effect for the Target Present trials remained identical across distractor ratio conditions, the concurrency effect for the Target Absent trials differed slightly, (see Figure 4), though the pattern remained consistent. Second, if, as Zohary and Hochstein suggest, subjects are searching through the ‘smaller and/or more salient’ dimension, we would expect an efficiency advantage in the Concurrent-onset condition that is somewhat *greater* than that found in the 50% condition; this would be the case because subjects would be searching through a smaller distractor set. Instead, subjects demonstrated numerically *less* of an efficiency advantage in both the 66% and 33% relevant conditions, when compared to a 50% baseline. Still, the fact that a distractor ratio manipulation produced a quadratic, rather than linear, function provides some insight as to why Experiment 2 produced similar results across distractor ratio conditions.

Experiment 3, in which we held the number of relevantly-coloured items (i.e. same colour as the target) constant across distractor ratio conditions, produced the anticipated pattern of results; in the 66% relevant condition the Concurrent-onset condition produced a somewhat smaller efficiency advantage, and in the 33% relevant condition the Concurrent-onset condition produced a somewhat larger efficiency advantage, when compared to a 50% baseline. These results support the interpretation that subjects are using the auditory target identification to parse the search set, searching only through those items that are the same colour as the target. However, the results of Experiment 2 contradict this interpretation. Comparing the stimuli for Experiments 2 and 3 we find that, in addition to holding the number of same-colour items constant across distractor-ratio conditions in Experiment 3, we let overall search size vary in order to obtain the desired ratios. As such, we offer two possible interpretations. First, because the overall set sizes in the 33% relevant condition were larger than those in the 66% relevant condition (see Figure 5 / Table 2), it is possible that the reversal across distractor ratio conditions was due to the fact that there were simply more items to search through in the 33% relevant condition. However, another interpretation is that by holding the colour dimension constant (i.e. 'relevant search set') across distractor-ratio conditions, we disrupted the *distractor ratio effect* reported by Zohary and Hochstein (1989). That is, because the amount of 'relevant' colour was consistent across distractor ratio conditions, the auditory target identification had a better chance of directing attention towards the colour dimension, thus producing the expected reversal across distractor ratio conditions.

## Conclusion

The present experiments provide further evidence that auditory identification of the search target, presented simultaneously with the onset of the search grid, produces more efficient search slopes. We tested the interpretation that this efficiency is due to the subject's ability to parse the search grid, searching through only the 'relevant' colours (i.e. those that are the same as the target). Here the data tell two stories. First, when a distractor ratio manipulation is implemented, such that either 33% or 66% of the distractors are the same colour as the target, the efficiency advantage remained equal across conditions. This contradicts the notion that subjects are searching only through the relevantly coloured items – if they were, then we would expect the efficiency advantage to co-vary with the distractor ratio. Instead, it is possible that subjects were searching through the 'smaller and/or more salient' dimension, thus allowing for equivalent searches in both the 33% and 66% relevant (colour) conditions.

The data from Experiment 3 complicate the issue, providing a situation in which the distractor ratio manipulation has the predicted effect of modulating the efficiency advantage across distractor ratios. We hypothesize that this result is due to either a) the asymmetrical set sizes that are a result of the 'relevant set size' manipulation, or b) the fact that we held the amount of relevant colour constant across distractor ratio conditions. Further research will be required to clarify this issue.

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## Appendix A: Analyses

**Experiment 1: Reaction Time**

| | Sum of Squares | df | Mean Square | F | *p* |
|---|---|---|---|---|---|
| Target Present / Absent | 756488.975 | 1 | 756488.975 | 19.227 | .001 |
| (error) Target Present / Absent | 432802.612 | 11 | 39345.692 | | |
| Onset Type | 7291146.793 | 1 | 7291146.793 | 44.279 | .000 |
| (error) Onset Type | 1811307.911 | 11 | 164664.356 | | |
| Set Size | 1755072.154 | 3 | 585024.051 | 59.323 | .000 |
| (error) Set Size | 325437.172 | 33 | 9861.732 | | |
| Target Present / Absent * Onset Type | 9168.188 | 1 | 9168.188 | 0.557 | .471 |
| (error) Target Present / Absent * Onset Type | 181041.043 | 11 | 16458.277 | | |
| Target Present / Absent * Set Size | 180702.628 | 3 | 60234.209 | 6.236 | .002 |
| (error)Target Present / Absent * Set Size | 318752.232 | 33 | 9659.159 | | |
| Onset Type * Set Size | 136235.136 | 3 | 45411.712 | 2.854 | .052 |
| (error) Onset Type * Set Size | 525047.814 | 33 | 15910.540 | | |
| Target Present / Absent * Onset Type * Set Size | 70171.757 | 3 | 23390.586 | 1.302 | .290 |
| (error) Target Present / Absent * Onset Type * Set Size | 592883.684 | 33 | 17966.172 | | |

**Experiment 1: Error**

| | Sum of Squares | df | Mean Square | F | *P* |
|---|---|---|---|---|---|
| Target Present / Absent | 10.547 | 1 | 10.547 | 5.270 | .042 |
| (error) Target Present / Absent | 22.016 | 11 | 2.001 | | |
| Onset Type | 0.422 | 1 | 0.422 | 0.297 | .597 |
| (error) Onset Type | 15.641 | 11 | 1.422 | | |
| Set Size | 1.557 | 3 | 0.519 | 0.593 | .624 |
| (error) Set Size | 28.880 | 33 | 0.875 | | |
| Target Present / Absent * Onset Type | 1.172 | 1 | 1.172 | 0.981 | .343 |
| (error) Target Present / Absent * Onset Type | 13.141 | 11 | 1.195 | | |
| Target Present / Absent * Set Size | 4.349 | 3 | 1.450 | 2.759 | .058 |
| (error) Target Present / Absent * Set Size | 17.339 | 33 | 0.525 | | |
| Onset Type * Set Size | 0.557 | 3 | 0.186 | 0.239 | .868 |
| (error) Onset Type * Set Size | 25.630 | 33 | 0.777 | | |
| Target Present / Absent * Onset Type * Set Size | 4.891 | 3 | 1.630 | 2.981 | .045 |
| (error) Target Present / Absent * Onset Type * Set Size | 18.047 | 33 | 0.547 | | |

**Experiment 2: Reaction Time**

| | Sum of Squares | df | Mean Square | F | *p* |
|---|---|---|---|---|---|
| Ratio Type | 564900.792 | 1 | 564900.792 | 19.615 | .000 |
| (error) Ratio Type | 431989.126 | 15 | 28799.275 | | |
| Target Present / Absent | 3830275.386 | 1 | 3830275.386 | 15.104 | .001 |
| (error) Target Present / Absent | 3803966.127 | 15 | 253597.742 | | |
| Onset Type | 11098173.845 | 1 | 11098173.845 | 54.542 | .000 |
| (error) Onset Type | 3052171.783 | 15 | 203478.119 | | |
| Set Size | 6174257.717 | 3 | 2058085.906 | 49.252 | .000 |
| (error) Set Size | 1880409.672 | 45 | 41786.882 | | |
| Ratio Type * Target Present / Absent | 454956.643 | 1 | 454956.643 | 25.994 | .000 |
| (error) Ratio Type * Target Present / Absent | 262532.092 | 15 | 17502.139 | | |
| Ratio Type * Onset Type | 91252.590 | 1 | 91252.590 | 12.601 | .003 |
| (error) Ratio Type * Onset Type | 108621.361 | 15 | 7241.424 | | |
| Target Present / Absent * Onset Type | 3167.682 | 1 | 3167.682 | 0.100 | .756 |
| (error) Target Present / Absent * Onset Type | 474601.783 | 15 | 31640.119 | | |
| Ratio Type * Target Present / Absent * Onset Type | 16589.084 | 1 | 16589.084 | 0.875 | .364 |
| (error) Ratio Type * Target Present / Absent * Onset Type | 284306.697 | 15 | 18953.780 | | |
| Ratio Type * Set Size | 81094.562 | 3 | 27031.521 | 2.550 | .068 |
| (error) Ratio Type * Set Size | 477034.098 | 45 | 10600.758 | | |
| Target Present / Absent * Set Size | 143968.074 | 3 | 47989.358 | 1.637 | .194 |
| (error) Target Present / Absent * Set Size | 1319198.993 | 45 | 29315.533 | | |
| Ratio Type * Target Present / Absent * Set Size | 39887.201 | 3 | 13295.734 | 0.601 | .617 |
| (error) Ratio Type * Target Present / Absent * Set Size | 994898.206 | 45 | 22108.849 | | |
| Onset Type * Set Size | 315048.907 | 3 | 105016.302 | 4.229 | .010 |
| (error) Onset Type * Set Size | 1117386.584 | 45 | 24830.813 | | |
| Ratio Type * Onset Type * Set Size | 17322.442 | 3 | 5774.147 | 0.409 | .748 |
| (error) Ratio Type * Onset Type * Set Size | 635937.750 | 45 | 14131.950 | | |
| Target Present / Absent * Onset Type * Set Size | 8389.996 | 3 | 2796.665 | 0.189 | .903 |
| (error) Target Present / Absent * Onset Type * Set Size | 665084.609 | 45 | 14779.658 | | |
| Ratio Type * Target Present / Absent * Onset Type * Set Size | 20800.268 | 3 | 6933.423 | 0.409 | .748 |
| (error) Ratio Type * Target Present / Absent * Onset Type * Set Size | 763590.375 | 45 | 16968.675 | | |

**Experiment 2: Error**

| | Sum of Squares | df | Mean Square | F | *p* |
|---|---|---|---|---|---|
| Ratio Type | 0.008 | 1 | 0.008 | 0.034 | .857 |
| (error) Ratio Type | 3.492 | 15 | 0.233 | | |
| Target Present / Absent | 26.281 | 1 | 26.281 | 22.249 | .000 |
| (error) Target Present / Absent | 17.719 | 15 | 1.181 | | |
| Onset Type | 0.781 | 1 | 0.781 | 0.569 | .462 |
| (error) Onset Type | 20.594 | 15 | 1.373 | | |
| Set Size | 2.023 | 3 | 0.674 | 1.358 | .268 |
| (error) Set Size | 22.352 | 45 | 0.497 | | |
| Ratio Type * Target Present / Absent | 7.031 | 1 | 7.031 | 18.855 | .001 |
| (error) Ratio Type * Target Present / Absent | 5.594 | 15 | 0.373 | | |
| Ratio Type * Onset Type | 1.531 | 1 | 1.531 | 2.363 | .145 |
| (error) Ratio Type * Onset Type | 9.719 | 15 | 0.648 | | |
| Target Present / Absent * Onset Type | 0.070 | 1 | 0.070 | 0.066 | .800 |
| (error) Target Present / Absent * Onset Type | 15.930 | 15 | 1.062 | | |
| Ratio Type * Target Present / Absent * Onset Type | 0.195 | 1 | 0.195 | 0.394 | .539 |
| (error) Ratio Type * Target Present / Absent * Onset Type | 7.430 | 15 | 0.495 | | |
| Ratio Type * Set Size | 1.211 | 3 | 0.404 | 1.188 | .325 |
| (error) Ratio Type * Set Size | 15.289 | 45 | 0.340 | | |
| Target Present / Absent * Set Size | 12.156 | 3 | 4.052 | 5.912 | .002 |
| (error) Target Present / Absent * Set Size | 30.844 | 45 | 0.685 | | |
| Ratio Type * Target Present / Absent * Set Size | 2.281 | 3 | 0.760 | 1.118 | .352 |
| (error) Ratio Type * Target Present / Absent * Set Size | 30.594 | 45 | 0.680 | | |
| Onset Type * Set Size | 2.344 | 3 | 0.781 | 1.543 | .216 |
| (error) Onset Type * Set Size | 22.781 | 45 | 0.506 | | |
| Ratio Type * Onset Type * Set Size | 1.031 | 3 | 0.344 | 0.488 | .693 |
| (error) Ratio Type * Onset Type * Set Size | 31.719 | 45 | 0.705 | | |
| Target Present / Absent * Onset Type * Set Size | 1.773 | 3 | 0.591 | 1.315 | .281 |
| (error) Target Present / Absent * Onset Type * Set Size | 20.227 | 45 | 0.449 | | |
| Ratio Type * Target Present / Absent * Onset Type * Set Size | 3.211 | 3 | 1.070 | 1.156 | .337 |
| (error) Ratio Type * Target Present / Absent * Onset Type * Set Size | 41.664 | 45 | 0.926 | | |

**Experiment 3: Reaction Time**

| | Sum of Squares | df | Mean Square | F | *p* |
|---|---|---|---|---|---|
| Ratio Type | 305998.547 | 1 | 305998.547 | 21.266 | .001 |
| (error) Ratio Type | 129499.479 | 9 | 14388.831 | | |
| Target Present / Absent | 1544936.439 | 1 | 1544936.439 | 22.965 | .001 |
| (error) Target Present / Absent | 605452.571 | 9 | 67272.508 | | |
| Onset Type | 8464855.774 | 1 | 8464855.774 | 29.340 | .000 |
| (error) Onset Type | 2596581.101 | 9 | 288509.011 | | |
| Set Size | 2764333.281 | 3 | 921444.427 | 23.423 | .000 |
| (error) Set Size | 1062143.154 | 27 | 39338.635 | | |
| Ratio Type * Target Present / Absent | 17273.826 | 1 | 17273.826 | 1.380 | .270 |
| (error) Ratio Type * Target Present / Absent | 112661.739 | 9 | 12517.971 | | |
| Ratio Type * Onset Type | 4092.446 | 1 | 4092.446 | 0.276 | .612 |
| (error) Ratio Type * Onset Type | 133573.004 | 9 | 14841.445 | | |
| Target Present / Absent * Onset Type | 23883.898 | 1 | 23883.898 | 1.203 | .301 |
| (error) Target Present / Absent * Onset Type | 178648.248 | 9 | 19849.805 | | |
| Ratio Type * Target Present / Absent * Onset Type | 20816.249 | 1 | 20816.249 | 1.519 | .249 |
| (error) Ratio Type * Target Present / Absent * Onset Type | 123365.872 | 9 | 13707.319 | | |
| Ratio Type * Set Size | 22624.543 | 3 | 7541.514 | 0.394 | .759 |
| (error) Ratio Type * Set Size | 517284.929 | 27 | 19158.701 | | |
| Target Present / Absent * Set Size | 430511.037 | 3 | 143503.679 | 7.941 | .001 |
| (error) Target Present / Absent * Set Size | 487952.546 | 27 | 18072.317 | | |
| Ratio Type * Target Present / Absent * Set Size | 104859.227 | 3 | 34953.076 | 1.942 | .147 |
| (error) Ratio Type * Target Present / Absent * Set Size | 486053.267 | 27 | 18001.973 | | |
| Onset Type * Set Size | 148287.121 | 3 | 49429.040 | 2.432 | .087 |
| (error) Onset Type * Set Size | 548802.428 | 27 | 20326.016 | | |
| Ratio Type * Onset Type * Set Size | 44421.024 | 3 | 14807.008 | 0.758 | .528 |
| (error) Ratio Type * Onset Type * Set Size | 527518.350 | 27 | 19537.717 | | |
| Target Present / Absent * Onset Type * Set Size | 69808.811 | 3 | 23269.604 | 1.381 | .270 |
| (error) Target Present / Absent * Onset Type * Set Size | 454865.982 | 27 | 16846.888 | | |
| Ratio Type * Target Present / Absent * Onset Type * Set Size | 67129.837 | 3 | 22376.612 | 1.033 | .394 |
| (error) Ratio Type * Target Present / Absent * Onset Type * Set Size | 584907.618 | 27 | 21663.245 | | |

**Experiment 3: Error**

| | Sum of Squares | df | Mean Square | F | *p* |
|---|---|---|---|---|---|
| Ratio Type | 2.113 | 1 | 2.113 | 6.311 | .033 |
| (error) Ratio Type | 3.013 | 9 | 0.335 | | |
| Target Present / Absent | 12.800 | 1 | 12.800 | 31.135 | .000 |
| (error) Target Present / Absent | 3.700 | 9 | 0.411 | | |
| Onset Type | 1.800 | 1 | 1.800 | 4.101 | .074 |
| (error) Onset Type | 3.950 | 9 | 0.439 | | |
| Set Size | 5.000 | 3 | 1.667 | 3.529 | .028 |
| (error) Set Size | 12.750 | 27 | 0.472 | | |
| Ratio Type * Target Present / Absent | 1.013 | 1 | 1.013 | 14.878 | .004 |
| (error) Ratio Type * Target Present / Absent | 0.613 | 9 | 0.068 | | |
| Ratio Type * Onset Type | 0.013 | 1 | 0.013 | 0.101 | .758 |
| (error) Ratio Type * Onset Type | 1.113 | 9 | 0.124 | | |
| Target Present / Absent * Onset Type | 1.250 | 1 | 1.250 | 1.667 | .229 |
| (error) Target Present / Absent * Onset Type | 6.750 | 9 | 0.750 | | |
| Ratio Type * Target Present / Absent * Onset Type | 0.012 | 1 | 0.012 | 0.027 | .872 |
| (error) Ratio Type * Target Present / Absent * Onset Type | 4.113 | 9 | 0.457 | | |
| Ratio Type * Set Size | 2.638 | 3 | 0.879 | 1.611 | .210 |
| (error) Ratio Type * Set Size | 14.738 | 27 | 0.546 | | |
| Target Present / Absent * Set Size | 6.300 | 3 | 2.100 | 5.845 | .003 |
| (error) Target Present / Absent * Set Size | 9.700 | 27 | 0.359 | | |
| Ratio Type * Target Present / Absent * Set Size | 2.638 | 3 | 0.879 | 1.338 | .283 |
| (error) Ratio Type * Target Present / Absent * Set Size | 17.738 | 27 | 0.657 | | |
| Onset Type * Set Size | 0.300 | 3 | 0.100 | 0.340 | .797 |
| (error) Onset Type * Set Size | 7.950 | 27 | 0.294 | | |
| Ratio Type * Onset Type * Set Size | 0.538 | 3 | 0.179 | 0.547 | .654 |
| (error) Ratio Type * Onset Type * Set Size | 8.838 | 27 | 0.327 | | |
| Target Present / Absent * Onset Type * Set Size | 0.950 | 3 | 0.317 | 0.740 | .537 |
| (error) Target Present / Absent * Onset Type * Set Size | 11.550 | 27 | 0.428 | | |
| Ratio Type * Target Present / Absent * Onset Type * Set Size | 1.238 | 3 | 0.413 | 1.458 | .248 |
| (error) Ratio Type * Target Present / Absent * Onset Type * Set Size | 7.638 | 27 | 0.283 | | |

## Appendix B: Subject Means

**Experiment 1:**
**REACTION TIME**

| | Target Present | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | Consecutive | | | | Concurrent | | | |
| SJ# | 5 | 10 | 15 | 20 | 5 | 10 | 15 | 20 |
| 1 | 725.88 | 1134.56 | 1268.50 | 1184.64 | 1003.64 | 1161.30 | 976.55 | 1180.36 |
| 2 | 990.08 | 1470.90 | 1238.30 | 1448.90 | 1738.67 | 1502.70 | 1914.55 | 1634.75 |
| 3 | 967.18 | 1183.20 | 1041.25 | 1337.82 | 1438.42 | 1539.00 | 1990.45 | 1633.27 |
| 4 | 941.09 | 1098.42 | 1223.58 | 1263.42 | 1376.20 | 1549.91 | 1467.67 | 1729.67 |
| 5 | 931.83 | 1166.58 | 1069.60 | 1174.64 | 1362.25 | 1353.36 | 1578.75 | 1410.64 |
| 6 | 872.25 | 968.25 | 1073.50 | 1116.27 | 1387.75 | 1467.50 | 1493.08 | 1476.00 |
| 7 | 759.50 | 593.36 | 728.25 | 819.36 | 933.33 | 1032.82 | 1032.64 | 1064.27 |
| 8 | 638.00 | 601.36 | 666.08 | 859.91 | 987.45 | 1074.00 | 1129.82 | 1145.33 |
| 9 | 1080.82 | 1150.36 | 1265.67 | 1167.80 | 1462.33 | 1551.92 | 1354.00 | 1394.89 |
| 10 | 1129.18 | 1311.75 | 1372.25 | 1436.00 | 1969.75 | 2212.17 | 2188.42 | 2095.18 |
| 11 | 736.00 | 895.08 | 965.20 | 891.25 | 893.00 | 1293.73 | 1199.17 | 1215.27 |
| 12 | 808.70 | 790.64 | 1057.17 | 1079.92 | 1195.82 | 1254.92 | 1364.82 | 1327.00 |
| mean | 881.71 | 1030.37 | 1080.78 | 1148.33 | 1312.38 | 1416.11 | 1474.16 | 1442.22 |

**Experiment 1:**
**REACTION TIME**

| | Target Absent | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | Consecutive | | | | Concurrent | | | |
| SJ# | 5 | 10 | 15 | 20 | 5 | 10 | 15 | 20 |
| 1 | 952.18 | 986.50 | 1096.90 | 1262.00 | 1128.18 | 1226.89 | 1290.00 | 1447.42 |
| 2 | 1121.67 | 1419.70 | 1823.75 | 1811.55 | 2207.08 | 2070.11 | 1938.50 | 2218.45 |
| 3 | 918.25 | 1139.83 | 1299.75 | 1430.33 | 1924.55 | 1597.08 | 1479.09 | 2273.27 |
| 4 | 1163.08 | 1324.83 | 1499.42 | 1524.58 | 1385.00 | 1424.55 | 1613.42 | 1789.00 |
| 5 | 1021.33 | 1178.91 | 1165.83 | 1322.58 | 1257.18 | 1483.42 | 1523.64 | 1609.00 |
| 6 | 677.18 | 894.75 | 870.25 | 1416.25 | 1434.83 | 1420.00 | 1328.91 | 1558.33 |
| 7 | 635.73 | 811.17 | 853.17 | 962.91 | 1141.50 | 1094.91 | 1344.83 | 1373.25 |
| 8 | 565.36 | 727.60 | 717.18 | 927.73 | 1076.50 | 1021.40 | 1171.64 | 1174.50 |
| 9 | 1035.92 | 1185.73 | 1556.73 | 1329.92 | 1358.45 | 1391.91 | 1571.17 | 1556.67 |
| 10 | 1321.82 | 1282.67 | 1368.09 | 1323.50 | 2146.00 | 2508.00 | 2210.73 | 2394.64 |
| 11 | 1089.91 | 1015.83 | 1287.55 | 1307.50 | 1178.27 | 1436.67 | 1349.91 | 1600.09 |
| 12 | 864.67 | 968.08 | 1236.33 | 1360.27 | 1229.08 | 1397.42 | 1460.58 | 1611.75 |
| mean | 947.26 | 1077.97 | 1231.25 | 1331.59 | 1455.55 | 1506.03 | 1523.53 | 1717.20 |

**Experiment 1:**
**ERROR**

| | Target Present | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | Consecutive | | | | Concurrent | | | |
| SJ# | 5 | 10 | 15 | 20 | 5 | 10 | 15 | 20 |
| 1 | 0.31 | 0.25 | 0.27 | 0.19 | 0.20 | 0.19 | 0.06 | 0.14 |
| 2 | 0.00 | 0.00 | 0.08 | 0.07 | 0.06 | 0.00 | 0.07 | 0.00 |
| 3 | 0.07 | 0.19 | 0.06 | 0.07 | 0.00 | 0.00 | 0.07 | 0.07 |
| 4 | 0.00 | 0.00 | 0.00 | 0.00 | 0.13 | 0.06 | 0.00 | 0.13 |
| 5 | 0.19 | 0.13 | 0.19 | 0.13 | 0.06 | 0.06 | 0.00 | 0.06 |
| 6 | 0.00 | 0.00 | 0.00 | 0.13 | 0.00 | 0.00 | 0.06 | 0.07 |
| 7 | 0.00 | 0.06 | 0.00 | 0.00 | 0.00 | 0.06 | 0.06 | 0.00 |
| 8 | 0.00 | 0.00 | 0.00 | 0.13 | 0.06 | 0.00 | 0.00 | 0.06 |
| 9 | 0.00 | 0.19 | 0.07 | 0.13 | 0.00 | 0.00 | 0.06 | 0.25 |
| 10 | 0.07 | 0.00 | 0.00 | 0.07 | 0.00 | 0.00 | 0.07 | 0.08 |
| 11 | 0.00 | 0.06 | 0.19 | 0.13 | 0.00 | 0.06 | 0.06 | 0.06 |
| 12 | 0.13 | 0.00 | 0.00 | 0.00 | 0.06 | 0.00 | 0.13 | 0.19 |
| mean | 0.06 | 0.07 | 0.07 | 0.09 | 0.05 | 0.04 | 0.05 | 0.09 |

**Experiment 1:**
**ERROR**

| | Target Absent | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | Consecutive | | | | Concurrent | | | |
| SJ# | 5 | 10 | 15 | 20 | 5 | 10 | 15 | 20 |
| 1 | 0.06 | 0.07 | 0.07 | 0.06 | 0.07 | 0.27 | 0.13 | 0.00 |
| 2 | 0.13 | 0.08 | 0.06 | 0.08 | 0.00 | 0.31 | 0.13 | 0.13 |
| 3 | 0.06 | 0.00 | 0.00 | 0.00 | 0.08 | 0.00 | 0.00 | 0.00 |
| 4 | 0.00 | 0.00 | 0.00 | 0.00 | 0.06 | 0.06 | 0.00 | 0.00 |
| 5 | 0.06 | 0.06 | 0.06 | 0.00 | 0.06 | 0.00 | 0.06 | 0.06 |
| 6 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.06 | 0.13 | 0.00 |
| 7 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| 8 | 0.06 | 0.00 | 0.00 | 0.06 | 0.00 | 0.00 | 0.00 | 0.00 |
| 9 | 0.00 | 0.06 | 0.06 | 0.06 | 0.00 | 0.00 | 0.00 | 0.00 |
| 10 | 0.00 | 0.00 | 0.00 | 0.07 | 0.00 | 0.11 | 0.08 | 0.00 |
| 11 | 0.00 | 0.00 | 0.25 | 0.06 | 0.00 | 0.00 | 0.00 | 0.00 |
| 12 | 0.00 | 0.00 | 0.00 | 0.06 | 0.00 | 0.07 | 0.00 | 0.00 |
| mean | 0.03 | 0.02 | 0.04 | 0.04 | 0.02 | 0.07 | 0.04 | 0.02 |

**Experiment 2:**
**REACTION TIME**

| | Target Present | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | 33:66 | | | | | | | |
| | Consecutive | | | | Concurrent | | | |
| SJ# | 6 | 12 | 18 | 24 | 6 | 12 | 18 | 24 |
| 1 | 875.75 | 1077.30 | 1133.13 | 1276.78 | 933.40 | 1325.10 | 1212.90 | 1048.20 |
| 2 | 580.90 | 728.78 | 633.00 | 721.20 | 1277.33 | 953.10 | 1204.10 | 1173.20 |
| 3 | 668.75 | 711.20 | 784.70 | 847.50 | 1143.60 | 1160.40 | 1125.30 | 1290.56 |
| 4 | 681.90 | 789.60 | 1026.70 | 1173.80 | 1196.67 | 1266.00 | 1230.13 | 1292.80 |
| 5 | 752.00 | 797.40 | 843.00 | 931.10 | 920.30 | 1106.10 | 883.80 | 1145.20 |
| 6 | 882.00 | 942.63 | 1207.75 | 1288.50 | 1460.22 | 1576.88 | 1557.20 | 1598.38 |
| 7 | 863.80 | 1181.83 | 893.38 | 1113.13 | 1267.40 | 1345.80 | 1239.00 | 1500.11 |
| 8 | 602.50 | 745.30 | 707.50 | 814.10 | 1213.10 | 1152.30 | 1243.40 | 1205.80 |
| 9 | 747.78 | 960.20 | 1025.10 | 1209.70 | 864.10 | 872.50 | 1007.40 | 1239.40 |
| 10 | 627.10 | 646.20 | 762.80 | 839.40 | 1275.22 | 1458.44 | 1345.70 | 1507.22 |
| 11 | 694.11 | 914.30 | 862.20 | 956.00 | 1095.44 | 1078.70 | 1274.00 | 1221.80 |
| 12 | 666.70 | 934.90 | 921.40 | 947.40 | 1046.40 | 1138.00 | 1269.00 | 1541.30 |
| 13 | 797.20 | 791.00 | 851.80 | 791.00 | 982.70 | 1062.90 | 994.00 | 1067.70 |
| 14 | 652.70 | 778.22 | 978.30 | 1003.20 | 1210.60 | 1352.60 | 1399.33 | 1497.00 |
| 15 | 678.40 | 849.11 | 957.33 | 1020.20 | 1017.90 | 1172.10 | 1329.40 | 1279.90 |
| 16 | 793.70 | 1065.60 | 1065.40 | 1224.20 | 1435.20 | 1406.30 | 1444.60 | 1427.33 |
| mean | 722.83 | 869.60 | 915.84 | 1009.83 | 1146.22 | 1214.20 | 1234.95 | 1314.74 |

**Experiment 2:**
**REACTION TIME**

| | Target Present | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | 66:33 | | | | | | | |
| | Consecutive | | | | Concurrent | | | |
| SJ# | 6 | 12 | 18 | 24 | 6 | 12 | 18 | 24 |
| 1 | 901.50 | 1145.44 | 1328.90 | 1347.10 | 1039.33 | 921.20 | 1376.70 | 1101.60 |
| 2 | 572.60 | 604.30 | 777.10 | 649.20 | 1026.89 | 936.33 | 1110.50 | 1101.20 |
| 3 | 558.10 | 835.70 | 786.10 | 635.50 | 1127.89 | 1234.70 | 1211.50 | 1422.40 |
| 4 | 714.10 | 991.70 | 1127.10 | 1015.90 | 1248.44 | 1369.78 | 1274.00 | 1636.56 |
| 5 | 840.10 | 899.90 | 889.60 | 1008.50 | 851.00 | 965.90 | 1085.80 | 1180.60 |
| 6 | 811.90 | 1211.78 | 1321.63 | 1565.10 | 1325.67 | 1563.71 | 1680.22 | 1518.40 |
| 7 | 879.89 | 1056.44 | 1243.43 | 1128.22 | 1176.80 | 1303.40 | 1331.40 | 1296.10 |
| 8 | 638.50 | 713.00 | 784.40 | 705.40 | 968.90 | 1021.60 | 1190.70 | 1250.80 |
| 9 | 776.78 | 934.40 | 1026.89 | 1266.50 | 908.80 | 1109.00 | 1145.30 | 1226.90 |
| 10 | 705.90 | 670.80 | 970.90 | 990.30 | 1372.56 | 1269.11 | 1372.33 | 1304.22 |
| 11 | 633.00 | 1001.20 | 991.90 | 1205.80 | 1056.11 | 1161.40 | 1275.80 | 1171.20 |
| 12 | 865.20 | 892.50 | 857.90 | 1024.50 | 1085.10 | 1142.80 | 1444.00 | 1424.10 |
| 13 | 563.80 | 918.70 | 938.80 | 910.10 | 881.20 | 996.60 | 1022.10 | 1025.00 |
| 14 | 849.90 | 825.90 | 898.20 | 886.00 | 1115.11 | 1183.89 | 1172.44 | 1324.44 |
| 15 | 750.43 | 1141.11 | 927.00 | 1082.80 | 997.70 | 1128.80 | 1136.80 | 1257.20 |
| 16 | 964.00 | 1025.10 | 1159.40 | 1301.60 | 1387.70 | 1424.40 | 1519.20 | 1471.70 |
| mean | 751.61 | 929.25 | 1001.83 | 1045.16 | 1098.08 | 1170.79 | 1271.80 | 1294.53 |

**Experiment 2:**
**REACTION TIME**

| | Target Absent | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | 33:66 | | | | | | | |
| | Consecutive | | | | Concurrent | | | |
| SJ# | 6 | 12 | 18 | 24 | 6 | 12 | 18 | 24 |
| 1 | 1032.75 | 1121.13 | 1239.44 | 1775.44 | 1108.22 | 1435.11 | 1724.30 | 1555.11 |
| 2 | 652.70 | 659.30 | 732.80 | 749.90 | 1047.00 | 1049.44 | 1005.40 | 1163.70 |
| 3 | 873.20 | 708.20 | 836.10 | 869.80 | 1000.50 | 1216.30 | 1119.10 | 1129.10 |
| 4 | 1016.60 | 899.25 | 1037.80 | 1132.50 | 1341.22 | 1545.30 | 1509.57 | 1430.50 |
| 5 | 766.70 | 897.10 | 877.70 | 763.90 | 922.90 | 1078.60 | 1067.30 | 1058.80 |
| 6 | 1020.50 | 1088.88 | 1209.00 | 1433.80 | 1446.00 | 1732.38 | 1589.70 | 1710.17 |
| 7 | 995.44 | 1073.78 | 937.38 | 1403.90 | 1384.50 | 1264.20 | 1388.70 | 1401.50 |
| 8 | 695.60 | 708.40 | 692.60 | 802.30 | 1164.00 | 1298.60 | 1189.60 | 1267.60 |
| 9 | 799.80 | 803.70 | 1051.80 | 1034.80 | 972.90 | 1048.00 | 1027.70 | 1090.60 |
| 10 | 675.00 | 646.89 | 813.80 | 891.30 | 1413.25 | 1363.40 | 1508.56 | 1369.80 |
| 11 | 809.78 | 831.30 | 921.00 | 1215.50 | 1233.70 | 1084.30 | 1230.60 | 1459.40 |
| 12 | 836.80 | 1299.89 | 1585.38 | 1752.11 | 1304.20 | 1626.30 | 1680.50 | 1929.80 |
| 13 | 710.60 | 755.90 | 857.50 | 1036.40 | 909.90 | 1072.00 | 1073.70 | 1243.20 |
| 14 | 700.10 | 797.10 | 875.22 | 1036.80 | 1440.11 | 1567.89 | 1406.00 | 1929.90 |
| 15 | 826.67 | 1078.33 | 928.30 | 1301.90 | 1090.10 | 1150.00 | 1234.70 | 1441.50 |
| 16 | 1165.20 | 1105.20 | 1199.30 | 1434.90 | 1387.40 | 1465.70 | 1560.90 | 1600.60 |
| mean | 848.59 | 904.65 | 987.19 | 1164.70 | 1197.87 | 1312.34 | 1332.27 | 1423.83 |

**Experiment 2:**
**REACTION TIME**

| | Target Absent | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | 66:33 | | | | | | | |
| | Consecutive | | | | Concurrent | | | |
| SJ# | 6 | 12 | 18 | 24 | 6 | 12 | 18 | 24 |
| 1 | 1214.20 | 1493.56 | 1673.22 | 2060.00 | 1341.44 | 1360.78 | 1651.30 | 1671.30 |
| 2 | 644.90 | 911.60 | 829.40 | 840.70 | 1033.40 | 1201.30 | 1174.40 | 1457.70 |
| 3 | 871.90 | 782.10 | 788.11 | 756.60 | 1145.40 | 1125.20 | 1255.50 | 1185.00 |
| 4 | 899.00 | 1249.75 | 1046.67 | 1319.80 | 1262.75 | 1271.86 | 1523.30 | 1524.78 |
| 5 | 832.10 | 789.60 | 1061.20 | 934.80 | 906.10 | 1031.50 | 1012.00 | 1104.30 |
| 6 | 1337.38 | 1332.67 | 1440.11 | 1907.10 | 1517.00 | 1504.17 | 2016.71 | 2066.14 |
| 7 | 1025.20 | 1503.30 | 1114.00 | 1411.60 | 1253.30 | 1459.33 | 1445.90 | 1460.30 |
| 8 | 793.78 | 689.50 | 749.10 | 867.10 | 1291.40 | 1059.20 | 1227.50 | 1297.00 |
| 9 | 809.50 | 882.80 | 1150.80 | 1403.80 | 957.30 | 1102.80 | 1133.90 | 1257.20 |
| 10 | 807.90 | 851.10 | 1081.30 | 1230.10 | 1442.63 | 1384.00 | 1407.63 | 1600.90 |
| 11 | 846.30 | 906.50 | 1243.70 | 1560.40 | 1087.00 | 1251.10 | 1611.80 | 1451.10 |
| 12 | 1197.10 | 1472.14 | 1909.75 | 2117.67 | 1494.80 | 1919.40 | 2030.70 | 2046.60 |
| 13 | 712.50 | 973.10 | 1350.30 | 1412.20 | 1085.40 | 1153.00 | 1235.60 | 1425.20 |
| 14 | 822.60 | 937.50 | 1148.40 | 1250.30 | 1353.70 | 1440.00 | 1954.20 | 1958.33 |
| 15 | 847.70 | 1063.30 | 1036.30 | 1423.50 | 1084.20 | 1326.80 | 1415.30 | 1548.80 |
| 16 | 1038.80 | 1282.30 | 1397.50 | 1674.30 | 1414.00 | 1571.40 | 1573.40 | 1731.00 |
| mean | 918.80 | 1070.05 | 1188.74 | 1385.62 | 1229.36 | 1322.61 | 1479.32 | 1549.10 |

**Experiment 2:**
**ERROR**

| | Target Present | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | 33:66 | | | | | | | |
| | Consecutive | | | | Concurrent | | | |
| SJ# | 6 | 12 | 18 | 24 | 6 | 12 | 18 | 24 |
| 1 | 0.00 | 0.00 | 0.13 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| 2 | 0.00 | 0.00 | 0.00 | 0.00 | 0.11 | 0.00 | 0.00 | 0.00 |
| 3 | 0.00 | 0.20 | 0.10 | 0.50 | 0.00 | 0.10 | 0.00 | 0.33 |
| 4 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.30 |
| 5 | 0.30 | 0.30 | 0.10 | 0.30 | 0.00 | 0.00 | 0.30 | 0.00 |
| 6 | 0.00 | 0.38 | 0.13 | 0.00 | 0.22 | 0.00 | 0.20 | 0.13 |
| 7 | 0.20 | 0.17 | 0.25 | 0.50 | 0.00 | 0.00 | 0.00 | 0.11 |
| 8 | 0.00 | 0.00 | 0.10 | 0.10 | 0.10 | 0.20 | 0.00 | 0.00 |
| 9 | 0.00 | 0.00 | 0.10 | 0.10 | 0.20 | 0.00 | 0.30 | 0.10 |
| 10 | 0.20 | 0.10 | 0.10 | 0.20 | 0.00 | 0.00 | 0.00 | 0.00 |
| 11 | 0.00 | 0.00 | 0.10 | 0.30 | 0.00 | 0.00 | 0.10 | 0.10 |
| 12 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.20 | 0.00 |
| 13 | 0.10 | 0.10 | 0.10 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| 14 | 0.00 | 0.00 | 0.00 | 0.10 | 0.10 | 0.00 | 0.00 | 0.10 |
| 15 | 0.00 | 0.00 | 0.11 | 0.10 | 0.00 | 0.10 | 0.10 | 0.10 |
| 16 | 0.00 | 0.00 | 0.00 | 0.10 | 0.10 | 0.00 | 0.00 | 0.11 |
| mean | 0.05 | 0.08 | 0.08 | 0.14 | 0.05 | 0.03 | 0.08 | 0.09 |

**Experiment 2:**
**ERROR**

| | Target Present | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | 66:33 | | | | | | | |
| | Consecutive | | | | Concurrent | | | |
| SJ# | 6 | 12 | 18 | 24 | 6 | 12 | 18 | 24 |
| 1 | 0.00 | 0.11 | 0.10 | 0.00 | 0.00 | 0.00 | 0.10 | 0.00 |
| 2 | 0.00 | 0.00 | 0.10 | 0.10 | 0.00 | 0.11 | 0.10 | 0.00 |
| 3 | 0.00 | 0.50 | 0.30 | 0.00 | 0.11 | 0.00 | 0.40 | 0.50 |
| 4 | 0.00 | 0.10 | 0.20 | 0.10 | 0.00 | 0.11 | 0.11 | 0.11 |
| 5 | 0.10 | 0.20 | 0.20 | 0.20 | 0.30 | 0.10 | 0.20 | 0.40 |
| 6 | 0.50 | 0.11 | 0.00 | 0.10 | 0.00 | 0.29 | 0.22 | 0.00 |
| 7 | 0.11 | 0.22 | 0.29 | 0.33 | 0.00 | 0.00 | 0.00 | 0.10 |
| 8 | 0.00 | 0.10 | 0.10 | 0.00 | 0.00 | 0.00 | 0.10 | 0.20 |
| 9 | 0.00 | 0.10 | 0.00 | 0.10 | 0.30 | 0.11 | 0.00 | 0.40 |
| 10 | 0.10 | 0.10 | 0.10 | 0.30 | 0.11 | 0.11 | 0.22 | 0.00 |
| 11 | 0.11 | 0.10 | 0.00 | 0.10 | 0.00 | 0.00 | 0.10 | 0.00 |
| 12 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.22 | 0.10 |
| 13 | 0.00 | 0.10 | 0.00 | 0.10 | 0.00 | 0.10 | 0.10 | 0.00 |
| 14 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.11 | 0.11 | 0.00 |
| 15 | 0.14 | 0.22 | 0.00 | 0.00 | 0.00 | 0.10 | 0.00 | 0.20 |
| 16 | 0.00 | 0.00 | 0.00 | 0.10 | 0.00 | 0.10 | 0.20 | 0.00 |
| mean | 0.07 | 0.12 | 0.09 | 0.10 | 0.05 | 0.08 | 0.14 | 0.13 |

**Experiment 2:**
**ERROR**

| | Target Absent | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | 33:66 | | | | | | | |
| | Consecutive | | | | Concurrent | | | |
| SJ# | 6 | 12 | 18 | 24 | 6 | 12 | 18 | 24 |
| 1 | 0.00 | 0.00 | 0.00 | 0.00 | 0.11 | 0.00 | 0.00 | 0.00 |
| 2 | 0.10 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| 3 | 0.30 | 0.30 | 0.10 | 0.00 | 0.00 | 0.10 | 0.00 | 0.00 |
| 4 | 0.00 | 0.00 | 0.10 | 0.00 | 0.11 | 0.00 | 0.14 | 0.10 |
| 5 | 0.10 | 0.20 | 0.00 | 0.20 | 0.10 | 0.20 | 0.00 | 0.00 |
| 6 | 0.13 | 0.00 | 0.14 | 0.10 | 0.00 | 0.00 | 0.10 | 0.00 |
| 7 | 0.22 | 0.22 | 0.13 | 0.00 | 0.00 | 0.00 | 0.00 | 0.10 |
| 8 | 0.10 | 0.00 | 0.00 | 0.10 | 0.10 | 0.00 | 0.00 | 0.00 |
| 9 | 0.10 | 0.10 | 0.00 | 0.00 | 0.10 | 0.10 | 0.00 | 0.10 |
| 10 | 0.10 | 0.00 | 0.10 | 0.10 | 0.00 | 0.10 | 0.00 | 0.00 |
| 11 | 0.11 | 0.10 | 0.00 | 0.00 | 0.10 | 0.30 | 0.10 | 0.00 |
| 12 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.10 |
| 13 | 0.00 | 0.00 | 0.00 | 0.00 | 0.10 | 0.00 | 0.00 | 0.00 |
| 14 | 0.10 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.10 | 0.00 |
| 15 | 0.11 | 0.00 | 0.10 | 0.00 | 0.00 | 0.10 | 0.10 | 0.00 |
| 16 | 0.00 | 0.00 | 0.00 | 0.00 | 0.10 | 0.00 | 0.00 | 0.00 |
| mean | 0.09 | 0.06 | 0.04 | 0.03 | 0.05 | 0.06 | 0.03 | 0.03 |

**Experiment 2:**
**ERROR**

| | Target Absent | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | 66:33 | | | | | | | |
| | Consecutive | | | | Concurrent | | | |
| SJ# | 6 | 12 | 18 | 24 | 6 | 12 | 18 | 24 |
| 1 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| 2 | 0.00 | 0.00 | 0.10 | 0.00 | 0.10 | 0.10 | 0.00 | 0.00 |
| 3 | 0.00 | 0.00 | 0.00 | 0.20 | 0.00 | 0.00 | 0.00 | 0.00 |
| 4 | 0.00 | 0.00 | 0.00 | 0.10 | 0.00 | 0.00 | 0.00 | 0.00 |
| 5 | 0.10 | 0.10 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| 6 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.14 | 0.00 |
| 7 | 0.00 | 0.00 | 0.00 | 0.00 | 0.10 | 0.11 | 0.00 | 0.00 |
| 8 | 0.00 | 0.00 | 0.00 | 0.00 | 0.10 | 0.00 | 0.00 | 0.00 |
| 9 | 0.20 | 0.00 | 0.00 | 0.00 | 0.10 | 0.00 | 0.00 | 0.00 |
| 10 | 0.00 | 0.10 | 0.00 | 0.00 | 0.13 | 0.00 | 0.13 | 0.10 |
| 11 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.10 | 0.10 | 0.10 |
| 12 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| 13 | 0.00 | 0.00 | 0.00 | 0.10 | 0.00 | 0.00 | 0.00 | 0.00 |
| 14 | 0.00 | 0.00 | 0.00 | 0.10 | 0.00 | 0.00 | 0.00 | 0.00 |
| 15 | 0.00 | 0.10 | 0.10 | 0.00 | 0.00 | 0.00 | 0.10 | 0.00 |
| 16 | 0.00 | 0.10 | 0.00 | 0.00 | 0.10 | 0.00 | 0.00 | 0.00 |
| mean | 0.02 | 0.03 | 0.01 | 0.03 | 0.04 | 0.02 | 0.03 | 0.01 |

**Experiment 3:**
**REACTION TIME**

| | Target Present | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | 33:66 | | | | | | | |
| | Consecutive | | | | Concurrent | | | |
| SJ# | 6 | 12 | 18 | 24 | 6 | 12 | 18 | 24 |
| 1 | 825.25 | 896.71 | 997.14 | 1409.33 | 1119.38 | 950.25 | 1137.63 | 1109.83 |
| 2 | 1118.25 | 822.83 | 981.43 | 1113.29 | 1245.71 | 1480.75 | 1312.38 | 1626.25 |
| 3 | 1440.57 | 1410.57 | 1477.25 | 1273.29 | 1396.86 | 1397.50 | 1465.63 | 1728.86 |
| 4 | 741.75 | 765.50 | 866.71 | 773.71 | 1042.43 | 1157.75 | 1187.00 | 964.00 |
| 5 | 679.00 | 896.38 | 1024.86 | 904.17 | 1135.88 | 1237.00 | 1262.86 | 1090.67 |
| 6 | 983.57 | 997.13 | 1006.43 | 1084.25 | 1422.38 | 1775.86 | 1275.00 | 1489.86 |
| 7 | 874.63 | 907.57 | 1111.00 | 1024.43 | 1126.00 | 1244.63 | 1371.86 | 1266.14 |
| 8 | 748.63 | 905.14 | 962.88 | 749.00 | 1455.13 | 1262.25 | 1145.00 | 1370.83 |
| 9 | 857.86 | 1109.14 | 1020.80 | 1184.86 | 974.38 | 1101.00 | 1126.63 | 1063.57 |
| 10 | 1286.71 | 1157.38 | 1927.00 | 1347.17 | 2426.43 | 2198.13 | 2112.00 | 2087.29 |
| mean | 955.62 | 986.84 | 1137.55 | 1086.35 | 1334.46 | 1380.51 | 1339.60 | 1379.73 |

**Experiment 3:**
**REACTION TIME**

| | Target Present | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | 66:33 | | | | | | | |
| | Consecutive | | | | Concurrent | | | |
| SJ# | 6 | 12 | 18 | 24 | 6 | 12 | 18 | 24 |
| 1 | 752.14 | 701.57 | 880.29 | 947.63 | 995.29 | 1120.88 | 997.43 | 1035.14 |
| 2 | 657.14 | 911.88 | 950.88 | 1208.00 | 1267.50 | 1184.86 | 1431.13 | 1502.88 |
| 3 | 984.00 | 1119.88 | 1333.57 | 1442.13 | 1178.75 | 1050.14 | 1666.38 | 1425.14 |
| 4 | 570.43 | 581.86 | 673.00 | 828.38 | 974.33 | 1241.88 | 1159.63 | 1212.00 |
| 5 | 776.43 | 973.33 | 786.00 | 861.86 | 1016.00 | 1144.75 | 1010.86 | 1155.43 |
| 6 | 718.86 | 1053.43 | 1077.43 | 1444.00 | 1121.13 | 1312.38 | 1573.63 | 1416.71 |
| 7 | 830.13 | 810.38 | 855.14 | 981.38 | 1190.75 | 1319.50 | 1162.25 | 1345.00 |
| 8 | 848.57 | 1004.25 | 895.00 | 911.25 | 1208.63 | 1353.75 | 1237.29 | 1285.29 |
| 9 | 755.00 | 1056.13 | 1201.43 | 1051.25 | 944.75 | 968.00 | 1025.63 | 1065.29 |
| 10 | 1559.38 | 1445.38 | 1078.86 | 1443.43 | 1787.13 | 2009.29 | 1849.29 | 1976.13 |
| mean | 845.21 | 965.81 | 973.16 | 1111.93 | 1168.42 | 1270.54 | 1311.35 | 1341.90 |

**Experiment 3:**
**REACTION TIME**

| | Target Absent | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | 33:66 | | | | | | | |
| | Consecutive | | | | Concurrent | | | |
| SJ# | 6 | 12 | 18 | 24 | 6 | 12 | 18 | 24 |
| 1 | 753.25 | 926.86 | 1407.00 | 1839.75 | 1046.50 | 1396.25 | 1237.50 | 1456.50 |
| 2 | 918.13 | 1298.25 | 1070.88 | 1167.43 | 1327.86 | 1421.50 | 1395.00 | 1666.13 |
| 3 | 1034.75 | 1651.75 | 1725.00 | 1747.75 | 1658.75 | 1578.63 | 1811.38 | 1952.38 |
| 4 | 724.14 | 1027.00 | 1083.00 | 1157.13 | 1015.00 | 1358.13 | 1422.75 | 1405.63 |
| 5 | 813.75 | 899.38 | 895.75 | 988.63 | 1063.57 | 1286.75 | 1305.88 | 1403.75 |
| 6 | 1038.25 | 1098.75 | 1605.63 | 1262.75 | 1200.43 | 1499.25 | 1861.75 | 1787.13 |
| 7 | 828.88 | 998.14 | 1085.50 | 1368.00 | 1260.63 | 1312.13 | 1382.88 | 1497.75 |
| 8 | 733.63 | 759.88 | 1027.00 | 1124.88 | 1386.00 | 1200.17 | 1274.17 | 1487.63 |
| 9 | 972.29 | 1053.50 | 868.00 | 1338.00 | 1076.75 | 1070.40 | 1224.00 | 1279.00 |
| 10 | 1117.63 | 1782.63 | 1772.00 | 1623.63 | 2439.00 | 2009.13 | 2431.75 | 2470.00 |
| mean | 893.47 | 1149.61 | 1253.98 | 1361.79 | 1347.45 | 1413.23 | 1534.70 | 1640.59 |

**Experiment 3:**
**REACTION TIME**

| | Target Absent | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | 66:33 | | | | | | | |
| | Consecutive | | | | Concurrent | | | |
| SJ# | 6 | 12 | 18 | 24 | 6 | 12 | 18 | 24 |
| 1 | 777.57 | 999.75 | 1172.25 | 1391.25 | 1102.50 | 1097.63 | 1267.13 | 1836.88 |
| 2 | 839.29 | 946.75 | 949.50 | 1127.88 | 1044.88 | 1240.38 | 1361.88 | 1473.63 |
| 3 | 1173.14 | 1246.13 | 1520.63 | 1709.75 | 1510.88 | 1513.63 | 1788.57 | 2005.88 |
| 4 | 708.00 | 890.88 | 1064.75 | 1058.17 | 1065.13 | 1272.00 | 1216.71 | 1420.00 |
| 5 | 664.75 | 902.25 | 887.38 | 960.86 | 1047.88 | 1160.13 | 1443.00 | 1195.50 |
| 6 | 1042.13 | 1417.25 | 1246.86 | 1560.63 | 1226.88 | 1432.25 | 1668.00 | 2038.50 |
| 7 | 944.25 | 1008.71 | 1009.50 | 1263.25 | 1320.38 | 1319.88 | 1293.71 | 1483.25 |
| 8 | 790.88 | 600.63 | 904.71 | 852.50 | 1449.88 | 1229.25 | 1343.50 | 1419.13 |
| 9 | 915.88 | 972.38 | 1096.88 | 1126.57 | 1119.13 | 1094.71 | 1189.43 | 1079.00 |
| 10 | 1244.25 | 1578.57 | 1907.88 | 1296.50 | 2498.43 | 2392.25 | 2273.00 | 2470.25 |
| mean | 910.01 | 1056.33 | 1176.03 | 1234.73 | 1338.59 | 1375.21 | 1484.49 | 1642.20 |

**Experiment 3:**
**ERROR**

| | Target Present | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | 33:66 | | | | | | | |
| | Consecutive | | | | Concurrent | | | |
| SJ# | 9 | 18 | 27 | 36 | 9 | 18 | 27 | 36 |
| 1 | 0.00 | 0.00 | 0.10 | 0.20 | 0.00 | 0.00 | 0.00 | 0.20 |
| 2 | 0.00 | 0.10 | 0.10 | 0.10 | 0.10 | 0.00 | 0.00 | 0.00 |
| 3 | 0.10 | 0.10 | 0.00 | 0.00 | 0.11 | 0.30 | 0.00 | 0.00 |
| 4 | 0.00 | 0.10 | 0.10 | 0.00 | 0.10 | 0.00 | 0.00 | 0.20 |
| 5 | 0.10 | 0.00 | 0.20 | 0.20 | 0.00 | 0.10 | 0.10 | 0.10 |
| 6 | 0.10 | 0.00 | 0.00 | 0.11 | 0.00 | 0.11 | 0.00 | 0.11 |
| 7 | 0.00 | 0.10 | 0.10 | 0.20 | 0.00 | 0.10 | 0.10 | 0.20 |
| 8 | 0.00 | 0.10 | 0.00 | 0.40 | 0.00 | 0.00 | 0.00 | 0.20 |
| 9 | 0.00 | 0.20 | 0.30 | 0.10 | 0.00 | 0.10 | 0.00 | 0.10 |
| 10 | 0.20 | 0.00 | 0.13 | 0.22 | 0.25 | 0.14 | 0.00 | 0.13 |
| mean | 0.05 | 0.07 | 0.10 | 0.15 | 0.06 | 0.09 | 0.02 | 0.12 |

**Experiment 3:**
**ERROR**

| | Target Present | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | 66:33 | | | | | | | |
| | Consecutive | | | | Concurrent | | | |
| SJ# | 4.5 | 9 | 13.5 | 18 | 4.5 | 9 | 13.5 | 18 |
| 1 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.10 |
| 2 | 0.00 | 0.00 | 0.00 | 0.20 | 0.00 | 0.00 | 0.00 | 0.00 |
| 3 | 0.00 | 0.00 | 0.10 | 0.00 | 0.00 | 0.00 | 0.11 | 0.10 |
| 4 | 0.10 | 0.00 | 0.00 | 0.00 | 0.10 | 0.00 | 0.00 | 0.10 |
| 5 | 0.00 | 0.40 | 0.20 | 0.20 | 0.00 | 0.00 | 0.10 | 0.10 |
| 6 | 0.00 | 0.10 | 0.00 | 0.00 | 0.00 | 0.00 | 0.10 | 0.10 |
| 7 | 0.00 | 0.00 | 0.10 | 0.20 | 0.00 | 0.00 | 0.00 | 0.00 |
| 8 | 0.10 | 0.00 | 0.20 | 0.00 | 0.00 | 0.00 | 0.30 | 0.00 |
| 9 | 0.00 | 0.10 | 0.30 | 0.10 | 0.00 | 0.10 | 0.00 | 0.10 |
| 10 | 0.00 | 0.00 | 0.10 | 0.13 | 0.00 | 0.00 | 0.11 | 0.00 |
| mean | 0.02 | 0.06 | 0.10 | 0.08 | 0.01 | 0.01 | 0.07 | 0.06 |

**Experiment 3:**
**ERROR**

| | Target Absent | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | 33:66 | | | | | | | |
| | Consecutive | | | | Concurrent | | | |
| SJ# | 9 | 18 | 27 | 36 | 9 | 18 | 27 | 36 |
| 1 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| 2 | 0.00 | 0.10 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| 3 | 0.00 | 0.00 | 0.00 | 0.11 | 0.00 | 0.00 | 0.00 | 0.00 |
| 4 | 0.11 | 0.10 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| 5 | 0.00 | 0.10 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| 6 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| 7 | 0.10 | 0.10 | 0.10 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| 8 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.20 | 0.10 | 0.00 |
| 9 | 0.13 | 0.00 | 0.00 | 0.00 | 0.10 | 0.20 | 0.10 | 0.00 |
| 10 | 0.14 | 0.00 | 0.00 | 0.10 | 0.25 | 0.00 | 0.14 | 0.14 |
| mean | 0.05 | 0.04 | 0.01 | 0.02 | 0.04 | 0.04 | 0.03 | 0.01 |

**Experiment 3:**
**ERROR**

| | Target Absent | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | 66:33 | | | | | | | |
| | Consecutive | | | | Concurrent | | | |
| SJ# | 4.5 | 9 | 13.5 | 18 | 4.5 | 9 | 13.5 | 18 |
| 1 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| 2 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.10 | 0.00 | 0.00 |
| 3 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| 4 | 0.10 | 0.00 | 0.00 | 0.10 | 0.00 | 0.00 | 0.00 | 0.00 |
| 5 | 0.10 | 0.00 | 0.10 | 0.00 | 0.00 | 0.00 | 0.10 | 0.00 |
| 6 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.10 |
| 7 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| 8 | 0.00 | 0.00 | 0.10 | 0.00 | 0.00 | 0.00 | 0.00 | 0.10 |
| 9 | 0.00 | 0.10 | 0.00 | 0.10 | 0.00 | 0.10 | 0.00 | 0.10 |
| 10 | 0.00 | 0.13 | 0.14 | 0.11 | 0.20 | 0.00 | 0.11 | 0.00 |
| mean | 0.02 | 0.02 | 0.03 | 0.03 | 0.02 | 0.02 | 0.02 | 0.03 |